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Examining the Relationships Between Stress, Depressive Symptoms, and the Neighborhood Food Environment on Diet Quality Among Racially-Diverse Pregnant Women in South Carolina

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Dedication

I dedicate this dissertation to my family. Mom, I am incredibly appreciative of your love, patience, continuous encouragement, and unwavering faith in my abilities. I thank you for teaching me the value of hard work, resilience, and balance throughout this journey. I truly could not have done this without you and I know Dad would be incredibly proud of this accomplishment. To the rest of my family and friends, your words of encouragement and support have helped me to stay motivated. I'm grateful for all of you.

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Abstract

Background

Women's diet quality during pregnancy often falls short of U.S. Dietary Guidelines and poor mental health and poor access to healthy food may be important barriers to improving diet quality during pregnancy. The purpose of this study was to 1) synthesize existing literature on the relationship between mental health and diet quality during pregnancy, 2) examine the relationship between mental health and diet quality in pregnancy, and 3) examine the relationship between healthy food density and diet quality in pregnancy.

Methods

For *Aim 1* (systematic review), articles were obtained from five databases; study characteristics and findings were extracted and synthesized. For *Aims 2 & 3*, a cross-sectional analysis was conducted on baseline demographic, mental health, food environment, and dietary data from African-American (AA) and White overweight/obese pregnant women participating in the Health in Pregnancy and Postpartum (HIPP) study. Assessments were conducted from January 2015 to March 2018 by research staff. Data from self-administered 24-hour dietary recalls were used to calculate Healthy Eating Index (HEI)-2015 total and component scores. Food retailer data were obtained from ReferenceUSA. Food retailer locations and participants' home addresses were geocoded to the point or street-address level in ArcGIS Pro. Healthy food density scores (via the

Modified Retail Food Environment Index) were calculated based on a 5-mile network buffer around each participant's home. For *Aim* 2, the associations between stress and depressive symptoms on HEI total scores and meeting HEI component recommendations were examined. For *Aim 3*, the associations between 5-mile healthy food density on HEI total scores and meeting HEI component recommendations were examined. Multiple linear and logistic regression models were conducted in SAS 9.4.

Results

Findings from the systematic review (n=24 studies) show that stress and depressive symptoms were generally related to unhealthy dietary patterns and lower diet quality scores in pregnancy. There were conflicting findings regarding the relationship between mental health and food group consumption in pregnancy. The review identified the following important gaps in the literature: 1) limited use of longitudinal and randomized designs, 2) few studies used comprehensive diet quality indices, 3) an underrepresentation of racial/ethnic minority women, and 4) a lack of multi-theoretical frameworks that informed the studies.

For *Aims 2 &* 3, women (n=169) were racially-diverse (40% AA), young (M=29.6±5.1 years), primarily married (67%), well-educated (61% earned a college degree or higher), almost a quarter (23%) were enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children, most were in early pregnancy (M=10.1±2.4 weeks), and most lived in urban areas (82%). Women had low levels of stress (M=4.8±3.3, range 0-14) and depressive symptoms (M=5.8±4.3, range 0-20), along with poor diet quality (M=55.9±10.6, range 28-76). As hypothesized, as stress and depressive symptoms increased, HEI total scores tended to decrease; alternatively, as healthy food density increased, HEI total scores tended to increase, but contrary to hypotheses, associations did not reach statistical significance. As hypothesized, a one-unit increase in stress was associated with a 14% decrease in the odds of meeting Seafood and Plant Protein recommendations [adjusted (adj) OR: 0.86 (95% CI=0.77, 0.96)]. The association between healthy food density and HEI total scores was in the expected direction but contrary to the hypothesis, did not reach statistical significance. As hypothesized, residential location moderated the relationship between healthy food density and meeting the Whole Fruit recommendation such that a one-unit increase in healthy food density was associated a 21% increase in the odds of meeting the Whole Fruit recommendation for participants living in an urban area (adj OR: 1.21 [95% CI=1.04, 1.40]) compared to those living in a rural area (adj OR: 0.97 [95% CI=0.91, 1.03]).

Conclusions

Overall, previous literature shows that stress and depressive symptoms are associated with unhealthy dietary patterns and lower diet quality scores in pregnancy; however, there is a need for prospective studies, standardization in diet quality assessment, greater representation of minority women, and the use of multi-level theoretical frameworks in future studies. HIPP participants' diet quality was poor overall. Mental health and healthy food density were not associated with overall diet quality; however, AA women seemed to have healthier diets related to unsaturated fatty acid consumption and limited refined grains consumption compared to White women. Additionally, having better access to healthy food was associated with greater whole fruit consumption among urban but not rural women. Future studies should examine the efficacy of interventions that incorporate stress management and nutrition education and investigate aspects of the consumer food environment to identify barriers to improving diet quality in pregnancy.

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List of Abbreviations

ASA24 .... Automated Self-Administered 24-Hour Dietary Recall

BMI .... Body Mass Index

CES-D .... Center for Epidemiologic Studies-Depression Scale

DQI-P .... Diet Quality Index for Pregnancy

EPDS .... Edinburgh Prenatal/Postnatal Depression Scale

FFQ .... Food Frequency Questionnaire

GWG .... Gestational Weight Gain

HEI .... Healthy Eating Index

HIPP .... Health in Pregnancy and Postpartum

mRFEI .... Modified Retail Food Environment Index

SEM .... Social Ecological Model

WIC .... Special Supplemental Nutrition Program for Women, Infants, and Children

Chapter 1: Introduction

Less than half (45%) of U.S. women begin pregnancy at a normal weight (body mass index (BMI) 18.5-24.9 kg/m^2), which makes excessive gestational weight gain (GWG) a major public health concern.[1] Women who begin pregnancy overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) are nearly three times as likely to exceed the Institute of Medicine's (IOM) 2009 GWG guidelines compared to normal weight women.[2,3] There are multiple adverse health consequences of excessive GWG for both mothers and their offspring (e.g., increased risk for pre-eclampsia, cesarean delivery, and infants born large-for-gestational-age).[4] Maternal diet quality, or overall dietary pattern during pregnancy, influences infant development[5] and may be an important modifiable factor for preventing excessive GWG.[6] Diet quality's dual influence on maternal and child health drives the need to understand factors that may act as barriers to achieving optimal diet quality during pregnancy.

In addition to the adverse consequences associated with excessive GWG, there are persistent racial health disparities associated with obesity, diet quality during pregnancy, postpartum (PPM) weight retention, and adverse birth outcomes that heighten the relevance of examining these factors in pregnancy. African-American (AA) women experience multiple burdens in this area, including having the highest obesity rates among U.S. adults,[7] the poorest diet quality around conception,[8] increased risk for PPM weight retention,[9] increased risk for future weight gain in PPM,[10] and experiencing poorer birth outcomes regardless of weight status (e.g., higher rates of fetal death, preterm birth, fetal growth restriction, and maternal death)[11] compared to their White counterparts. These inequalities make AA women a high-risk group for experiencing adverse pregnancy outcomes, which deserve further investigation.

In addition to pregnancy being a high-risk time for excessive weight gain and weight retention, it may also be a time of increased stress due to the series of social, psychological, behavioral, and biological changes that accompany pregnancy.[12] Experiencing stress is closely linked with depressive symptoms,[13] both of which have been associated with poor diet quality in pregnancy.[14] However, stress and depressive symptoms are relatively understudied modifiable factors that may act as barriers to achieving proper diet quality in pregnancy.[15] Previous studies on stress, depressive symptoms, and diet quality in pregnancy have assessed diet quality through various statistical techniques that result in dietary patterns specific to that study population.[16] Few studies have examined the associations between stress, depressive symptoms, and diet quality in pregnancy using a standardized diet quality index score,[17] which could allow for comparisons across different study populations.[18]

While stress and depressive symptoms are often overlooked individual-level characteristics, very few studies have broadened their perspective and integrated the food environment in their examination of factors influencing diet quality in pregnancy.[19,20] The community nutrition environment is comprised of the number, type, location, and accessibility of food outlets such as grocery stores, fast-food restaurants, and limited-service, and full-service restaurants in neighborhoods.[21] This community-level factor may play an important role in influencing dietary intake and obesity among the general population.[22] A growing body of literature has found that greater neighborhood access and availability to healthy foods tend to be associated with better dietary outcomes.[23] Similarly greater access and availability to less healthy foods are associated with poorer dietary outcomes.[23] Much of the existing literature on the relationship between the food environment and nutrition-related outcomes have used ecological designs, which focus on comparisons at the aggregate level (e.g., county, state, region, country), which limits generalizability at the individual-level.[22,24] Furthermore, very few studies have examined the relationship between the food environment and diet quality in pregnancy at the individual-level, which is an important gap in the literature.

This dissertation project was informed by preliminary work that was conducted in Spring 2017. The relationship between perceived stress, depressive symptoms and the engagement of unhealthy behaviors were examined in a nationally representative sample of U.S. pregnant women as part of a class project. Restricted, in-home interview data from Wave IV (2008/9) of the National Longitudinal Study of Adolescent to Adult Health were analyzed. The analytic sample (n=406) consisted of women who were pregnant at Wave IV and had complete data on variables of interest. The outcome of engagement in unhealthy behaviors was a composite measure of 7 behaviors (i.e., smoking cigarettes, alcohol consumption, illegal drug use, marijuana use, sedentary behavior, fast-food consumption, and drinking sugar-sweetened beverages). Multivariate ordinary least squares (OLS) regression models indicated that overall, AA pregnant women had worse mental health (i.e., higher average perceived stress and depressive symptoms), compared to White women. Additionally, there was a significant association between depressive symptoms and greater engagement in unhealthy behaviors, after controlling for socioeconomic status, race, and marital status. The current research built upon this preliminary work by narrowing the main outcome to diet quality and utilizing detailed 24-hour dietary recall data as opposed to a single-item fast-food consumption measure. Additionally, the current study examined the influences of stress and depressive symptoms on diet quality in a racially-diverse sample of pregnant women who enter pregnancy overweight or obese, which is a high-need population who is typically underrepresented in pregnancy interventions.

The objective of the current study was to examine the associations between maternal mental health (i.e., stress and depressive symptoms), the neighborhood food environment, and diet quality in early pregnancy among women participating in the Health in Pregnancy and Postpartum (HIPP) study. The HIPP study is a randomized controlled trial examining the efficacy of a theory-based behavioral lifestyle intervention to reduce excessive GWG and promote postpartum weight loss among women who begin pregnancy overweight or obese, as compared to a standard care intervention. Additional details about the larger study are described in Section 3.3.

1.1 Present Study

The aims of the present study were to synthesize the existing literature on the relationship between stress, depressive symptoms, and diet quality during pregnancy, summarize the measurement tools, identify gaps in the literature, and present ideas for future research. Additionally, the present study cross-sectionally analyzed baseline data from the HIPP study to examine if stress, depressive symptoms, and neighborhood healthy food density were associated with diet quality among White and AA pregnant women in SC.

This study was informed by multiple theoretical frameworks, including the Social Ecological Model (SEM),[25] the Ecological Model for Healthy Eating,[26] and a stress-reactivity framework for the development of maternal obesity and related disparities.[27] Further details about the study's conceptual model are presented below in Section 2.19.

Specific Aim 1: Conduct a systematic literature review on the associations between stress, depressive symptoms, and diet quality during pregnancy.

> **Research questions for Aim 1:** 1) What are the associations between poor mental health (i.e., stress and depressive symptoms) and diet quality during pregnancy?; 2) what measurement tools have been used to assess stress, depressive symptoms, and diet quality?; (3) what are the current gaps in the extant literature?; and (4) how can future research build upon previous studies to address the gaps in the literature?

Specific Aim 2: Examine if stress scores and depressive symptoms are associated with poorer diet quality (using the Healthy Eating Index-2015, or HEI) and test race as a moderator.

Hypothesis 2a: As stress and depressive symptoms increase, HIPP participants would have lower HEI total scores and lower odds of meeting HEI component recommendations.

Hypothesis 2b: In terms of moderation, as stress and depressive symptoms increase, AA women would have lower HEI total scores and lower odds of meeting HEI component recommendations compared to White women.

Specific Aim 3: Examine if higher healthy food density (via the CDC's Modified Retail Food Environment Index (mRFEI) is associated with better diet quality (via Healthy

Eating Index (HEI)-2015 total scores and meeting HEI component recommendations) and test residential location as a moderator.

Hypothesis 3a: As healthy food density increases, HIPP participants would have higher HEI total scores and higher odds of meeting HEI component recommendations.

Hypothesis 3b: In terms of moderation, as healthy food density increases, urban women would have higher HEI total scores and higher odds of meeting HEI component recommendations compared to rural women.

1.2 Justification for the Research

The present research contributes to the field of health promotion by examining psychological factors, which are modifiable and currently understudied risk factors that can influence outcomes for healthy GWG interventions. Additionally, this research contributes to the field of epidemiology by using geographic information systems (GIS) analysis to examine healthy and unhealthy neighborhood food access in pregnancy. Study findings could help inform future structural interventions focused on increasing healthy food access in vulnerable populations. Finally, the current research is important in the context of health disparities initiatives, as AA women and women who begin pregnancy overweight or obese are at greater risk for adverse birth outcomes associated with weight gain during pregnancy.

Chapter 2: Background and Significance

2.1. Maternal Obesity and Gestational Weight Gain

Obesity is the most burdensome and costly chronic health condition worldwide, affecting over one-third (36.5%) of U.S. adults.[7,28,29] Over half of U.S. women (55%) begin pregnancy overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2).[1] This trend is likely related to a combination of economic changes, technological advances, and changes to the environment resulting in an abundance of cheap, energy-dense food and fewer opportunities to be physically active.[30] High pre-pregnancy BMIs are concerning since starting pregnancy with an elevated BMI is associated with being nearly three times as likely to exceed the Institute of Medicine's (IOM) 2009 gestational weight gain (GWG) guidelines compared to normal weight women.[2,3] Almost one-half (47%) of all pregnant women in the U.S. exceed the IOM's 2009 weight gain recommendations during pregnancy, with higher rates of excessive GWG (45%-64%) among women who begin pregnancy overweight or obese.[2] Several literature reviews have found GWG to be positively associated with postpartum weight retention and a strong risk factor for new or persistent obesity in women, independent of other risk factors.[31–34]

Excessive GWG is associated with unfavorable outcomes for both the mother and her offspring. Adverse maternal pregnancy outcomes associated with beginning pregnancy overweight or obese and/or exceeding GWG guidelines include an increased risk for gestational diabetes[35,36] and pregnancy-associated hypertension.[37] For infants born to women who began pregnancy overweight, obese, or had excessive GWG, adverse birth and infant outcomes include greater risk for cesarean section, anesthetic complications, wound infection, stillbirth, congenital abnormalities, macrosomia (fetal growth beyond 4,500 g or 9 lb. 4 oz. regardless of fetal gestational age), and neonatal death compared to infants born to women who began pregnancy at a healthy weight or were within IOM GWG recommendations.[38–42] Maternal GWG has important implications for obesity prevention for future generations. Either independently or through gestational diabetes, maternal obesity increases the risk of obesity in the offspring,[43–47] contributing to the intergenerational cycle of obesity. Furthermore, obese children are more likely to become obese adults and their chronic disease risk factors are more likely to be severe compared to children of a healthy weight.[48,49]

In the general population, AAs experience the highest obesity rates compared to other ethnic groups.[50] This is concerning because beginning pregnancy overweight or obese is associated with three times higher risk of excessive GWG.[2] Additionally, AA women and low-income women are more likely to retain excess weight after delivery, causing some women to become obese for the first time, maintain obesity for others, or transition to a higher class of obesity.[31,32,51–53] Given the adverse health effects and associated disparities of excessive GWG and postpartum weight retention, addressing weight gain during pregnancy has important implications for both the mother and her infant. Improving diet quality is one important modifiable risk factor to address excessive GWG[6,54] and an important factor influencing infant development.[55]

2.2 Diet Quality in Pregnancy

A woman's nutritional status before and during pregnancy is critical for healthy development of the infant and for increasing the chances of successful birth outcomes.[56,57] Slight increases in energy intake and greater consumption of important micronutrients (e.g., iron and folate) throughout the gestational period are needed to facilitate a healthy pregnancy.[58] Traditionally, research on maternal nutrition has focused on nutrient deficiencies during the gestational period.[59] It is commonly recognized that individuals do not consume nutrients or foods individually, but through complex combinations of a variety of nutrients and non-nutrients through meals, which have possible interactions with one another. While the consumption of individual nutrients is important to understand, the assessment of overall dietary patterns more accurately represent nutrient and food intake by taking nutrient interactions into consideration.[59]

Diet quality is a comprehensive way of assessing dietary intake as it aligns with the recommendations established by the U.S. Department of Agriculture in the Dietary Guidelines for Americans.[60] Measures of diet quality have been shown to be a valuable method of assessing nutritional status by providing an integrative summary of multiple dimensions of nutrient intake (i.e., protein, percent energy from fats, folate, calcium).[61] The Healthy Eating Index-2015 (HEI) is a commonly used diet quality index that captures the entire complexity of the diet by assessing both food and nutrient consumption, allowing researchers to examine variation in composite scores, variation in the individual diet components that comprise the index, and in other dietary characteristics not directly measured (e.g., empty calories).[62]

Evidence suggests that income and pre-pregnancy weight status are important predictors of diet quality during pregnancy.[63–68] Low-income, overweight, and obese mothers tend to eat fewer vegetables, less iron and folate, and more fried potatoes, high-fat biscuits/muffins, juice, and whole milk compared to their normal weight pregnant counterparts.[63,64] This dietary pattern of reduced fruit and vegetable intake, and increased consumption of energy-dense, fried food has been associated with excessive GWG.[51,69,70] Research indicates that an inadequate understanding of nutritional needs, limited ability to purchase healthy foods, relative low-cost and ubiquitous availability of highly palatable foods are likely contributors to the energy-dense, nutrient-poor dietary pattern seen among low-income, obese mothers.[64,71] It is important to optimize diet quality during pregnancy because it is a critical factor in preventing excessive GWG[6,54] and increasing chances of proper infant development.[55,72]

Maternal diet quality has important implications for adverse birth outcomes, such as infant birth weight. For example, Phillips and Johnson found that diet quality explained 6%-8% of the variance in birth weight after controlling for maternal age, gestational age at delivery, maternal weight at delivery, and smoking status.[72] Proper diet quality is especially important in the first trimester of pregnancy, the time frame when the developing placenta and fetus are sensitive to changes in the mother's nutrition. For example, maternal protein consumption in the first trimester is positively related to both placental weight and birth weight, after taking into account maternal age, parity, smoking status, maternal nutrition, and GWG in the second and third trimesters.[73] This highlights the importance of ensuring women achieve optimal diet quality as early during pregnancy as possible to increase the chances of positive infant health outcomes.

2.3 Maternal Stress during Pregnancy

The perinatal period (i.e., pregnancy and up to one year postpartum) is a time when women are at increased risk of experiencing serious mental health problems that can affect the health and well-being of both the mother and infant.[74–76] During this time, women go through major anatomical, physiological, and psychological changes, which can be stressful.[77,78] Additionally, pregnancy can be a stressful experience, particularly when there is a lack of socioeconomic resources, lack of social support, interpersonal conflict, and increased work and family responsibilities for women.[79]

Prenatal maternal stress has been conceptualized in multiple ways, including global or generalized experiences of stress and pregnancy-specific stress.[80,81] For the current study, prenatal maternal stress is an assessment of general life stressors, which are assessed during pregnancy, and characterized by feelings of being overwhelmed.[82] Maternal stress is an under-appreciated and novel modifiable risk factor for understanding and addressing unfavorable maternal health outcomes.[27] Existing research has focused on how maternal stress during pregnancy has detrimental effects on a variety of infant health outcomes such as poor cognitive development, disruptive behavior, low birth weight, and being born premature.[83–86] While the linkage between maternal stress and poor infant health has been established, there is increasing evidence that suggests psychosocial factors, such as stress and depressive symptoms, may affect dietary intake and overall diet quality in mothers,[87] which have important implications for maternal and infant health.

Financial resources are an important consideration in the context of stress during pregnancy. Low-income pregnant women experience multiple stressful life events, such as financial insecurity, evictions, homelessness, worry regarding how their partner, family, and friends will respond to the pregnancy, recurring arguments with significant others, and domestic violence,[88] which could influence dietary intake and overall diet quality.[89] Generally, pregnant women who experience high stress levels are more likely to eat energy-dense, nutrient-poor food, which reduces their dietary quality throughout pregnancy.[87]

In SC, there are clear racial heath disparities in experiencing stressful life events during pregnancy. According to 2013 SC Pregnancy Risk Assessment Monitoring System (PRAMS) data, AA women experience disproportionately high levels of stress compared to White women having a live birth (29% vs. 21.5%).[90] Despite the increased experience of stress among AA women in SC, few studies have examined the impact of stress on diet quality in pregnancy in this population. The current research could contribute to the body of literature on the health disparities related to stress and resulting diet quality among AA women in SC.

2.4 Maternal Depressive Symptoms during Pregnancy

Depression is the number one cause of disease-related disability among women worldwide, with the prevalence of depression reaching its peak during the childbearing years.[91] The increasing prevalence of poor mental health during pregnancy has become a worldwide public health concern.[92] In the U.S., rates of depression in pregnancy range from 7.1% to 13%,[93] which is of great concern since maternal depression is associated with a variety of adverse maternal and infant health outcomes. In regards to maternal health outcomes, mothers experiencing depressive symptoms during pregnancy report more somatic symptoms such as nausea, stomachaches, shortness of breath, and headaches compared to women with fewer depressive symptoms.[94] Depression during pregnancy has also been associated with poor self-care, a decrease in seeking proper medical care, excessive GWG, pregnancy-induced hypertension, and increased risk of suicide ideation;[74,95,96] highlighting the importance of identifying depressive symptoms during pregnancy. Infants are also adversely affected by maternal depression during pregnancy.[97] For example, babies of depressed mothers have increased risk of being born premature or low birth weight, increased stress hormones and stress behaviors, increased admissions to neonatal intensive care, more disruptive sleep patterns, and increased irritability, all of which can negatively impact mother-child attachment.[97–100] Both the early prenatal environment and mother-child interactions play an important role in infant cognitive and emotional development.[84,101–104] Gaining a better understanding of how depressive symptoms may influence diet quality during pregnancy can help inform mental health and nutrition interventions during pregnancy.

2.5 Maternal Depressive Symptoms and Diet Quality

Over the past several years, there has been a rise in research examining the relationship between mental illness and diet; however, many of these studies were conducted in non-pregnant populations.[105–108] Previous studies that have investigated the relationship between maternal depressive symptoms and diet in pregnancy have focused on the consumption of specific key nutrients (e.g., iron, folic acid, omega-3 fatty acids, vitamin D, zinc, vitamin B_6).[75] This narrow focus on individual nutrients is a major limitation because it does not capture the synergistic effect of food as they are consumed as complex meals.[109] There are complex interactions that occur between the many micronutrients, macronutrients, vitamins, and minerals that make up one's habitual diet.[108] By examining individual nutrients in isolation, we may end up with an incomplete understanding of the relationship between depressive symptoms and overall diet quality.[108] Another limitation of existing literature on depressive symptoms and diet quality in pregnancy is a predominant focus on depressive symptoms in the postpartum period, with less emphasis on examining depressive symptoms *during* pregnancy.[92] Experiencing depressive symptoms during pregnancy can increase one's risk of experiencing depressive symptoms in the postpartum period.[110] The sooner depressive symptoms are identified during pregnancy, the sooner they can be addressed; highlighting the importance of early detection and treatment. While it has been established that depression in pregnancy is associated with a variety of maternal and child health outcomes (e.g., pre-eclampsia, birth complications, poor infant cognitive and emotional development, and excessive GWG),[74,95,97] there is inadequate research examining the relationships between depressive symptoms and diet quality in pregnancy, and if these associations differ by race.[89]

2.6 Stress is Linked with Depressive Symptoms

Stress is inextricably linked with the most common mental illness, depression.[111–113] Depression is a debilitating and recurrent disorder, including but not limited to feelings of extreme sadness, anxiety, exhaustion, difficulty concentrating, and feelings of helplessness, which can have a negative impact on the depressed individuals' families and social support systems.[114] Experiencing one episode of depression places an individual at a 50% risk for experiencing an additional episode, and further increases the likelihood of experiencing episodes in the future.[115] Stress is related to depressive symptoms in multiple ways. There is a large body of literature that indicates stressful life events are associated with risk for depression.[112,113] Additionally, the relationship between stress and risk for depression has been seen in acute stress,[116] chronic stress,[117] and both recent and early negative life events.[118,119] Furthermore, not only does stress increase risk for depression, but depression in turn, also increases susceptibility to stressful events,[111] creating a feedback loop for chronic stress. Taken together, AA pregnant women are a vulnerable population for high stress levels and depressive symptoms. Given the unique context of pregnancy, characterized by potentially stressful physiological, psychological, physical, and social changes,[77,78] and the linkage between stress and depressive symptoms,[111] it is important to examine the relationship between stress and depressive symptoms on diet quality in pregnancy.

2.7 The Impact of Stress and Depressive Symptoms on Diet Quality

Mental health factors, such as stress and depressive symptoms, can have a negative impact on diet quality in pregnancy by hindering a woman's ability to cope with barriers to eating healthy foods.[120] There is inconclusive evidence on the direction of the relationship between mental health (i.e., stress and depressive symptoms) and diet quality in pregnancy due to the common use of cross-sectional study designs;[92] however, it is hypothesized that the relationship is bi-directional.[92] The majority of studies in this area have examined stress and depressive symptoms as psychosocial factors that can influence diet quality in pregnancy.[14,87,89,121–126] Of these studies, six have used validated diet quality indices that capture the quality of the entire diet (i.e., Diet Quality Index for Pregnancy (DQI-P) and modified HEI).[14,89,121–124] The DQI-P consists of 8 components: grains, fruit, vegetables, percent of recommended intake for folate, calcium, and iron; percent of energy from fat; and meal/snack pattern.[61] Scores for each component range from 0-10, with the sum of all components ranging from 0 to 80. A composite score of 70+ reflects the most desirable diet quality in pregnancy for the DQI-P.[61] Studies that have investigated the relationship between stress and depressive symptoms on diet quality using the DQI-P have found that higher stress and depressive symptoms are associated with lower diet quality scores in pregnancy.[14,89] As expected from the literature on the linkage between stress and depressive symptoms, Fowles and colleagues observed that stress is positively associated with depressive symptoms (r=0.63) among a racially-diverse sample of low-income pregnant women.[14] Furthermore, in another study, Fowles et al. found that a combination of stress, depressive symptoms, and emotional eating explained 45% of the variance in DQI-P scores among a sample of majority Hispanic, low-income women in their first trimester.[123] Multiple studies indicate that prenatal depressive symptoms may exacerbate the negative effect of maternal stress on overall diet quality, contributing to a greater feeling of distress.[89,127] Results from a 2015 systematic review by Baskin et al. concluded that it is possible that women experiencing stress or depressive symptoms may eat poorly as a self-coping mechanism.[92] Additionally, women experiencing stress or depressive symptoms may have reduced motivation to maintain a healthy diet over the entire 9-month duration of pregnancy.[92]

While the DQI-P was the most commonly used measure to assess diet quality, comparable findings were observed in the relationship between depressive symptoms and poor diet quality using a modified HEI. Saeed et al. modified the traditional HEI to assess only the adequacy components (areas where typical consumption is too low) such as fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein, and seafood and plant proteins.[121] The overall score of the modified HEI was reduced to 50, with a score ≥ 40 indicating good diet quality. They examined the relationship between depressive symptoms during pregnancy and diet quality in a cohort study design of women in Pakistan. Their findings suggest that being depressed during pregnancy increased the risk of having a poor HEI score (RR=2.58, CI=1.60-5.23, $p \leq 0.0001$).[121] Among their participants, 62% of poor maternal dietary intake could be attributed to experiencing depressive symptoms during pregnancy, highlighting the importance of mental well-being in relation to diet quality during pregnancy.

Use of standardized and validated diet quality indices (i.e., DQI-P and HEI) allow for accurate comparisons between research studies since they reflect current nutritional recommendations for pregnancy[61] and are based on national dietary guidelines.[128] While a diet quality index is preferable, multiple studies have assessed diet quality through statistical techniques to identify dietary patterns.[87,125,126] For example, Molyneaux et al. analyzed data from the Avon Longitudinal Study of Parents and Children (ALSPAC), a large population-based cohort study in South West England.[125] Authors examined the relationship between depressive symptoms during pregnancy and five different dietary patterns, identified through principal component analysis of Food Frequency Questionnaire (FFQ) data. The dietary patterns consisted of: 1) health conscious (e.g., salad, fruit, rice, fish, White meat, and non-White bread); 2) traditional (e.g., veggies, red meat, poultry, and potatoes); 3) processed (e.g., pizza, sausages/burgers, and chips); 4) confectionary (e.g., biscuits, puddings, cakes/buns, and sweets); and 5) vegetarian (e.g., soybeans, tofu, and legumes). Using the Edinburgh Prenatal/Postnatal Depression Scale (EPDS), they found 7.9% of their sample had persistently elevated depressive symptoms (EPDS > 12 at both 18- and 32-wks), which was their criteria for identifying depressive symptoms. Authors concluded that depressive symptoms were not meaningfully associated with dietary patterns after adjusting for potential confounders.[125] Hurley et al. used dietary analysis software to analyze FFQ data from the Health Habits and History Questionnaire and found that stress was associated with higher intakes of breads and foods from the fats, oils, sweets, and snack group ($p<.05$).[87] Overall, findings on the relationship between stress and depressive symptoms on diet quality are inconclusive among studies that have not used a comprehensive diet quality index.[87,125,126] Since 24-hour dietary recalls and FFQs are multi-dimensional, dietary data need to be simplified into a composite score in order to have a meaningful interpretation of diet quality.[61] The current study will enhance the findings on the relationship between stress and depressive symptoms on diet quality in pregnancy by using a standardized and validated measure of overall diet quality, the HEI.[62]

2.8 Lack of Diversity in Race and Pre-Pregnancy BMI

Among the studies that have examined the relationship between stress and depressive symptoms on diet quality in pregnancy, there has been very limited research conducted among racially-diverse samples of pregnant women.[14,89] Additionally, very few studies recruit samples of overweight or obese pregnant women.[87] This is a gap in the literature that should be addressed because AA pregnant women in SC experience disproportionate amounts of stress compared to their White counterparts,[90] stress is associated with experiencing depressive symptoms,[112,113] AA women have the highest rates of obesity among the general population,[7] and obese pregnant women have increased odds of experiencing depressive symptoms.[125]

There has only been one previous study that has investigated the relationship between stress, depressive symptoms, and diet quality using a validated index (DQI-P) among a predominantly AA (53% AA) sample of overweight and obese pregnant women.[14] They found a negative relationship between stress and diet quality, and depressive symptoms and diet quality; indicated by higher stress and depressive symptoms being associated with lower DQI-P scores; however, this was a small pilot study.[14] Similar relationships have been observed in studies investigating the relationship between diet quality and distress (an index of stress and depressive symptoms) among a sample of majority Hispanic, low-income overweight and obese women (46.6% Hispanic, 51% overweight/obese).[89] It is common for diet quality studies to be conducted among relatively affluent White pregnant women.[87,125] Given the existing disparities in GWG and diet quality,[31,32,52,64] future studies should aim to increase their inclusion of AA, overweight, obese, and low-income pregnant women to better understand intrapersonal and environmental factors contributing to diet quality in pregnancy. The current study will address this gap in the literature since the HIPP study recruited a racially-diverse sample of overweight and obese AA and White pregnant women. In addition to psychosocial influences, there are structural factors that can influence diet quality in pregnancy, such as neighborhood healthy food access.[20]

2.9 Neighborhood Food Access and Diet Quality

Community nutrition environments, also commonly referred to as neighborhood food environments, encompass the distribution of food sources which includes the number, type, location, and accessibility of food retailers that are available to the general population.[21] Emerging research has suggested that neighborhood food environments may be an important contextual factor influencing dietary intake, overall diet quality, and obesity among the general U.S. population.[22,23,129] Moore et al., (2008) found that individuals living in the worst-ranked food environments were 22-35% less likely to have healthy diet quality, compared to those in the best-ranked food environments among non-pregnant adults;[130] however, there is a paucity of research investigating the relationship between the neighborhood food environment and diet quality in pregnant women.[19,20] It is theorized that individuals are more likely to engage in healthier behaviors when they are in supportive environments,[131] so poor access to healthy food may act as a barrier to improving diet quality during the critical period of pregnancy.[20]

Examining food environments may help to explain some of the existing racial/ethnic and socioeconomic disparities related to nutrition and associated health outcomes.[21] AA women have the poorest diet quality during pregnancy compared to White and Hispanic women.[8] Generally, AA women face unique barriers in improving the quality of their diet, especially those who experience financial hardship.[132] Limited accessibility to affordable healthy foods is a cited barrier to consuming a healthy diet among AAs.[133–136] Alternatively, previous research has demonstrated beneficial dietary outcomes associated with the presence of supermarkets among AA adults in the general population. In the Atherosclerosis Risk in Communities (ARIC) study, they found that fruit and vegetable intake among AAs increased by 32% with each additional supermarket in the census tract, after taking individual attributes and other food retail outlets into account.[137] Neighborhoods with sufficient healthy food retailers (e.g., grocery stores and supermarkets) may lead to healthier food purchases that can facilitate healthier eating and improve women's health in the long-term.[138]

Historically, the availability of food retailers has differed by the racial composition of one's neighborhood. For example, research indicates that supermarkets are less prevalent in minority neighborhoods, while fast-food restaurants are more prevalent compared to predominantly-White neighborhoods.[137,139,140] Additionally, the availability and quality of some healthy foods (e.g., low-fat dairy products, fruits, and vegetables) may be compromised in minority and lower-income areas,[139,141] making it more challenging to consume healthy diets; therefore, poor access to affordable healthy food could be a contributing factor for why AA women have the poorest diet quality,[8] highest rates of obesity,[7] and an increased risk for postpartum weight retention compared to their White counterparts.[142] Research examining the relationship between food accessibility and diet quality in pregnancy should be conducted in order to address these disparities in diet and weight-related outcomes.

2.10 Eating Away-From-Home and Diet Quality

Dining out, or eating food prepared away-from-home, has become increasingly popular over the past two decades, increasing the proportion of our nutrient intake coming from retail food outlets such as restaurants (i.e., fast-food and full-service restaurants) and stores (e.g., grocery stores, supermarkets, and convenience stores).[21,143]

In 2014, 29% of food purchased outside of the home came from limited-service restaurants, such as fast-food restaurants.[144] A study conducted among a community-sample of non-pregnant women indicated that women who perceived time pressure as a barrier to healthy eating were significantly less likely to meet fruit and vegetable recommendations and more likely to consume fast food more frequently.[145] This time pressure is likely related to the multiple caregiving roles of women which can influence dietary intake.[68] Frequent fast-food consumption is a factor that may contribute to poor dietary quality[146] because foods prepared outside of the home typically have poorer nutrition profiles, characterized by higher total fat, saturated fat, and sodium and lower fiber, calcium, and iron content.[147] This is important in the context of pregnancy since fiber, calcium, and iron are all nutrients that are particularly important for proper infant development in pregnancy.[148]

Research on how fast-food consumption impacts diet quality in pregnancy is limited, but could help identify modifiable factors to positively impact diet quality. For example, Fowles and Murphey found that consuming food prepared away-from-home was common among their sample of (N=13) pregnant women, with 84.6% reported eating more than half of their meals at fast-food restaurants or full-service restaurants.[122] Fast-food consumption has been associated with higher energy intake and poor diet quality among low-income pregnant women.[123] For example, Fowles and colleagues examined the relationship between fast-food consumption and diet quality in a racially-diverse (47% Hispanic) sample of low- income pregnant women (n=118) and found that women who consumed fast-food frequently consumed significantly more vegetables, gravies/sauces, less fruit, a higher percentage of total calories from fat, and less foods rich in Docosahexaenoic acid (DHA) compared to women who ate fast-food less frequently.[123] Addressing frequent eating-out could help address poor diet quality, having implications for excessive GWG.[123]

2.11 Mental Health and Eating Away-From-Home

Poor mental health has been associated with more frequent fast-food consumption, which can negatively impact diet quality in pregnancy.[89] For example, distress (a combination of stress and depressive symptoms) during pregnancy has a direct effect on poor eating habits such as eating at fast-food restaurants, which in turn has a negative effect on diet quality among low-income pregnant women.[89] Additionally, higher frequency of fast-food consumption has been observed among pregnant women with higher depressive symptoms.[122] This supports findings from Fowles et al. who found that pregnant women who ate fast-food frequently were more likely to be stressed, depressed, and obese.[123] Taken together, previous research suggests that women who frequently ate fast-food were more likely to engage in emotional eating as a coping mechanism in response to mental health factors such as stress or depressive symptoms.[122,123] Examining the consumption of fast-food and food prepared away-from-home in relation to diet quality in pregnancy is important given the widespread availability of both healthy and unhealthy food outlets in our environments.

2.12 Measurement of Food Access and Diet Quality

There is great variability in the methods used to define neighborhood food access, such as proximity or density of food outlets which contributes to a largely inconclusive body of evidence on the relationship between food environments and dietary intake.[149] Proximity can be defined as the distance between a food outlet and another location, such as an individual's home address.[22] The concept of proximity aligns with Zipf's Principle of Least Effort, which suggests that relative proximity of healthy vs. unhealthy foods affect the odds of consuming a healthy vs. unhealthy diet.[21,150] Density is defined as the number of food outlets surrounding a location (e.g., an individual's home), within a defined area (e.g., 5-mile radius).[22] The spatial relationship between density of fast-food restaurants and obesity rates at the state-level has been explored. The density of fast-food restaurants explained 6% of the variance in state-level obesity prevalence across the U.S.[151] While examining the exposure of individual food retailers can provide some insight into the relationship between the food environment and dietary intake, there is value in accounting for the presence of multiple types of food retailers simultaneously through a food environment index.[152]

Researchers have called for greater standardization in the methods used to define and assess the community food environment.[153] The Centers for Disease Control's (CDC) Modified Retail Food Environment Index (mRFEI) combines the concepts of food deserts (i.e., areas with poor access to supermarkets) with the concept of food swamps (i.e., areas with a high amount of unhealthy food) into a single score at the census-tract level.[152] The mRFEI score represents the percentage of food retailers considered healthy, out of the total number of food retailers considered healthy or less healthy in a census tract. The national average mRFEI score is 10, and SC falls below the national average with a score of 9.[152]

Another limitation of previous studies that have examined the association between the neighborhood food environment and dietary intake is a predominant focus on the consumption of specific food groups (e.g., fruit and vegetable consumption[154–158], consumption of five food groups relevant to a Japanese diet[159], or fast-food consumption[160,161]) or dietary patterns (e.g., high consumption of savory snacks or fizzy drinks),[162] as opposed to overall diet quality. Alternatively, there have been fewer studies examining the relationship between the neighborhood food environment (via GIS-based measures) and comprehensive diet quality (e.g., Alternate Healthy Eating Index[129,130]) and very few studies that have examined these relationships in pregnant women specifically.[19,20]

Diet quality indices have the advantage of capturing the totality of one's diet, accounting for the synergistic relationship between dietary components, and adapting to fit personal and socio-cultural preferences.[59,163] Taken together, there is a significant gap in the literature of studies examining the relationship between neighborhood healthy food density (via comprehensive food environment indices) and diet quality (via comprehensive diet quality indices) during pregnancy. The few studies that have examined the relationship between the food environment and diet quality in pregnancy have results that are inconclusive;[19,20] driving the need for additional research. Furthermore, racially-diverse women and overweight or obese pregnant women have been underrepresented.[19]

Additionally, the majority of previous literature on the relationship between the food environment and nutrition-related outcomes (e.g., obesity) have used ecological study designs, which focus on comparisons at the aggregate level (e.g., county, state, region, country), limiting generalizability at the individual-level.[22,24] A major limitation of ecological studies is that they have the potential to oversimplify complex relationships.[164] While assessing the healthfulness of the food environment at the census tract-level can provide an overview of food access at the aggregate level, there is a need to understand how the food environment relates to individual-level dietary intake in order to inform policies and structural interventions.[23] The current study has the benefit of analyzing the relationship between the neighborhood food environment and diet quality at the individual-level, which very few studies have done. The following section will review studies that have used GIS-based methods to examine the relationship between the neighborhood food environment and diet quality in pregnancy.

2.13 Use of GIS to Examine the Neighborhood Food Environment and Diet Quality in Pregnancy

Examining the relationship between the neighborhood food environment and diet quality in pregnancy through GIS analysis is a significant gap in the built environment and health promotion literature. To the author's knowledge, there have only been two studies that have investigated neighborhood food access and how it relates to diet quality in pregnancy at the individual-level.[19,20] Laraia et al. conducted a study to examine the accessibility of supermarkets, grocery, and convenience stores in Wake County, NC.[20] Their goal was to assess the impact of the food environment on overall diet quality in pregnancy by analyzing the association between distance to the closest supermarket and DQI-P scores. Researchers constructed a Euclidean distance (or straight-line distance) from participants' homes to the nearest supermarket, grocery store, and convenience store. On average, participants lived 1.6 miles from the nearest supermarket, 1.5 miles from the nearest convenience store, and 1.9 miles from the nearest grocery store. They found that women who lived more than 4 miles from a supermarket had more than twice the odds (aOR: 2.16; 95% CI= 1.2, 4.0) of having DQI-P scores in the lowest compared to the highest tertile, compared to women living within 2 miles of a supermarket, after controlling for individual characteristics and other food retail outlets.[20] There was also a significant decreasing trend in mean DQI-P for women who lived more than 5 miles away from a convenience store (mean DQI-P= 49$\pm$13.8, $p<0.01$). However, the density of food retail outlets (i.e., the number of food outlets per block group and within .5 mile of each woman's home) was not associated with diet quality. Overall, their findings suggest that the proximity of supermarkets to women's homes influences diet quality in pregnancy.[20]

A major strength of this study is that the sample was racially-diverse (47% AA). In this sample, AA women had higher average diet quality scores as assessed by the DQI-P (55.9$\pm$12.4 vs. 53.8$\pm$11.8) compared to White women. Authors highlighted the fact that a conceptual framework that can portray potential pathways for how neighborhood environments influence dietary behaviors would be greatly beneficial. The current research aims to accomplish this by presenting a conceptual model that unifies intrapersonal-level mental health factors (i.e., stress and depressive symptoms) and nutrition environment factors (i.e., healthy food density) that could influence diet quality in pregnancy (Section 2.18).

Nash and colleagues conducted a cross-sectional study to assess both personal and food environment determinants of diet quality in pregnancy among participants from the

Prenatal Health Project in Canada.[19] For their diet analysis, they modified the DQI-P to a Canadian-specific version to align with Canadian dietary guidelines. Regarding mental health measures, they assessed depressive symptoms using the Center for Epidemiologic Studies-Depression Scale (CES-D), but the association between depressive symptoms and diet quality was not presented. They assessed the availability of three types of retail food vendors (i.e., grocery stores/local markets, fast-food restaurants, and convenience stores) within 500m (5-minute walk) of participants' homes. In terms of accessibility, they found that 47.5% of their participants lived within 500m of a convenience store, 33.3% within 500m of a fast-food restaurant, and only 10.7% within 500m of a grocery store/local market. Authors found no significant associations between the presence of a grocery store/local market, fast-food restaurant, or convenience store within 500m and diet quality after controlling for personal variables.[19] A limitation of this study is that it was conducted in a fairly well-educated and high-income sample of women, who may not experience the same constraints low-income women endure. Given the paucity of studies that have examined access to multiple retail food outlets and diet quality in pregnancy, these environmental influences deserve further examination to better understand factors contributing to poor diet quality and adverse maternal and child health outcomes.

2.14 Lack of Theoretical Frameworks in Diet Quality Studies

According to a 2010 IOM report, there is a need to investigate multiple levels of influence that impact eating and physical activity in order to inform systems-level approaches for obesity prevention in the U.S.[165] There is a shortage of studies that have examined diet quality in pregnancy that have reported a specific framework that informs their research, let alone frameworks that incorporate multiple levels of influence on dietary behavior. Fowles and colleagues developed a path analytic model of the relationships between distress (an index of stress and depressive symptoms), social support, nutritional knowledge, and eating habits on diet quality in low-income pregnant women.[89] They reported using a model informed by existing literature on potentially-modifiable psychobehavioral factors on diet quality during pregnancy; however, authors do not specify whether the model was a theoretical model or a path analytic model similar to the one they created. The same lead author, Fowles, reported using the psychoneuroimmunology (PNI) framework to show the linkage between psychosocial factors (e.g., stress, depressive symptoms, income, and social support), diet quality, and placental development in pregnant women in a different study.[124] While this framework can provide insight into how maternal stress and depressive symptoms can influence diet quality and subsequently placental development, it does not take into consideration influences from one's neighborhood food environment; leaving a gap in the literature.

The current study's conceptual framework (explained in Section 2.19), aligns with the IOM's initiative of bridging intrapersonal-level factors (i.e., stress and depressive symptoms) with environmental-level factors (i.e., neighborhood food access) to better understand the multiple factors that influence diet quality, which have important implications for disparities associated with GWG and postpartum weight retention.[6,31,32,52] Additionally, the current research will test these hypotheses to determine if stress, depressive symptoms, and neighborhood healthy food density are associated with diet quality in a diverse sample of overweight and obese pregnant women in SC.

2.15 Future Directions

To summarize the literature reviewed in this section, pregnancy is an important time to optimize nutrition and mental well-being to increase chances of positive health outcomes for both mothers and children. With high rates of overweight and obesity among pregnant women,[7] there is a need to identify and examine factors that contribute to poor diet quality. The literature suggests that women who are low-income, AA, or begin pregnancy overweight or obese are more likely to have poorer diet quality,[63,64] which has implications for GWG and postpartum weight retention in the future.[32] Previous studies have found a negative relationship between stress and diet quality during pregnancy, with higher stress scores being associated with lower overall diet quality scores. In terms of depressive symptoms, previous studies have given a lot of attention to the consumption of specific micronutrients, instead of overall dietary patterns and have primarily focused on depressive symptoms during the postpartum period.[75,166] The few studies that have examined the relationship between depressive symptoms and diet quality during pregnancy have also found that higher depressive symptoms scores are associated with poorer diet quality scores.[167] These findings are important because stress and depressive symptoms are modifiable factors that have the potential to improve diet quality during pregnancy. AA pregnant women in SC experience disproportionate amounts of stress compared to their White counterparts,[90] so it is imperative to gain a better understanding of how poor mental health may impact diet quality in order to inform future diet quality interventions.

Prior research has found that low-income, AA women experience additional barriers to improving their diet quality,[132] with a lack of healthy affordable food as a potential contributing factor.[133] To the author's knowledge, only two previous studies have objectively assessed the relationship between access to food outlets and diet quality during pregnancy using GIS analysis.[19,20] This is a major gap in the literature since many epidemiological studies analyze data at the aggregate level, which does not allow for the generalization of health behaviors at the individual-level. Examining multiple levels of influence (e.g., intrapersonal- and environmental-level factors) can help improve our understanding of these complex relationships in order to inform policy and systems-level initiatives to improve maternal and child health.

In terms of theoretical frameworks, only one study reviewed in this section reported a specific framework that informed their research[124] and one study mentioned using a model derived from the literature.[89] None of these frameworks included both intrapersonal- and environmental-level factors for understanding diet quality in pregnancy. The current research aims to address this gap in the literature by combining mental health and environmental factors to create an overarching framework for how these factors can impact diet quality in pregnancy (Section 2.19).

Based on the literature on stress, depressive symptoms, the neighborhood food environment, and diet quality in pregnancy, the following gaps were identified: 1) lack of racial diversity in samples of overweight and obese pregnant women;[87] 2) limited number of studies that have examined overall diet quality, especially using a validated measure of diet quality;[14,121–123] 3) limited number of studies that have examined the relationship between depressive symptoms and diet quality during pregnancy;[92] 4) lack of studies that have used GIS to assess the neighborhood food environments of pregnant women;[19,20]

and 5) lack of theoretical frameworks that bridge intrapersonal- and environmental-level influences of diet quality during pregnancy.[27]

Given the adverse maternal and child health effects associated with maternal obesity and excessive GWG,[41] understanding the role of the neighborhood food environment on diet quality in pregnancy should be a priority. Analyzing individual-level data is one of the most pertinent gaps in the literature concerning the relationship between the neighborhood food environment and diet quality in pregnancy. The current research aims to provide insight on the linkages between maternal stress, depressive symptoms, neighborhood healthy food density, and diet quality during the important period of pregnancy.

2.16 Significance

Rates of overweight (BMI=25-29.9 kg/m^2) or obesity (BMI$\geq$30 kg/m^2) are more common than healthy weight (BMI=18.5-24.9 kg/m^2) among women of childbearing age.[168] Additionally, the increasing rates of overweight and obesity among pregnant women is a significant public health concern.[169] For many women, gaining excess weight during pregnancy is associated with become obese for the first time, maintaining obesity, or transitioning to a higher class of obesity in the postpartum period.[31–33,53]

As previously discussed, beginning pregnancy overweight or obese, or experiencing excessive GWG, have important implications for both the mother (i.e., increased risk for gestational diabetes, pregnancy-associated hypertension, cesarean section)[35–37] and her infant (i.e., increased risk for miscarriage, stillbirth, macrosomia, congenital abnormalities, and neonatal death).[38–41]

There are important racial health disparities in obesity, GWG, and diet quality. Not only do AAs have disproportionately high rates of overweight and obesity,[50] but AA women are at greater risk for excessive GWG and postpartum weight retention,[31,51,52] and have the poorest diet quality in pregnancy compared to other racial/ethnic groups.[8,170] Diet quality during pregnancy is an important modifiable risk factor for addressing disparities in excessive GWG and the associated adverse maternal and child health outcomes.[5,61]

It is well-established that maternal nutrition before and during pregnancy plays an important role in proper infant development and increases the chances of successful birth outcomes.[56,57] The majority of previous research on nutrition during pregnancy has focused on the consumption of individual nutrients (e.g., iron, folate, and zinc); however, the examination of comprehensive diet quality has been less commonly researched and could provide new insights.[59]

The current research is significant because the HIPP study is being conducted in SC, a southeastern state located in the "stroke belt," an area characterized by disproportionately-high rates of overweight and obesity, poor maternal and child health outcomes, and high poverty rates.[171] In 2009, more than half (54.8%) of pregnant women in SC were overweight.[172] The current study is important because the sample of racially-diverse, overweight and obese pregnant women are a high-need population that has not been included in much research to date.

2.16.1 Psychological Factors are Understudied in Understanding Diet Quality during Pregnancy

Stress and depressive symptoms are important psychological factors to examine since they can hinder a woman's ability to cope with barriers to eating healthy foods, contributing to poor diet quality.[23] Additionally, stress can be easily screened for using validated tools,[173,174] and can be modified to influence health outcomes.[27,175] In SC, AA women experience more stressful life events during pregnancy, compared to their White counterparts.[90] This disparity is important to address because stress increases one's risk for depressive symptoms,[115] and maternal depressive symptoms are associated with poor mother-child interaction and adverse child development outcomes.[84,101,102] Researchers have highlighted the need to identify, understand, and address depressive symptoms during pregnancy since they can increase one's risk for experiencing postpartum depression.[176]

2.16.2 Understanding the Influence of Neighborhood Food Environments on Diet Quality during Pregnancy

There has been very limited research on the nutritional built environment in relation to diet quality during pregnancy, which is a major gap in the literature.[19,20] The majority of food environment research using GIS analysis has been conducted at an aggregate level (e.g., county, state, region, country).[22] The current study is important because it will be examining neighborhood healthy food density (via a comprehensive food environment index) in relation to diet quality in pregnancy at the individual-level.

Identifying aspects of the food environment that could be improved could have broad, large-scale effects as opposed to only targeting individual-level behavior change strategies.[21] The food environment has changed in multiple ways that encourages greater consumption of energy-dense foods (e.g., surplus of fast-food restaurants, convenience items, larger portion sizes, and cost incentives for unhealthy items),[177] resulting in an "obesogenic environment," characterized by factors that make it difficult to maintain a healthy weight.[178] Individually-based interventions often encounter the challenge of maintaining newly-adopted health behaviors in the long-term.[179] This could be due to a lack of environmental changes; without adding environmental supports for healthy eating, it remains difficult to eat healthy.[180] Understanding environmental influences could help explain racial and socioeconomic disparities in health outcomes and help inform structural interventions.[181]

2.17 Innovation

2.17.1 Use of Geographic Information Systems (GIS) Analysis

This dissertation project is innovative for several reasons. First, this study will analyze participants' neighborhood food environments objectively through GIS analysis. Few studies have objectively examined the relationship between neighborhood healthy food density and diet quality in pregnancy.[19,20] Previous research indicates that there is a poor match between individuals' subjective perception of the food environment and what is captured through objective measures, highlighting the limitation of only using perceptions as a proxy for the objective environment.[182] Use of GIS is innovative because the majority of GIS studies assessing the food environment are limited to using data at the aggregate level,[22,24] as opposed to the home address data obtained from the HIPP study. The data obtained from GIS analysis can help shed light on geospatial disparities in healthy food access that might otherwise be unattainable. This study will be the *first of its kind* to examine the relationships between stress, depressive symptoms, and healthy food density on comprehensive diet quality in a sample of overweight and obese, racially-diverse sample of pregnant women in SC.

2.17.2 Use of Multiple Theories to Inform a New Framework

In addition, the current study is informed by multiple health behavior theories, specifically aspects of the SEM,[32] and Davis' framework for stress reactivity and maternal obesity development,[27] which allows for the examination of multiple levels of influence on dietary quality in pregnancy. McLeroy's SEM, which builds off of previous work by Broffenbrenner[183] and Belsky,[184] describes behavior as being influenced by a combination of factors at five different levels: 1) intrapersonal factors, 2) interpersonal factors, 3) institutional factors, 4) community factors, and 5) public policy.[25] The intrapersonal level examines personal traits such as knowledge, attitudes, behavior, self-efficacy, skills, etc. Pregnant women's experiences of perceived stress and depressive symptoms are additional factors that comprise the intrapersonal-level that influence health and represent the intrapersonal-level factors examined in the current study. The community-level examines relationships among organizations, institutions, and informal networks within defined boundaries (e.g., one's neighborhood). Pregnant women's access to healthy and unhealthy food retailers in their neighborhoods have important health implications at the community level. The current research examined the relationship between intrapersonal-level factors (i.e., stress and depressive symptoms) and environmental-level factors (i.e., neighborhood healthy food density) on diet quality in pregnancy.

The current research is also informed by Davis' framework for stress reactivity, maternal obesity development, and associated health disparities in minority women.[27] This framework is based on the idea that health disparities are due to a combination of genetic risk, suboptimal physical and social environments, differential exposure and response to chronic stress, coping ability, and health risk behaviors.[185,186] While Davis' framework builds off existing frameworks, such as Geronimus' "weathering hypothesis"[187] and McEwen's "allostatic load" concept,[188,189] it is unique because it situates the stress-reactivity processes specifically within pregnancy, a time of great psychological and physiological stress for many women.[190] Specifically, stress is thought to disrupt the hypothalamic-pituitary-adrenal axis system (HPA), which elevates cortisol levels, encouraging increased consumption of energy-dense foods, insulin resistance, and abdominal obesity.[191,192] Davis' framework combines social, environmental, genetic, behavioral, and biological determinants of obesity within the context of pregnancy.[27] Using the SEM and Davis's stress-reactivity framework, the current research aimed to understand the relationship between intrapersonal-level factors (i.e., stress, depressive symptoms) and community-level factors (i.e., neighborhood healthy food density) on diet quality in pregnancy. The overarching conceptual framework for the current study is presented below.

2.18 Conceptual Model

The overall conceptual model for the hypothesized relationship between sociodemographic factors, mental health, the neighborhood food environment, and the main outcome measure of diet quality is depicted in Figure 2.2. Since the HIPP study recruited both AA and White women who vary in their income levels, it is important to consider **sociodemographic characteristics** that may influence mental health status (i.e., stress and depressive symptoms), one's neighborhood food environment (e.g., access to both healthy and less healthy food retailers), and ultimately impact diet quality. Race is an important factor to consider since it is associated with a variety of health disparities, with AAs commonly experiencing long-standing poor health outcomes compared to their White counterparts.[171] Similarly, race is closely linked with one's socioeconomic status in the U.S. (e.g., one's level of educational attainment, employment opportunity, and income),[193] which has important implications for being able to engage in health-promoting behaviors. The current research examined if race moderated the relationship between mental health (stress and depressive symptoms) and diet quality.

Rooted in the SEM, the **neighborhood food environment** is an important component of this model because it is understood that place, or the neighborhoods where people live, can have important effects on health outcomes.[21,137] Commonly, race and socioeconomic status play a role in what type of neighborhood people live in, and the amenities or health-promoting resources residents have access to (e.g., access to grocery stores or supermarkets).[194] Predominantly AA neighborhoods have been found to have less access to healthy food and greater access to unhealthy food (e.g., fast-food restaurants), which can play a role in their diet quality.[137,139,195] In the current study, we examined if neighborhood healthy food density (proportion of healthy retailers out of the total) was associated with participants' diet quality. Additionally, we examined if residential location moderated the relationship between healthy food density and diet quality in pregnancy.

Informed by both the SEM and Davis' stress-reactivity framework,[25,27] we included mental health factors of **stress and depressive symptoms** in the model since stress and depressive symptoms have been associated with poor diet quality in pregnancy. AAs may experience disproportionate amounts of stress, and stress is associated with the consumption of more energy-dense, nutrient-poor food, which negatively impacts overall diet quality. Additionally, it is hypothesized that there is a bi-directional relationship between stress and depressive symptoms, whereby experiencing stress increases one's risk for depressive symptoms. Similarly, depressive symptoms increases one's chances of experiencing more stressful life events.

Diet quality, the comprehensive measure of the overall pattern of eating, is the study's main outcome. Diet quality has important implications for both maternal and child health and is currently understudied in pregnancy.

Figure 2.1 McLeroy's Social Ecological Model

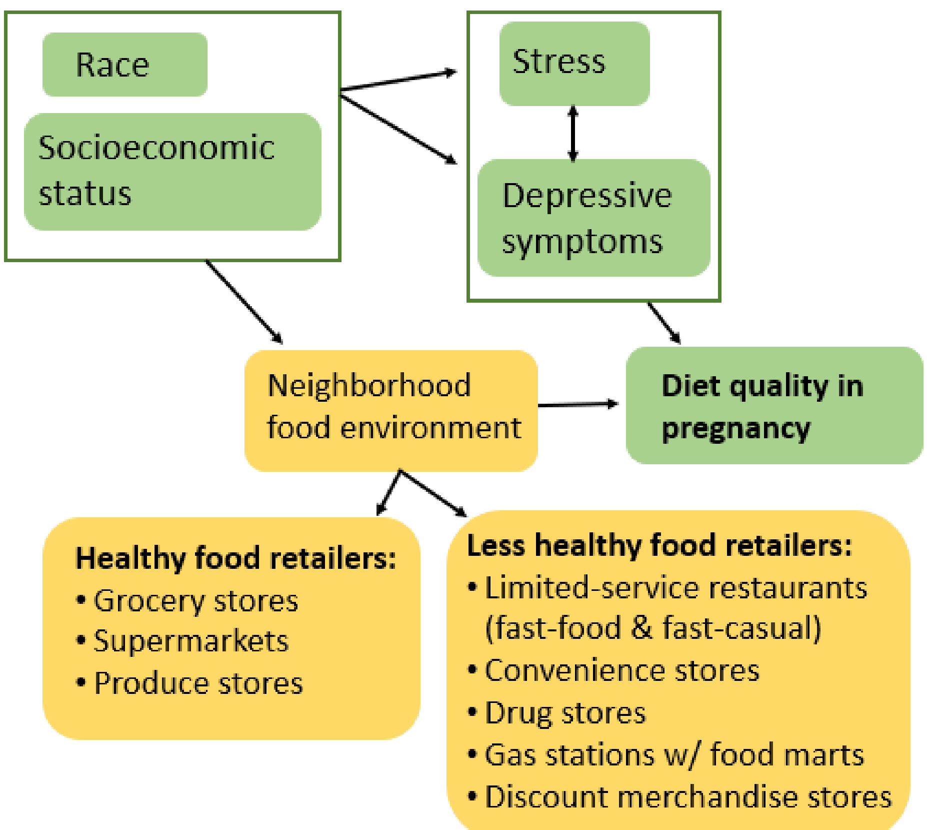

Figure 2.2 Conceptual Model

Chapter 3: Methodology

3.1 Overview

This project built on the Health in Pregnancy and Postpartum (HIPP) study, an NIH-funded R01 project (PIs: Wilcox/Liu, Co-I: Turner-McGrievy), which is a large-scale randomized controlled trial targeting excessive GWG during pregnancy and postpartum weight loss. The overall goal of the present study was to understand how psychosocial factors (i.e., stress and depressive symptoms) and built environment factors (i.e., neighborhood healthy food density) were associated with diet quality among racially-diverse overweight and obese pregnant women in SC. *Specific Aim 1* was to conduct a systematic literature review to (1) synthesize findings of original, peer-reviewed studies that examined the associations between stress and/or depressive symptoms, and diet quality during pregnancy; (2) review the measurement tools used to assess stress, depressive symptoms, and diet quality; (3) identify current gaps in the extant literature; and (4) offer recommendations for future research. *Specific Aim 2* was to 1) examine if stress and depressive symptoms were associated with poorer diet quality [via Healthy Eating Index-2015 (HEI) total and component scores] among HIPP participants, and 2) test whether race moderated the relationship between mental health and HEI scores. *Specific Aim 3* was to 1) examine if higher healthy food density [via the Centers for Disease Control's Modified Retail Food Environment Index (mRFEI) within 5-miles of participants' homes] was associated with higher HEI total and component scores; and 2) to test whether residential location moderated the relationship between healthy food density and HEI scores.

This study was a cross-sectional analysis of demographic, mental health, and dietary data measured at baseline to date (N=169). This study was the first of its kind to examine stress, depressive symptoms, and neighborhood healthy food density in a racially-diverse sample of overweight and obese pregnant women in SC. Findings from the present study can make important contributions to the maternal and child health and built environment bodies of literature.

3.2 Study Setting and Sample Description

The present research was conducted in SC, which currently ranks 10th in obesity, with a prevalence of 34.1%.[196] Additionally, SC has a high prevalence of people living in poverty (15.4% vs. 12.3% nationwide),[197] poor maternal and child health indicators,[198] a high proportion of African-Americans (AAs) (27.3% vs. 13.4% nationwide),[197] and long-standing racial health disparities.[90,196,197,199] Furthermore, over half of South Carolinian women who begin pregnancy overweight or obese have excessive GWG (61.3% and 54.0%, respectively) as shown in Table 3.1 below.[200] Since beginning pregnancy overweight or obese is associated with greater risk of excessive GWG[2] and there are multiple adverse health effects associated with excessive GWG,[4,201,202] the HIPP intervention could address a timely public health challenge for overweight and obese pregnant women, who have not been included in much research to date.[203–205] The target sample for the HIPP study was overweight or obese AA and White pregnant women who were $\leq$ 16 weeks pregnant. The study aimed to recruit equal numbers of AA and White women. Specific inclusion/exclusion criteria and sampling procedures are detailed below.

3.3 Study Recruitment

HIPP participants were primarily recruited from obstetrics and gynecology (OB/GYN) clinics (N=13) in the Columbia metropolitan, Sumter, Winnsboro, and Charleston areas of SC. Within OB/GYN clinics, study flyers were posted in waiting rooms and other high-traffic areas. Trained research assistants, nursing staff, or reception staff asked women attending their first prenatal appointment to complete a one-page 7-item screening form. The form assesses initial eligibility and provides permission for study staff to follow-up with the participant to conduct a comprehensive telephone screening to identify and exclude women with contraindications to exercise.[206,207] Multiple clinics serve women on Medicaid, which allows for some variability in income among participants. In addition to OB/GYN clinics, flyers were posted in the greater Columbia community in establishments commonly frequented by pregnant women, such as a large pediatric clinic, university bulletin board, local grocery stores, WIC offices, and Healthy Start offices. Study advertisements were also distributed through online outlets (i.e., Craig's list, social media sites, participating clinics' websites), local parenting magazines, and local events that targeted women or mothers with young infants. Interested women completed the screening form on the study website or by telephone with study staff. A full description of the study enrollment and motivational interviewing process has been published elsewhere.[208]

3.4 Inclusion/Exclusion Criteria

Women were eligible to participate if: (a) they were between 18-44 years of age, (b) identified as White or Black/AA, (c) could read and speak English, (d) had no plans to move outside of the geographic area in the next 18 months, (e) were $\leq$ 16 weeks gestation, (f) had a pre-pregnancy body mass index (BMI) $\geq$ 25 kg/m^2 and a pre-pregnancy weight $\leq$ 370 pounds. Women were excluded if they had contraindications to physical activity during pregnancy.[206] Medical exclusions included uncontrolled blood pressure (> 160 systolic or > 100 diastolic), use of insulin for diabetes, uncontrolled or untreated thyroid disease, hospitalization for a mental health or substance abuse disorder in the past 6 months, multiple gestation, persistent bleeding in first trimester, history of > 3 miscarriages, history of eating disorder or malnutrition, history of incompetent cervix, physical disabilities that prevent exercise, and physician advice to not exercise during pregnancy. Intervention-related exclusions were irregular or inconsistent access to a telephone and unwillingness to take part in weekly telephone calls.

Eligible women who met inclusion criteria and completed a baseline measurement visit were randomized to either the behavioral intervention or standard care group and were included in these analyses regardless of their long-term participation in the intervention. The following section describes intervention activities for the behavioral intervention and standard care groups.

3.5 Summary of Intervention Activities

Participants in the behavioral lifestyle intervention group began intervention activities before 18 weeks gestation and continued through 6 months postpartum. The intervention was grounded in Social Cognitive Theory and tailored to fit the unique needs, interests, and barriers of pregnant and postpartum women. Intervention activities were designed to teach women behavioral skills and knowledge, self-regulation strategies (e.g., goal setting, self-monitoring, problem solving), how to seek out social support, and identifying high-risk situations and coping strategies to address them.

The intervention involved two in-depth counseling sessions (one in early pregnancy and one in early postpartum), weekly or bi-weekly telephone counseling, behavioral podcasts with accompanying handouts (10 in pregnancy, 16 in postpartum), and a private Facebook group (one for pregnancy, one for postpartum). The in-depth pregnancy counseling session (approximately an hour) was typically conducted on USC's campus and at the participant's home during postpartum, based on the participant's preference. During pregnancy, the counseling session encouraged participants to eat a balanced diet (i.e., high in fruits, vegetables, and whole grains; low in saturated and trans fats) that was designed to meet but not exceed dietary needs for pregnancy and lactation. Additionally, they were encouraged to engage in 150 minutes of moderate intensity physical activity (PA) (e.g., brisk walking) per week. All of the nutrition, exercise, and weight gain guidance were consistent with guidelines for pregnant women.[207,209,210] The pregnancy counseling session also addressed guidelines for appropriate GWG and provided participants with a customized weight gain tracking graph based on the participant's pre-pregnancy body mass index (BMI). Healthy eating recommendations were in accordance with the United States Department of Agriculture's (USDA's) MyPlate Plan. The eating plan was customized based on the participant's age, sex, PA level, height, pre-pregnancy weight, and due date. Trimester-specific calorie recommendations and information on the number of servings of each food group were provided. The intervention was primarily delivered through weekly or bi-weekly telephone counseling calls. The first 10 calls were approximately 20 minutes long and addressed the previously mentioned behavioral strategies to facilitate changes in healthy eating and PA. After the first 10 calls were completed, participants were provided the option to switch to a bi-weekly schedule and the remaining pregnancy calls were shorter (approximately 10 minutes), which focused on applying strategies learned in the first 10 calls.

To reinforce information provided in the counseling calls, participants also received behavioral podcasts to listen to at their convenience. The 10 pregnancy podcasts aligned with the information and behavioral strategies covered in that week's counseling call. The 16 postpartum podcasts were based on the Diabetes Prevention Program; participants were either emailed a link to the podcast, the link was sent via text message, or sent through both channels based on the participant's preference. Lastly, in the pregnancy and postpartum counseling sessions, participants were encouraged to join the study's private Facebook group. In the group, they could connect with other women in the intervention group, provide support to and receive support from each other, and access additional resources posted by study staff to help reinforce intervention knowledge and behavioral strategies (e.g., healthy recipes and pre- and post-natal exercise videos).

Participants randomized to the standard care group attended their regularly scheduled prenatal care appointments with their healthcare providers. Participants received standard nutrition counseling provided by physicians, nurses, nutritionists, and counselors from the WIC program (if applicable). Participants were sent 6 monthly informational mailings during pregnancy and 6 during postpartum. During pregnancy, the mailings focused on a healthy pregnancy and on fetal development. During postpartum, the mailings focused on infant development. Similar to intervention participants, standard care participants also received 10 podcasts in pregnancy and 16 during postpartum. The podcasts were all commercially-available and focused on having a healthy pregnancy, fetal and infant development, and parenting. Participants who listened to at least 9 of the 10 podcasts received a small incentive (e.g., baby wipes and bibs). Further details on intervention and standard care components can be found in the study's methodology manuscript.[208]

3.6 Data Collection and Measures

3.6.1 Overview

For the larger HIPP study, measurements were collected from participants at baseline, 32-weeks during pregnancy, 6 months postpartum, and 12 months postpartum. The current study analyzed data collected at baseline only. Baseline assessments for the current analysis were conducted from January 2015 to March 2018. At the baseline visit, demographic data and anthropometric measures were collected. Demographic and psychosocial questionnaires were interviewer-administered, while 24-hour dietary recalls were self-administered. Copies of relevant questionnaires can be found in Appendices A and B.

3.6.2 Demographic Data

Demographic variables, such as age (18-24 years, 25-29 years, 30-34 years, or 35-42 years), race/ethnicity (White or AA/Black), education (high school diploma/GED, some college, or college degree/higher), income (<$10K-34.9K, $35K-49.9K, $50K-74.9K, or $75K+), employment status (employed full-time, part-time/self-employed, homemaker, or student/unemployed), parity (nulliparous or multiparous), marital status (married or not married), and enrollment in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (yes or no) were assessed at baseline. WIC enrollment was used as a proxy for low-income since financial burden is a requirement to receive WIC benefits.[211] Self-reported pre-pregnancy height and weight were used to calculate pre-pregnancy BMI by dividing their weight, in kilograms, by their height in squared meters (kg/m2). Participants' pre-pregnancy BMI was dichotomized into overweight (BMI 25.0-29.9 kg/m2) or obese (BMI >30 kg/m2) categories. Details regarding other measures and questionnaires that were collected, but not relevant to the current study have been published elsewhere.[212]

3.6.3 Mental Health Data

The baseline mental health variables that were relevant to the current analysis were perceived stress and depressive symptoms.

Stress: Stress was measured using Cohen's 4-item Perceived Stress Scale (PSS), an abbreviated version of the 14-item scale, which is a global measure of perceived stress designed to assess the degree to which situations in the previous month were perceived as stressful.[82] Items assessed the frequency of feeling overwhelmed (e.g., "in the last month, how often have you found that you could not cope with all the things you had to do?”). Responses were indicated on a 5-point Likert-type scale, ranging from 0 “never” to 4 “very often.” Possible scores ranged from 0 to 16, with higher scores indicating higher perceived stress. The 4-item PSS has acceptable internal consistency reliability (Cronbach’s α= .79) and convergent validity with the Edinburgh Prenatal/Postnatal Depression Scale (EPDS) and has been validated in pregnant women.[173]

Depressive symptoms: Depressive symptoms were measured using the 10-item Edinburgh Prenatal/Postnatal Depression Scale (EPDS), a widely-used self-report scale that has been validated for use during pregnancy and postpartum.[213] The scale screens for depressive symptoms, such as blaming oneself unnecessarily or feeling anxious. Respondents rated how often in the past seven days they experienced the described thoughts or feelings from 0 (never) to 3 (very often), with possible scores ranging from 0 to 30. Higher scores indicate more depressive symptoms. Satisfactory internal consistency reliability was previously reported (Cronbach’s α= .80 to .87).[214] Depressive symptoms were assessed as a continuous score with higher scores indicating more depressive symptoms.[215]

3.6.4 Dietary Data

ASA24 dietary recall: Participants completed two unannounced 24-hour dietary recalls (one weekday and one weekend day, which included Fridays) at baseline through the National Cancer Institute’s (NCI’s) Automated Self-Administered 24-hour Dietary Recall (ASA24) online system.[216] The ASA24 is a web-based dietary assessment tool that provides complete nutrient analysis of all foods and beverages reported during the data collection timeframe.[216]

Healthy Eating Index-2015 (HEI): Based on the 24-hour dietary recall data, participants' diet quality was calculated using SAS code provided by the NCI to generate HEI scores, which measure adherence to the 2015 Dietary Guidelines for Americans (DGAs).[128] The HEI-2015 includes 13 components, including nine adequacy components (i.e., Total Fruits, Whole Fruits, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids), which are dietary aspects that need to be increased. There are four moderation components (i.e., Refined Grains, Sodium, Added Sugars, and Saturated Fats), which are dietary aspects that need to be reduced. All components are scored on a density basis out of 1,000 calories, with the exception of Fatty Acids, which is a ratio of unsaturated to saturated fatty acids.[217] For each component, higher scores reflect greater adherence to the 2015 DGAs. Component scores were summed to create a total score ranging from 0 to 100 points, with higher scores indicating better diet quality. Due to floor and ceiling effects of many HEI components, components were analyzed as dichotomous outcomes of achieving the maximum score or not. A major benefit of the HEI is that it uses density standards for scoring (i.e., intake per 1,000 kcals), which are independent of an individual's energy requirement. Additionally, it is appropriate for all segments of the U.S. population, including pregnant and lactating women.[62] The HEI also accommodates a variety of eating patterns, allowing for variability among cultural, ethnic, and traditional diet practices, in addition to personal preferences, food costs, and availability. Diet quality results have enhanced the nutrition-related outcomes of the HIPP study. Table 3.2

presents the scoring standards set forth by USDA and NCI, which were used to determine maximum scores for each HEI component.

3.6.5 Retail Food Outlet Data Acquisition

Food retailers were acquired from ReferenceUSA, a commercial database of U.S. businesses.[218] Food retailer addresses for SC were obtained from the database in December 2017. Retailers were categorized based on North American Industry Classification System (NAICS) codes. The categories of interest included: grocery stores/supermarkets (Group 445110), convenience stores (445120), gas stations with food marts (447110), drug stores (446110), discount merchandise stores (452319), and limited-service restaurants (722513). Drug stores (e.g., Walgreens) and discount merchandise stores (e.g., Dollar General) were included since they typically sell a limited variety of food products such as milk, bread, soda, and snacks.[219] Limited-service restaurants are establishments where customers order and pay before eating, the food is typically served quickly after ordering, and the food is kept cold, cooked in advance, and/or reheated.[177] This category included fast-food restaurants, fast-casual restaurants, limited-service family restaurants, pizza delivery shops, delicatessen restaurants, and takeout eating places. For the purposes of the current study, gas stations with food marts, drug stores, and discount merchandise stores were combined with convenience stores and referred to as convenience stores moving forward.

3.6.6 Healthy Food Density

Healthy food density was assessed by the Centers for Disease Control's (CDC's) Modified Retail Food Environment Index (mRFEI). The mRFEI combines the concepts of food deserts (i.e., areas with poor access to supermarkets) with the concept of food swamps (i.e., areas with a high amount of unhealthy food) into a single score at the census-tract level.[152] The original mRFEI score represents the percentage of food retailers considered healthy, out of the total number of food retailers considered healthy and less healthy in a census tract (see Figure 3.1); however, the current study calculated the mRFEI at the *individual-level* within a 5-mile network radius based on HIPP participants' home addresses. mRFEI scores range from zero (no food retailers that typically sell healthy food) to 100 (only food retailers that sell healthy food). The designation of healthy and less healthy retailers was based on the CDC's definition[152], where *healthy food retailers* included grocery stores/supermarkets and *less healthy food retailers* included limited-service restaurants, convenience stores, drug stores, gas stations with food marts, and discount merchandise stores. Drug stores and discount merchandise stores were not included in the original formula but were added since they sell a limited variety of food items similar to a convenience store.[219] Full-service restaurants are not included in mRFEI scores. Farmers' markets were not included in the current study due to their seasonal nature, variability in operating hours, and lack of standardization in produce offered.

An overview of each type of retail food outlet and definition of healthy and less healthy retailers are presented below in Table 3.3.

3.6.7 Classification of Urban Areas

Urban and rural areas were determined by the Census Bureau's 2017 Urban Areas Boundary file. The Census defines two categories of urban areas—urbanized areas (50,000 people or more) and urban clusters (at least 2,500 people and less than 50,000 people). Rural areas include all populations and areas not included within an urban area.[220] Participants' addresses were spatially joined to associated urban area boundaries. Participants' addresses that fell within urban areas were categorized as urban participants and those outside urban areas were categorized as rural.

3.7 Data Protection

All baseline survey data and participants' home addresses were extracted from the HIPP study database by the PIs of the study and stored on USC's secure computer network. Participant privacy was ensured by using the 4-digit ID numbers they were assigned at the time of the baseline survey completion. The ID numbers were linked to participant names in the password-protected Access database, which was stored on password-protected computers within the locked campus suite. Study ID numbers were used for all study documents and questionnaires. Participants used their study ID numbers and a unique investigator-generated password to log on to the ASA24 dietary recall website. Data were backed-up on OneDrive, which is secure, password-protected, and allowed for the storage of data at USC.

3.8 Protection of Human Subjects

All participants provided written informed consent prior to participating in any intervention activities. Institutional Review Boards (IRBs) at Palmetto Health, University of South Carolina, Lexington Medical Center, and the Medical University of South Carolina approved the main study's protocol. Since the current research did not involve primary data collection, the HIPP study's informed consent document was not revised. IRB approval for the current study was obtained from Palmetto Health as a sub-study amendment to the original HIPP study's IRB application. Additionally, there were no additional risks posed to HIPP participants. Participants' home locations were not shared outside of authorized study personnel. Quantitative and geospatial analyses were conducted on password-protected computers.

3.9 Data Quality Control

Participants' home address data were retrieved by HIPP PIs and exported to an Excel spreadsheet which was saved to the university's password-protected server. To ensure that baseline addresses were used in geospatial analyses, addresses in the spreadsheet were compared with addresses provided at the time of initial screening. For participants who moved since screening, their addresses were revised in the spreadsheet prior to geocoding. Baseline demographic, mental health, and dietary data were read into SAS version 9.4 and checked for missing responses and outlying values.

3.10 Data Analysis

3.10.1 Overview

The overall goal of the current study was to understand how psychosocial factors (i.e., stress and depressive symptoms) and built environment factors (i.e., neighborhood healthy food density) were associated with diet quality among racially-diverse overweight and obese pregnant women in SC. Quantitative analyses were conducted in SAS version 9.4 (SAS Institute, Inc., Cary, NC, 2013)[221] and geospatial analyses were conducted in ArcGIS Pro version 1.2 (Esri, Inc., Redlands, CA, 2016).[222] Findings were considered statistically significant at $p < .05$.

***Specific Aim 1:** Conduct a systematic literature review to (1) synthesize findings of original, peer-reviewed studies that examined the associations between stress and/or depressive symptoms, and diet quality during pregnancy; (2) review the measurement tools used to assess stress, depressive symptoms, and diet quality; (3) identify current gaps in the extant literature; and (4) offer recommendations for future research.

Research Questions for Aim 1: 1) What are the associations between poor mental health (i.e., stress and depressive symptoms) and diet quality during pregnancy?; 2) Do findings differ among racial minorities?; 3) What methods are used to assess stress, depressive symptoms, and diet quality?; and 4) What theoretical models are informing the research?

Articles were collected from five databases: PubMed, CINAHL Complete, PsycINFO, Academic Search Complete, and Psychology & Behavioral Sciences Collection. The search was originally conducted in December 2017 and updated in

October 2018. The search was restricted to English, peer-reviewed articles published between January 1997 and October 2018. This time frame captures the emergence of assessing mental health in relation to overall diet quality in pregnancy.[87] The search was run using both free text words and controlled vocabulary. A Health Sciences Librarian assisted in revising and validating the search strategy for all the different databases. The PubMed search strategy is detailed in Table 4.1.

Briefly, studies were eligible for inclusion if they: (1) were full-text articles; (2) were cohort, cross-sectional, or randomized designs; and (3) examined associations between stress and/or depressive symptoms, and diet quality in pregnancy. Studies were excluded if they: (1) examined only individual nutrients or micronutrients (ex: omega-6 fatty acids); (2) examined diet in relation to disordered eating or gestational diabetes; (3) measured diet quality, stress, or depressive symptoms during pre-pregnancy or postpartum only; (4) assessed diet in relation to malnutrition or food insecurity; (5) used animal models; (6) used only qualitative methods; (7) focused on child outcomes; (8) were pilot studies; (9) were review articles; or (10) measured stress biomarkers.

The article screening process was completed independently by two researchers, which is further explained in Manuscript 1. After completing the screening process, researchers met to discuss discrepancies and reached consensus on which articles to retain. The extracted data included study characteristics (sample size, study design, location where the study was conducted, racial composition of participants, and inclusion of a theoretical framework); diet quality assessment (measures used, time of completion, and method for assessing diet quality); stress assessment (measures used, time of completion, and cut-off scores); depressive symptoms assessments (measures used, time of completion, and cut-off scores); statistical tests used; inclusion of covariates; and a brief summary of the relevant findings.

<u>*Specific Aim 2:</u> Examine if stress scores and depressive symptoms are associated with poorer diet quality (using the Healthy Eating Index-2015, or HEI) and test race as a moderator.

<u>Hypothesis2a:</u> Pregnant women with higher stress scores and depressive symptoms would have lower HEI total scores and lower odds of meeting HEI component recommendations.

<u>Hypothesis2b:</u> In terms of moderation, as stress and depressive symptoms increase, AA women would have lower HEI total scores and lower odds of meeting HEI component recommendations compared to White women.

Descriptive statistics (e.g., means, standard deviations (SD), and percentages) were used to summarize participants' sociodemographic characteristics, stress, depressive symptoms, and diet quality (i.e., HEI total scores and components) at baseline. Independent samples t-tests were used to test for mean differences in continuous variables (e.g., age, parity, gestational age, perceived stress, depressive symptoms, HEI total scores, HEI component scores) by race. The χ^2 test was used to examine differences in the proportion of categorical characteristics (e.g., marital status, education level, employment, and pre-pregnancy weight status) by race and to assess for differences in the percentage of women meeting HEI component recommendations by race.

Multiple linear regression models were used to predict HEI total scores. The independent variables were stress and depressive symptoms, which were modeled separately as continuous variables. Potential confounders were chosen a priori based on existing literature and included maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. WIC enrollment was used as a proxy for low-income since financial burden is a requirement to receive WIC benefits.[211] Multiplicative interaction terms of stress or depressive symptoms with race were used to examine if race moderated the relationship between stress, depressive symptoms, and diet quality in adjusted models. Beta coefficients and standard errors for both crude and adjusted models were presented.

To test the hypothesis that higher stress and depressive symptoms would be associated with lower odds of meeting HEI component recommendations, multiple logistic regression models were used to predict the odds of meeting HEI component recommendations for 12 out of the 13 HEI components as secondary outcomes. The Sodium component could not be analyzed due to the small cell size of participants who met the Sodium recommendation. Models adjusted for maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. Multiplicative interaction terms of stress or depressive symptoms with race were used to examine if race moderated the relationship between stress, depressive symptoms, and meeting HEI component recommendations in adjusted models. Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for crude and adjusted models are presented. For all analyses, a P-value <0.05 indicated statistical significance. Statistical analyses were performed using SAS® software, version 9.4.[221]

<u>*Specific Aim 3:</u> Examine if higher healthy food density (via the CDC's Modified Retail Food Environment Index (mRFEI) is associated with better diet quality (via Healthy

Eating Index (HEI)-2015 total scores and meeting HEI component recommendations) and to test residential location as a moderator.

Hypothesis3a: An increase in healthy food density would be associated with higher HEI total scores and higher odds of meeting HEI component recommendations.

Hypothesis3b: In terms of moderation, as healthy food density increases, urban women would have higher HEI total scores and higher odds of meeting HEI component recommendations compared to rural women.

Food retailers were acquired from ReferenceUSA, a commercial database of U.S. businesses.[218] Food retailer addresses for SC were obtained from the database in December 2017. Retailers were categorized based on North American Industry Classification System (NAICS) codes. The categories of interest included: grocery stores/supermarkets (Group 445110), convenience stores (445120), gas stations with food marts (447110), drug stores (446110), discount merchandise stores (452319), and limited-service restaurants (722513). Drug stores and discount merchandise stores (e.g., Walgreens & Dollar General) were included since they typically sell a limited variety of food products such as milk, bread, soda, and snacks.[219] Limited-service restaurants are where customers order and pay before eating, the food is typically served quickly after ordering, and the food is kept cold, cooked in advance, and/or reheated.[177] This category included fast-food restaurants, fast-casual restaurants, limited-service family restaurants, pizza delivery shops, delicatessen restaurants, and takeout eating places. Food retailers and participants' home addresses were geocoded to the point or street address level using the ArcGIS Online World Geocoding Service address locator in ArcGIS Pro, version 1.2 (Esri, Inc., Redlands, CA, 2016).[222]

The neighborhood food environment was determined by calculating the 5-mile network distance from participants' homes using the "Network Analyst" tool. The 5-mile distance was based on the average distance participants reported traveling to buy groceries across urban and rural areas. Five-mile network buffers were created around each participant's home. Food retailers that were contained in each buffer were clipped and summed for use in the mRFEI formula (Figure 3.1). Further details regarding the mRFEI are detailed in Manuscript 3.

Urban and rural areas were determined by the Census Bureau's 2017 Urban Areas Boundary file. The Census defines two categories of urban areas—urbanized areas (50,000 people or more) and urban clusters (at least 2,500 people and less than 50,000 people). Rural areas include all populations and areas not included within an urban area.[220] Participants' addresses were spatially joined to associated urban area boundaries. Participants' addresses that fell within urban areas were categorized as urban and those outside urban areas were categorized as rural.

Descriptive statistics (i.e., means, standard deviations (SD), and percentages) were used to summarize participants' sociodemographic characteristics, food environment variables (proximity to food retailers, self-reported distance for grocery shopping, and healthy food density scores), and diet quality (i.e., HEI total scores and components) at baseline. Independent samples t-tests were used to test for mean differences in continuous variables (e.g., age, parity, gestational age, healthy food density scores, HEI total scores, HEI component scores) by residential location. The χ^2 test was used to examine differences in the proportion of categorical characteristics (e.g., marital status, education level, and pre-pregnancy weight status) by residential location and to assess for differences in the percentage of women meeting HEI component recommendations by residential location.

Multiple linear regression models were used to predict HEI total scores. The independent variable was the healthy food density score, which was analyzed as a continuous variable. Potential confounders were chosen *a priori* based on existing literature and included race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. WIC enrollment was used as a proxy for low-income status since financial burden is a requirement to receive WIC benefits.[211] A multiplicative interaction term of healthy food density and residential location was used to examine if urban vs. rural status moderated the relationship between healthy food density and diet quality in adjusted models. Beta coefficients and standard errors for both crude and adjusted models were presented.

To test the hypothesis that higher healthy food density scores would be associated with higher odds of meeting HEI component recommendations, multiple logistic regression models were used to predict the odds of meeting HEI component recommendations for all of the HEI components as secondary outcomes, with the exception of sodium. The Sodium component could not be analyzed due to the small cell size of participants who met the Sodium recommendation. Models adjusted for maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. A multiplicative interaction term of healthy food density and residential location was used to examine if urban vs. rural status moderated the relationship between healthy food density and diet quality in adjusted models. Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for crude and adjusted models were presented. For all analyses, a *P* value <0.05 indicated statistical significance. Statistical analyses were performed using SAS® software, version 9.4 (SAS Institute, Inc., Cary, NC, 2013)[221].

Table 3.1 Study Setting Characteristics

	S.C.	U.S.
Population, 2017	5,024,369	325,719,178
African-American, %	27.3%	13.4%
Below poverty line, %	15.4%	12.3%
Obesity prevalence, %	34.1%	39.6%
Gestational weight gain prevalence (overweight, obese), %	61.3%, 54.0%	61.6%, 55.8%

Table 3.2 HEI-2015 Components and Scoring Standards

HEI-2015 Component	Standard for Maximum Score	Maximum Score
Adequacy[1]		
Total Vegetables	≥1.1 cup equiv. per 1,000 kcal	5.0
Greens and Beans	≥0.2 cup equiv. per 1,000 kcal	5.0
Total Fruits	≥0.8 cup equiv. per 1,000 kcal	5.0
Whole Fruits	≥0.4 cup equiv. per 1,000 kcal	5.0
Whole Grains	≥1.5 oz equiv. per 1,000 kcal	10.0
Dairy	≥1.3 cup equiv. per 1,000 kcal	10.0
Total Protein Foods	≥2.5 oz equiv. per 1,000 kcal	5.0
Seafood and Plant Proteins	≥0.8 oz equiv. per 1,000 kcal	5.0
Fatty Acids	(PUFAs + MUFAs)/SFAs ≥2.5	10.0
Moderation[2]		
Sodium	≤1.1 gram per 1,000 kcal	10.0
Refined Grains	≤1.8 oz equiv. per 1,000 kcal	10.0
Saturated Fats	≤8% of energy	10.0
Added Sugars	≤6.5% of energy	10.0

[1]Adequacy components- dietary components that should be increased.

[2]Moderation components- dietary components that should be consumed in moderation.

PUFA-Polyunsaturated fatty acids

MUFA-Monounsaturated fatty acids

SFA-Saturated fatty acids

Table 3.3 Retail Food Outlet Categories and Definitions

Food Outlet Types	NAICS Code	Definitions
Grocery Stores/Supermarkets	NAICS: 445110	Retail food store that primarily sells a variety of fresh produce, dairy, meat and other perishable groceries, in addition to general merchandise, including supercenters (e.g., Kroger & Walmart). Since warehouse clubs are not accessible to everyone due to a membership fee,[223] warehouse clubs were excluded from this analysis.
Convenience Stores	NAICS: 445120, 447110, 446110	Convenience store, discount merchandise store, drug store, or a food mart within a gas station that sells a limited line of products that generally includes milk, bread, soda, and snacks (e.g., QuikTrip, Dollar General, or Walgreens).
Limited-Service Restaurants	NAICS: 722513	Limited-service restaurants are where customers generally order and pay before eating, food is served quickly after ordering, and often cooked in advance and reheated (e.g., McDonald's, Pizza Hut, Panera Bread). This category includes fast-food restaurants, fast-casual restaurants, limited-service family restaurants, pizza delivery shops, delicatessen restaurants, and takeout eating places.
Healthy food retailers	NAICS: 445110	Supermarkets, grocery stores
Less healthy food retailers	NAICS: 445120, 447110, 446110, 722513	Convenience stores and limited-service restaurants

$$mRFEI = 100 \times \frac{\text{\# Healthy Food Retailers}}{\text{\# Healthy Food Retailers} + \text{\# Less Healthy Food Retailers}}$$

Figure 3.1 Modified Retail Food Environment Index Formula

Chapter 4: Manuscripts

The Associations between Maternal Stress, Depressive Symptoms, and Diet Quality during Pregnancy: A Systematic Review[1]

[1] Boutté A.K., Turner-McGrievy G., Wilcox S, Liu J., Eberth J.M., and Kaczynski A.T. To be submitted to *Journal of the Academy of Nutrition and Dietetics*.

Keywords: stress; depression; mental health; diet quality; pregnancy; systematic review

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Abstract

Background: Pregnancy can be a stressful time for many women; however, it is unclear if higher stress and depressive symptoms are associated with poorer diet quality during pregnancy.

Objective: The aims of this systematic review were to (1) synthesize findings of original, peer-reviewed studies that examined the associations between stress and/or depressive symptoms, and diet quality during pregnancy; (2) review the measurement tools used to assess stress, depressive symptoms, and diet quality; (3) identify current gaps in the extant literature; and (4) offer recommendations for future research.

Methods: A search strategy was used to identify peer-reviewed manuscripts published between January 1997 and October 2018 using the following databases: PubMed, CINAHL Complete, PsycINFO, Academic Search Complete, and Psychology & Behavioral Sciences Collection. Two reviewers independently assessed title, abstract, and full-text of the studies that met inclusion criteria. Data were extracted and a quality assessment was conducted.

Results: Twenty-four observational studies were identified in this review (18 cross-sectional and 6 longitudinal). Twenty studies found that higher stress and/or depressive symptoms were associated with poorer diet quality/unhealthy dietary patterns, while four studies found no association. Findings are mixed and inconclusive regarding the relationship between stress, depressive symptoms, and food groups related to diet quality and frequency of fast-food consumption.

Conclusions: The current data suggests that stress and depressive symptoms may be a barrier to proper diet quality during pregnancy; however, variability in the assessment tools, timing of assessments, and use of covariates likely contribute to the inconsistency in study findings. Gaps in the literature include limited use of longitudinal study designs; limited use of comprehensive diet quality indices; underrepresentation of minority women; and lack of multi-level theoretical frameworks. These factors should be addressed in future studies in order to better assess the relationship between stress and depressive symptoms on diet quality during pregnancy.

Introduction

Almost one-half (46%) of women in the United States (U.S.) exceed the Institute of Medicine's (IOM) 2009 gestational weight gain (GWG) recommendations,[1,2] which has become a significant public health challenge. Excessive GWG is associated with adverse maternal outcomes (e.g., increased risk of preeclampsia, failed induction, and cesarean delivery)[3] and poor infant health. Maternal diet quality during pregnancy influences infant development and can help prevent excessive GWG, making it an important modifiable factor to address during pregnancy.[4,5] Diet quality is a broad term for the assessment of both the quality and variety of one's entire diet, measured by scoring food patterns in terms of their alignment with national dietary guidelines (e.g., 2015-2020 Dietary Guidelines for Americans)[6] and the diversity of healthy choices within core food groups or international groupings (e.g., Mediterranean diet).[7] Comprehensive food-based dietary guidelines for pregnant women are not included in the current dietary guidelines, but are forthcoming in the 2020-2025 edition of the guidelines.[8]

In the past decade, there has been an increase in research examining the relationship between diet quality and mental health due to the major life transition that accompanies pregnancy.[9] This transition is often characterized by a series of social, psychological, behavioral, and biological changes in women's lives,[10] which may act as a barrier to healthy eating through increased stress.[11] However, limited research has examined the relationship between maternal mental health factors (i.e., stress, depressive symptoms) and overall diet quality in pregnancy exclusively.[12] Previous reviews that have explored the relationship between stress and/or depressive symptoms, and diet quality during pregnancy are limited in three main ways: 1) a predominant focus on the impact of nutrient deficiencies (e.g., zinc, iron, and omega-3 fatty acids);[13,14] 2) synthesis of studies that examined outcomes during the entire perinatal period (including pregnancy and up to one-year postpartum);[9,14,15] and 3) a focus on how diet quality impacts child health and dietary outcomes (e.g., height, blood pressure, and fruit and vegetable intake).[16–19] These previous approaches leave important gaps in the literature as it pertains to maternal physical and mental health during pregnancy.

Over the past two decades, public health nutrition has shifted away from examining individual nutrients to examining overall diet quality.[20,21] There are many benefits to assessing overall diet quality such as using a standardized approach to capture the totality of one's diet, accounting for the synergistic relationship between dietary components, and the adaptability to fit personal and socio-cultural preferences.[13,22] Pregnancy has been regarded as a "teachable moment",[23] where women are more engaged with health services and may be more receptive to making health-promoting behavior changes, such as improving their nutrition.[9,24] It is imperative to gain a better understanding of how psychosocial factors may be associated with diet quality during pregnancy exclusively, to develop relevant screening processes and interventions for high-risk populations.

The aims of this systematic literature review were to: (1) synthesize findings of original, peer-reviewed studies that examined the associations between stress and/or depressive symptoms, and diet quality during pregnancy; (2) review the measurement tools used to assess stress, depressive symptoms, and diet quality; (3) identify current gaps in the extant literature; and (4) offer recommendations for future research.

Methods

This systematic review was conducted using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[25]

Search Strategy

A literature search was run in October 2018 in the following databases: PubMed, CINAHL Complete, PsycINFO, Academic Search Complete, and Psychology & Behavioral Sciences Collection. The search was run using both free text words and controlled vocabulary. Additionally, the search was run with the following filters: English articles and published since Jan. 1, 1997. A Health Sciences Librarian assisted in revising and validating the search strategy for all the different databases. The PubMed search strategy is detailed in Table 4.1.

Inclusion and Exclusion Criteria

Studies were eligible for inclusion if they: (1) were full-text articles; (2) were cohort, cross-sectional, or randomized designs; (3) examined associations between stress and/or depressive symptoms, and diet quality in pregnancy. Stress was defined as self-reported perceived stress or stressful life events.[26,27] Depressive symptoms were self-reported or assessed by diagnostic measurement tools.[28,29] Diet quality was defined as the quality of one's typical food intake determined by a diet quality score,[30] alignment with healthy eating guidelines,[31] adherence to a specific dietary pattern (e.g., 'Western' diet or 'traditional' diet),[32] or intake of food groups related to diet quality in pregnancy.[12] Cohort studies were included if they examined the relationship between stress and/or depressive symptoms and diet quality as the outcome. Cross-sectional studies were included if they examined stress and/or depressive symptoms as the exposure or the outcome since the direction of the relationship is unclear. Articles were included if they were published after the year 1997.

Studies were excluded if they: (1) examined only individual nutrients or micronutrients (ex: omega-6 fatty acids); (2) examined diet in relation to disordered eating or gestational diabetes; (3) measured diet quality, stress, or depressive symptoms during pre-pregnancy or postpartum only; (4) assessed diet in relation to malnutrition or food insecurity; (5) used animal models; (6) used only qualitative methods; (7) focused on child outcomes; (8) were pilot studies (studies with a sample size less than 20 women); (9) were review articles; or (10) measured stress biomarkers.

Selection Process

All records obtained across the databases were uploaded into Covidence systematic review software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia). Covidence automatically identified and removed duplicate records. Two reviewers independently screened titles and abstracts to identify potential studies that met the inclusion criteria. A calibration exercise, which involved screening 50 titles and abstracts, was conducted to clarify the eligibility criteria. After agreement was achieved, the reviewers identified the relevant articles. All potentially eligible articles were retrieved, and a full-text screening was conducted by two reviewers. Discrepancies were resolved through consensus.

Data Extraction and Quality Assessment

The lead reviewer extracted data from the studies that met the inclusion criteria. A second reviewer independently checked the extraction to ensure accuracy. The extracted data included study characteristics (sample size, study design, location where the study was conducted, racial composition of participants, and inclusion of a theoretical framework); diet quality assessment (measures used, time of completion, and method for assessing diet quality); stress assessment (measures used, time of completion, and cut-off scores); depressive symptoms assessments (measures used, time of completion, and cut-off scores); statistical tests used; inclusion of covariates; and a brief summary of the relevant findings. If information needed to be added, reviewers had a discussion and came to an agreement. The same two reviewers independently assessed the quality of the studies using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) 4 guidelines, which evaluate observational studies against four criteria: developing and including eligibility criteria, unflawed measurement of exposure and outcome, controlling for confounding, and incomplete follow-up.[33]

Results

Study Selection

An overview of the search process is summarized in the PRISMA flow chart (Figure 4.1). The final search of databases occurred in October 2018. Out of a total of 7,058 identified records, Covidence removed 1,848 duplicates, and 5,210 records were screened by title and then by abstract. There were 5,158 records excluded because they were irrelevant to the topic of this review due to various reasons such as using animal models, examining individual nutrients, examining child outcomes, examining associations either pre-pregnancy or postpartum, focusing on eating disorders, using plant samples, using non-pregnant samples, using clinical samples, being a review, and not examining the main associations of interest. The full-text for the resulting 52 studies were read and an additional 29 articles were excluded for the following exclusion criteria: 10 studies did not examine the main associations of interest, 9 articles were editorial articles, 2 studies were duplicates that were not detected by Covidence, 2 studies focused on individual nutrients, 2 studies had very small sample sizes due to being pilot studies, 2 studies assessed stress biomarkers and not perceived stress, 1 study assessed associations either pre-pregnancy or post-partum, and 1 study was a previously unidentified review article. Of the screened records, 23 met the inclusion criteria. Reference lists of relevant articles were reviewed, and one additional article was identified for a total of 24 articles included and assessed in this systematic review.

Study Characteristics

The characteristics of the included studies are reported in Table 4.2.

Methodology. All included studies were observational and used a survey methodology. 18 studies used cross-sectional designs[12,30,31,34–48] and 6 studies used prospective cohort designs[11,32,49–52].

Setting. The studies were conducted in multiple countries. Just under a third of the studies were conducted in the U.S.[11,12,30,34–36,45], five studies were conducted in Japan,[39,43,44,46,48] four studies were conducted in the United Kingdom (UK),[32,38,42,51] two took place in Australia,[31,50] and one study was conducted in Brazil,[40] New Zealand,[41] Pakistan,[49] Canada,[37] China,[52] and Iran[47] respectively.

Population. Sample sizes ranged from n=82[49] to n=13,314[32] women in cohort studies and from n=50[35] to n=14,541[42] in cross-sectional studies. Six cross-sectional studies included targeted populations: low-income women,[30,34–36,45] pre-pregnancy BMI overweight/obese,[36,45] and well-educated, middle-class women.[12] One cohort study included a targeted population of middle-income women.[49]

Dietary assessment. Dietary intake was assessed through a variety of tools. Dietary intake was most commonly assessed through Food Frequency Questionnaires

(FFQs), which were used in 11 studies.[12,31,32,37,38,40–42,48,50,51] FFQs estimate one's usual intake, typically over the previous month.[53] The level of detail of FFQs varied among these studies: one study used a three-item version,[42] one study used a four-item version,[37] one study used a six-item version,[31] and the remaining studies used detailed FFQs, ranging from 43-items[32] to 100-items.[50] Three of these studies assessed dietary intake through systematic 24-hour dietary recalls,[30,34,35] one study used a 21-item dietary recall questionnaire,[52] four studies used Diet History Questionnaires (DHQs),[39,43,44,46] two studies used a Rapid Food Screener,[36,45] one study used a Prenatal Health Behaviors Scale,[11] one study used a combination of 24-hour dietary recalls and a Food Frequency Checklist that was modified to fit the cultural context of Pakistan,[49] and one study used a Health-Promoting Lifestyle Profile (Persian version).[47]

Comprehensive diet quality index scores were estimated in three studies[30,34,49] and were derived from 24-hour dietary recalls. The Diet Quality Index for Pregnancy (DQI-P), was used in two studies[30,34] and consisted of eight components: grains; fruit; vegetables; percent of recommended intake for folate, calcium, and iron; percent of energy from fat; and meal/snack pattern.[54] Scores for each component ranged from 0-10, with total scores ranging from 0-80. A composite score of 70+ reflected the most desirable diet quality in pregnancy.[54] The third study modified the traditional Healthy Eating Index (HEI) to assess only the adequacy components (areas where typical consumption is too low) such as fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein, and seafood and plant proteins.[49] The overall score of the modified HEI was reduced to 50, with a score > 40 indicating good diet quality.

Eight studies identified dietary patterns through factor analysis,[38,39,50,51] other statistical techniques,[32,40,41] or 'healthy'/'unhealthy' subscales.[11] Standardized scores for each dietary pattern were calculated for study participants, with higher scores indicating greater similarity to that dietary pattern.[32] Some of the identified patterns include 'healthy' versus 'unhealthy';[38,50] 'Japanese';[39] 'health-conscious';[32,41] 'common-Brazilian';[40] 'junk'/'processed'/ 'confectionary'/ 'Western';[32,39,41] and 'vegetarian'.[32] One study assessed diet quality by examining dietary diversity across 9 food groups and creating a composite score, with higher scores indicating greater dietary diversity and better diet quality.[52] Additionally, seven studies assessed food groups (e.g., fruit, vegetables, fish, or dairy)[12,31,36,37,42–44] and one assessed fast-food intake.[35]

Mental health assessment. Mental health was assessed through multiple tools. A total of 21 studies assessed depressive symptoms during pregnancy.[12,30,32,34–47,49–52] Of these, 12 studies used the Edinburgh Postnatal Depression Scale (EPDS),[30,32,34–36,38,41,42,45,49–51] a validated self-report screening tool used in clinical and research settings to identify depressive symptoms during pregnancy and postpartum.[28] Scores from this scale can be used as a continuous variable with greater scores indicating greater depressive symptoms or categorized into levels of depressive symptoms using validated cut-off scores.[28] Four studies analyzed depressive symptoms as a continuous variable[38,45,50,51] and eight studies used cut-off scores ranging from ≥ 9 to ≥ 13 to identify high levels of depressive symptoms.[30,32,34–36,41,42,49] Five studies used the Center for Epidemiologic Studies-Depression Scale (CES-D) to assess depressive symptoms,[37,39,43,44,46] which is a research screening tool to identify high depressive symptoms and has been validated in community samples.[55] Of these, one study used a cut-off score of > 16[39] and four studies used a cut-off of ≥ 16[37,43,44,46] to identify depressive symptoms. One study used the Primary Care Evaluation of Mental Disorders (PRIME-MD),[40] a valid tool designed to facilitate the diagnosis of major depressive disorder by primary care physicians.[29] One study used the Profile of Mood States-Depression subscale,[12] a continuous measure that assesses depressed mood with higher scores reflecting greater negative mood.[56] Additionally, one study used the Self-Rating Depression Scale,[52] a previously validated screening tool used to evaluate one's mood in the past 7 days, with higher scores indicating greater depressive symptoms (range from 20-80; cut-off ≥53).[57] Lastly, one study used the Beck Depression Inventory-II,[47] which is a widely-used and valid instrument for detecting depression in normal and clinical populations where higher scores indicate more severe depressive symptoms.[58]

Ten studies assessed self-reported stress or psychological distress during pregnancy.[11,12,30,31,34–36,45,47,48] Three studies used the Prenatal Psychosocial Profile-Stress subscale,[30,34,35] a validated continuous measure of stress during pregnancy.[59] One study used the full-length (14-item) Perceived Stress Scale (PSS),[12] two studies used the 9-item version,[36,45] and one study used the brief 4-item version,[31] with all versions measuring general perceived stress.[26] Two studies assessed pregnancy-specific stress, with one study using the original Prenatal Distress Questionnaire, and one study using a revised version.[11] The Prenatal Distress Questionnaire is a continuous measure of pregnancy-specific stress.[60] One study examined stressful life events in conjunction with prenatal distress by using the Prenatal Life Events Scale, which is comprised of a count of the number of stressful life events during pregnancy and resulting level of distress.[27] Lastly, one study used the 6-item Kessler Psychological Distress Scale,[48] which is a widely-used screening tool for identifying psychological distress in the general population.[61] On all stress measures, higher scores indicated higher levels of stress or distress.

Methodological Quality. The results of the quality of evidence assessment of the included studies are summarized in Table 4.3 according to GRADE 4 guidelines.[33] Eight studies provided adequate and appropriate information regarding eligibility criteria, including exclusion for pre-existing health conditions that could impact diet quality.[12,30,34,35,37,47,49,52] The majority of the studies provided unflawed measurement of exposure and outcome.[12,30–32,34,35,37–44,46,48,49,51–53] Only 4 studies failed to adequately control for potential confounding factors,[34–36,45] and only 6 studies had complete follow-up or results for multiple time-points in pregnancy.[11,32,49,51–53] Two studies had the strongest methodological design as determined by GRADE 4 criteria,[33] relative to the other included studies. Both studies found significant associations between mental health and diet quality in pregnancy.[49,52] There was variation in the covariates included across studies. Sociodemographic factors such as age, education, income, and marital status were controlled for in half of the studies.[12,30–32,39,40,42,46–48,52,53] Parity was controlled for in eight studies,[12,31,32,42,46,48,52,53] gestational age (weeks) was controlled for in six studies,[39,43,44,46–48] history of depression was controlled for in six studies,[39,43,44,46,48,53] and Body Mass Index was controlled for in ten studies.[12,31,39,41,43,44,46,48,52,53]

Study findings are summarized in Table 4.2 and are grouped into three categories based on the way diet quality was assessed: 1) dietary patterns, such as ‘healthy’ or ‘Western’ patterns; 2) diet quality determined from standardized diet quality indices (e.g., Diet Quality Index for Pregnancy (DQI-P) or Healthy Eating Index (HEI)); and 3) dietary diversity, consumption of fast-food, or specific food groups commonly included in diet quality indices (e.g., fruit, vegetable, and seafood intake).

Stress and depressive symptoms: Studies assessing dietary patterns (Non-indices)

Cohort. There are mixed findings across three cohort studies assessing the relationship between depressive symptoms in early pregnancy (i.e., 16 or 18 weeks) and various dietary pattern scores at 32 weeks (e.g., 'unhealthy', 'confectionary', 'health conscious).[32,51,53] For example, Baskin and colleagues found that higher depressive symptoms at 16 weeks significantly predicted lower 'unhealthy' dietary pattern scores at 32 weeks [β=-0.17, $p<.05$, 95% CI (-0.32,-0.02)], after adjusting for covariates in a sample of Australian women (n=167).[53] A study by Molyneaux and colleagues was the only study that designated 'elevated depressive symptoms' for women who had EPDS scores > 12 at two timepoints (18 and 32 weeks).With this criteria, they found that consistently elevated depressive symptoms were significantly associated with higher 'confectionary' dietary pattern scores [β=0.10, 95% CI (0.02, 0.17)]; however, they found no relationship between elevated depressive symptoms and four other dietary patterns (i.e., 'health conscious', 'traditional', 'processed', or 'vegetarian').[32] Stress, specifically pregnancy-specific stress, was assessed in only one cohort study.[11] Lobel et al.'s study found that higher pregnancy-specific stress was significantly associated with higher 'unhealthy' dietary pattern scores (β=0.29, $p<.05$) and lower 'healthy' dietary pattern scores (β=-.14, $p<.05$) in a majority White sample of US women (n=279), after controlling for obstetric risk.[11]

Cross-sectional. Two cross-sectional studies examined stress and/or depressive symptoms as the exposure and dietary patterns as the outcome.[38,47] These studies also indicate mixed findings. For example, Barker et al.'s analysis of British women (n=6,979) from the Avon Longitudinal Study of Children and Parents (ALSPAC) cohort study found that higher depressive symptoms were associated with higher 'unhealthy' dietary pattern scores [β=-0.01, 95% CI (-0.015, -0.006)] and lower 'healthy' dietary pattern scores [β=-0.005, 95% CI (-0.009, -0.003)] at 32 weeks, after adjusting for social factors (e.g., poverty, police involvement).[38] Alternatively, Omidvar and colleagues found that neither depressive symptoms nor pregnancy-specific stress were significantly associated with healthy nutrition scores in their sample of Iranian pregnant women (n=445).[47]

Cross-sectional. Four cross-sectional studies examined dietary patterns or dietary diversity as the exposure and level of depressive symptoms[39,41,52] or diagnosis of major depressive disorder as the outcome.[40] Overall, findings consistently indicate an inverse relationship between consuming a healthy dietary pattern and presence of depressive symptoms or prevalence of major depressive disorder. For example, Miyake and colleagues found that Japanese women (n=1,744) who scored in the upper quartiles of the 'healthy' dietary pattern (second, third, or fourth quartiles) had a lower prevalence of depressive symptoms, indicated by CES-D scores > 16 [adjusted prevalence ratio (aPR) 0.56, 95% CI (0.43, 0.73)], compared to those in the lower quartile of the 'healthy' dietary pattern scores.[39] Similarly, Jiang and colleagues found that higher dietary diversity scores were significantly associated with lower depressive symptoms at multiple time-points throughout pregnancy (i.e., 10 weeks, 28 weeks, and 36 weeks; *p*'s <.0001).[52] In terms of diagnosed depression, Paskulin and colleagues found that women with high 'common-Brazilian' dietary pattern scores had a 43% higher prevalence of major depressive disorder compared to those with high scores on the ‘varied’ dietary pattern [aPR 1.43, 95% CI (1.01, 2.02)], after adjusting for covariates in their sample (n=712) of Brazilian women.[40]

Overall, higher depressive symptoms were generally associated with higher scores on ‘unhealthy’ and ‘confectionary’ dietary patterns in pregnancy. Additionally, higher depressive symptoms and pregnancy-specific stress were both cross-sectionally related to higher ‘unhealthy’ dietary pattern scores and lower ‘healthy’ dietary pattern scores. A similar inverse relationship was observed even when considering depressive symptoms as the outcome, with higher ‘healthy’ and ‘Japanese’ dietary pattern scores being associated with a lower prevalence of depressive symptoms.

Stress and depressive symptoms: Studies assessing diet quality scores (Indices)

Cohort. Only three studies to date have investigated associations between stress and/or depressive symptoms, and diet quality during pregnancy using a standardized diet quality index score,[30,34,49] and only one that used a cohort study design.[49] Saeed et al.’s cohort study found that middle-income women with higher depressive symptoms (EPDS score $\geq$ 9) at 13 weeks had an increased incidence of poor diet quality at 36 weeks, indicated by lower Healthy Eating Index scores after the scale was modified for the cultural context of Pakistan [relative risk (RR) 2.58, 95% CI (1.60, 5.23)], compared to women with lower depressive symptoms.[49] Depressive symptoms explained 62% of the variance in diet quality during pregnancy, highlighting the importance of mental well-being in relation to diet quality during pregnancy.[49]

Cross-sectional. Fowles et al. examined the independent relationships between stress and depressive symptoms on diet quality in pregnancy using the Diet Quality

Index-Pregnancy.[54] In a sample of (n=71) majority Hispanic, low-income women, they found that women with diet quality scores below the median (DQI-P=53.3) had higher depressive sx (9.6$\pm$5.1 vs. 6.7$\pm$5.1, p=.02) and stress scores (22.1$\pm$5.4 vs. 19.3$\pm$4.8, p=.03) than women with diet quality scores above the median.[34] Fowles and colleagues built upon their previous study by recruiting additional women (n=118) and combining stress and depressive symptoms into an index called "distress" to examine their synergistic effects on diet quality.[30] They found that higher distress scores were significantly associated with higher 'poor eating habits' scores (β=.36, p<.01), and were directly (β=-.23, p<.05) and indirectly (β=-.30, p<.05) associated with lower scores on the DQI-P in their sample of low-income, majority Hispanic women.[30]

Overall, few studies have investigated the relationship between stress, depressive symptoms, and diet quality in pregnancy using a standardized diet quality index. Emerging research indicates that higher levels of stress and depressive symptoms are both independently and synergistically associated with lower diet quality scores in pregnancy. This inverse relationship is observed regardless if diet quality scores were assessed with the DQI-P or modified HEI.[30,34,49]

Stress and depressive symptoms: Studies assessing food groups and fast-food consumption

Proper diet quality involves consuming foods from a variety of different food groups, such as those that make up diet quality indices (e.g., fruits, vegetables, dairy, grains, fish/seafood, and soy products).[62] Fast-food consumption is important to examine because it is associated with excess energy intake and eating behaviors related to poor diet quality (e.g., higher sodium intake and more added sugar).[63] Eleven articles in this review examined associations between stress and/or depressive symptoms, and consumption of food groups (e.g., dairy, seafood intake)[12,31,36,37,42–44,46,48] or fast-food consumption in pregnancy.[35,45] All eleven articles used a cross-sectional study design.

Three studies investigated the association between stress and/or depressive symptoms, and the consumption of food groups relevant to diet quality or adherence to food group recommendations as the outcome.[12,31,36] Chang and colleagues examined the mediating role of depression on the relationships between stress, fat intake, and fruit and vegetable intake according to specific trimesters among a sample of majority African-American low-income overweight/obese pregnant women (n=213).[36] They found that women with higher levels of stress were less likely to eat fruits and vegetables during their first trimester ($b=-0.56$, $p \leq 0.05$); however, this association was not significant in the second or third trimester. Similarly, women with greater depressive symptoms (EPDS score ≥ 13) were more likely to have higher fat intake during the first trimester ($b=0.67$, $p \leq 0.05$), but the association was not significant in the second or third trimester.[36] These findings highlight the importance of measuring stress, depressive symptoms, and dietary intake at multiple points throughout pregnancy since the associations may differ depending on the trimester. Hurley et al. found that higher stress at 24 weeks was associated with higher intake of breads ($r=.23$, $p<.01$) and foods from the fats, oils, sweets, and snack group ($r=.18$, $p<.05$) at 28 weeks in their sample (n=134) of majority White well-educated women, after controlling for covariates.[12] Alternatively, they found no significant relationship between depressive symptoms and food group intake.[12]

Instead of examining individual food group consumption, Malek and colleagues investigated the relationship between maternal stress and adherence to the Australian food group recommendations in a sample of Australian pregnant women (n=455) and found that perceived stress was not a significant predictor of adherence to food group recommendations (β=0.04, p>.05), after adjusting for covariates.[31] This was the only study in the review that was informed by an evidence-based theory (i.e., Theory of Planned Behavior); however, they did not assess depressive symptoms. Depressive symptoms are important to investigate since they may exacerbate the negative effect of maternal stress on diet quality.[30]

Seven studies examined the relationship between dairy/fermented foods, fish/seafood intake, or soy products on stress, psychological distress, or depressive symptoms in pregnancy.[35,37,42–44,46,48] Dairy is the primary source of dietary calcium in the U.S.,[64] making it an important component of overall diet quality.[62] More recently, research has started examining the relationship between the consumption of fermented foods more broadly (e.g., yogurt, cheese, and fermented milk) and mental health during pregnancy.[48] The limited research examining dairy or fermented food intake and depressive symptoms or psychological distress have found conflicting results. Miyake and colleagues examined the relationship between dairy intake (i.e., full-fat milk, low-fat milk, yogurt, cheese, and cottage cheese consumption) and depressive symptoms during pregnancy.[44] In their sample of Japanese women (n=1,745) from the Kyushu Okinawa Maternal and Child Health Study (KOMCHS) cohort, they found that scoring in the highest quartile for yogurt intake was associated with a lower prevalence of depressive symptoms (CES-D $\geq$ 16) during pregnancy [aOR 0.69; 95% CI (0.48, 0.99)].[44] Alternatively, Takahashi and colleagues examined the consumption of probiotics and a variety of fermented foods (i.e., yogurt, lactic acid beverages, fermented milk, cheese, milk, Japanese pickles, miso soup, fermented soybeans, and beans) and psychological distress during pregnancy and found no significant relationship among a large sample of Japan women (n=9,030) from the Japan Environment and Children's Study cohort.[48]

Epidemiologic data indicates that greater fish consumption has been associated with a lower occurrence of depressive symptoms among the general population;[65–67] however, there were only three studies that examined the relationship between fish or seafood intake and the presence of depressive symptoms in pregnancy,[37,42,43] resulting in conflicting findings. For example, Golding and colleagues found that women who did not consume any omega-3s from seafood were significantly more likely to have higher depressive symptoms at 32 weeks [aOR 1.54; 95% CI (1.25,-1.89)], compared to women consuming more than 1.5g of omega-3s from seafood/week in their large sample (n=14,541) of British women from the ALSPAC cohort.[42] Additionally, Miyake et al. found that women who scored in the highest quartile of fish intake had a significantly lower prevalence of depressive symptoms during pregnancy [aOR 0.61; 95% CI (0.42, 0.87)], compared to those in the lowest quartile in the same sample of Japanese women (n=1,745) from the KOMCHS cohort.[43] Alternatively, Sontrop et al. found no relationship between fish intake and depressive symptoms after adjusting for confounders.[37]

Soy product consumption has been gaining attraction due to the multiple health benefits of isoflavones (e.g., prevention of hormone-dependent cancers and cardiovascular diseases);[68] however, the mental health benefits of soy consumption in pregnancy has not received much attention to date.[46] Miyake and colleagues investigated the consumption of a variety of soy products (i.e., tofu, tofu products, fermented soybeans, boiled soybeans, miso, miso soup, and soymilk) and depressive symptoms in pregnancy.[46] They found that higher intake of total soy products, tofu, tofu products, fermented soybeans, boiled soybeans, and miso soup were independently significantly associated with a lower prevalence of depressive symptoms [adjusted PRs (95% CI, P for trend) between extreme quartiles were: 0.63 (0.47, 0.85, 0.002), 0.72 (95% CI: 0.54, 0.96, 0.007), 0.74 (95% CI: 0.56, 0.98, 0.04), 0.57 (95% CI: 0.42, 0.76, < 0.0001), 0.73 (95% CI: 0.55, 0.98, 0.03), and 0.65 (0.49, 0.87, 0.003)], respectively.[46] Since only one study investigated these relationships, additional research should be conducted to confirm these findings.

Two studies examined the relationship between fast-food intake and stress and/or depressive symptoms in pregnancy. Overall, these studies found that higher stress and/or depressive symptoms were significantly associated with greater fast-food intake among pregnant women, which negatively impacted their diet quality.[35,45] For example, Chang and colleagues examined fast-food consumption as a potential mediator in the relationship between stress, depression, and fruit, vegetable, and fat consumption among low-income overweight/obese pregnant women.[45] They found that women with more depressive symptoms were more likely to eat fast-food, which was significantly associated with higher vegetable intake (p=0.01) and higher fat intake compared to women with less depressive symptoms (p=0.003). Additionally, Fowles and colleagues examined the relationship between frequency of fast-food consumption and mental health in a largely Hispanic sample (n=50) of pregnant women.[35] Their study found that eating fast-food three or more times in the past week was associated with having significantly higher stress [23.7$\pm$6.8 vs. 18.9$\pm$4.1; 95% CI (-7.87, -1.70)] and depressive symptoms

[10.4±6.0 vs. 6.8±4.1; 95% CI (-6.45, -0.71)] compared to eating fast-food less frequently.[35] Both studies were consistent in demonstrating that higher stress and depressive symptoms are associated with fast-food intake, which present leverage points for future health behavior interventions in pregnancy.

Overall, findings regarding the relationship between stress, depressive symptoms, and identified dietary patterns suggest that higher depressive symptoms and pregnancy-specific stress were both associated with higher ‘unhealthy’ dietary pattern scores and lower ‘healthy’ dietary pattern scores. In terms of comprehensive diet quality as assessed through a diet quality index, higher stress and depressive symptoms were consistently associated with lower diet quality scores in pregnancy; however, the evidence base is very limited. The associations between stress and depressive symptoms as they relate to the consumption of specific food groups were generally inconclusive. Research suggests that higher stress and depressive symptoms may be associated with lower fruit and vegetable consumption and higher fat intake during the first trimester only; making the implications unclear for the remainder of pregnancy. Stress was not associated with adhering to Australian food group recommendations.[69] There was limited evidence in support of higher yogurt consumption and lower prevalence of depressive symptoms, while evidence on the relationship between fish/seafood consumption and depressive symptoms were conflicting. Alternatively, there were consistent relationships between poor mental health and greater fast-food consumption, with two studies demonstrating that higher stress and depressive symptoms were associated with greater fast-food intake in pregnancy. Lastly, there was a predominant focus on depressive symptoms, with fewer studies investigating stress in relation to diet quality.

Discussion

This study aimed to examine the associations between stress and/or depressive symptoms, and diet quality during pregnancy; review the measurement tools used to assess stress, depressive symptoms, and diet quality; identify current gaps in the literature; and offer recommendations for future research. This study found higher stress and depressive symptoms were associated with higher 'unhealthy' dietary pattern scores and lower diet quality index scores in pregnancy. Similarly, lower stress and depressive symptoms were associated with higher 'healthy' dietary pattern scores. We found limited and inconclusive evidence for the association between stress, depressive symptoms, and the consumption of specific food groups (i.e., fruits, vegetables, dairy, fish/seafood) and fast-food consumption. Overall, there was a dominant focus on depressive symptoms, with much fewer studies investigating stress in relation to diet quality in pregnancy.

Conflicting findings could be influenced by sample characteristics, assessment tools used, and timing of assessments. Most studies were conducted with samples outside of the U.S. and with the use of factor analysis to identify dietary patterns, making it difficult to compare specialized patterns (i.e., 'Japanese', 'common-Brazilian', and 'Western') across populations.[39,40] Previous authors have highlighted the need for high-quality studies that use standard definitions and methods of assessing diet quality and dietary patterns.[9,70,71] Studies that analyze dietary intake data as a comprehensive diet quality score allow for a more standardized approach to compare findings across different populations. While many studies used the EPDS to measure depressive symptoms, studies varied in their use of a continuous score or varying cut-off scores,[32,53] as evidenced in Table 4.2. Stress was assessed multiple ways, including general and pregnancy-specific stress, limiting the ability to compare results across studies. Additionally, studies varied in the amount of covariates that were controlled for, with four studies not adjusting for any covariates;[34–36,49] however authors either found no significant differences in sample characteristics that could pose as confounding factors,[35,49] or were unable to include covariates due to small sample sizes.[34,36] In terms of timing of assessments, only one study reported findings across all three trimesters,[36] demonstrating varying results as pregnancy progressed.

The majority of the studies in this review were cross-sectional studies, very few were cohort studies, and none were randomized studies. Thus, the direction of the relationship between mental health and diet quality is unclear. A bi-directional association is plausible for the relationship between stress or depressive symptoms and diet quality during pregnancy;[32] therefore, there is a need for more large-scale, prospective cohort studies that assess stress, depressive symptoms, and diet quality across multiple time-points to help determine the direction of the relationship.[9] A recent feasibility study found that two novel 8-week stress-reduction interventions were able to facilitate meaningful reductions in stress and depressive symptoms and improved eating behaviors among a sample of multi-ethnic, low-income overweight/obese pregnant women.[72] Future studies could also investigate the effectiveness of stress management interventions in improving diet quality during pregnancy on a larger-scale through randomized controlled trials.

When considering the racial and ethnic diversity of women in the U.S. studies, three studies consisted primarily of Hispanic women (>45%),[30,34,35] while only two studies had more than 20% of African-Americans represented in their sample.[36,45] This is a major gap in the literature since African-American women have disproportionately high rates of obesity,[73] worse diet quality,[74] increased risk of excessive GWG,[75] and increased risk of postpartum weight retention[1,75–78] compared to their White counterparts. Given the racial disparities related to obesity, GWG, and diet quality between White and African-American U.S. women, it is imperative that African-American and minority women overall are adequately represented in future studies to better understand the contextual factors influencing diet quality and to develop culturally-relevant interventions to improve diet quality.

A 2010 IOM report specified the need to investigate multiple levels of influence that impact eating in order to inform systems-level approaches for obesity prevention in the U.S.[79] Only one study in this review reported a specific framework that informed their research (i.e., Theory of Planned Behavior), which focused on individual-level factors.[31] Examining multiple levels of influence (e.g., intrapersonal-, interpersonal-, and environmental-level factors) can help improve our understanding of these complex relationships in order to inform policy, systems, and environmental-level initiatives to improve health.[80]

A major strength of this study is that it synthesized literature on the relationship between stress and/or depressive symptoms, and diet quality during pregnancy, which has not been thoroughly researched. Additionally, the review was exhaustive since it involved multiple reviewers, involvement of a research librarian, five databases, and a thorough review of the measurement tools used to assess stress, depressive symptoms, and diet quality during pregnancy. This study also highlighted important gaps in the literature that need to be addressed to achieve health equity. This review identified the following gaps: 1) limited use of longitudinal study designs assessing variables at multiple timepoints throughout pregnancy; 2) paucity of studies that have examined overall diet quality using comprehensive indices; 3) underrepresentation of minority women in samples; and 4) lack of theoretical frameworks that bridge multiple levels of influences to explain diet quality in pregnancy beyond individual-level factors.

Regarding limitations, only English-language papers were included, which may limit the generalizability of findings. Since this is a growing area of research, there were limited sources of data. For example, four studies came from the ALSPAC cohort in England,[32,38,42,51] four studies came from the KOMCHS cohort in Japan,[39,43,44,46] and three studies came from the same research group in Texas.[30,34,35] This may limit the generalizability to other study populations.

Conclusion

This review highlighted the limited amount of research that has been conducted on the association between stress and/or depressive symptoms, and diet quality during pregnancy. Overall, findings suggest that higher stress and depressive symptoms are associated with unhealthy dietary patterns. Pregnancy-specific stress should be further investigated but is associated with higher scores on 'unhealthy' dietary patterns and lower scores on 'healthy' dietary patterns. Very few studies have examined mental health in relation to diet quality indices in pregnancy; however, findings show that higher stress and depressive symptoms are associated with poorer diet quality index scores. During pregnancy, women have an increased risk of experiencing stress and depressive symptoms, both of which have been associated with poor diet quality.[9] In general, diet quality during pregnancy is inadequate[81] and nutrition is very important during pregnancy;[5,82] thus, there is a need to identify and examine factors that contribute to poor diet quality in pregnancy. Clinical health professionals should consider implementing standardized screening practices to identify women with high stress and depressive symptoms during prenatal care visits to determine women who may need targeted dietary or mental health interventions or linkages with additional resources. Pregnancy is an important time to optimize maternal diet quality and mental well-being to increase chances of positive health outcomes for both mothers and children.

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Table 4.1 PubMed search strategy for the systematic review investigating the association of stress, depressive symptoms, and diet quality in pregnancy

Concept	Search terms
Concept 1: Stress	1. Hydrocortisone [mesh[a]] 2. Stress, physiological [mesh] 3. Stress, psychological [mesh] 4. Cortisol [tw[b]] 5. Hydrocortisone [tw] 6. Stress [tw] 7. Stressed [tw] 8. Stresses [tw] 9. Stressful [tw] 10. Stressor [tw] 11. Stressors [tw] 12. Psychosocial [tw] 13. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12
Concept 2: Depression	14. Depression [mesh] 15. Depressive disorder [mesh] 16. Mental health [mesh] 17. Depressed [tw] 18. Depression [tw] 19. Depressive [tw] 20. Mental health [tw] 21. Mental wellbeing [tw] 22. Emotional wellbeing [tw] 23. 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22
Concept 3: Diet Quality	24. Diet [mesh] 25. Diet records [mesh] 26. Feeding Behavior [mesh] 27. Food [mesh] 28. Maternal Nutritional Physiological Phenomena [mesh] 29. Nutrition Assessment [mesh] 30. Nutrition Surveys [mesh] 31. Nutritional status [mesh] 32. Diet [tw] 33. Diets [tw] 34. Dietary behavior*[c][tw] 35. Dietary guideline* [tw] 36. Dietary intake* [tw] 37. Dietary pattern* [tw] 38. Dietary quality [tw] 39. Eating behavior* [tw] 40. Eating habit* [tw] 41. Eating pattern* [tw] 42. Food group* [tw] 43. Food habit [tw] 44. Food habits [tw] 45. Fruit [tw] 46. Healthy diet* [tw]

Diet Quality Continued	47. Healthy eating [tw] 48. Nutrition assessment [tw] 49. Nutrition index* [tw] 50. Nutrition survey* [tw] 51. Vegetable [tw] 52. 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 43 OR 44 OR 45 OR 46 OR 47 OR 48 OR 49 OR 50 OR 51
Concept 4: Pregnancy	53. Maternal health [mesh] 54. Pregnancy [mesh] 55. Pregnant women [mesh] 56. Antenatal [tw] 57. Maternal [tw] 58. Perinatal [tw] 59. Pregnancy [tw] 60. Pregnant [tw] 61. Prenatal [tw] 62. 53 OR 54 OR 55 OR 56 OR 57 OR 58 OR 59 OR 60 OR 61 63. 13 OR 23 AND 52 AND 62

[a]Mesh=medical subject headings.
[b]tw=text word.
[c]Asterisk(*) indicates truncation.
Filters: English articles, published between January 1997- present.

Table 4.2 Summary of (n=24) studies evaluating associations between stress, depressive symptoms, and diet quality during pregnancy

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Dietary Patterns (Non-indices)							
Barker et al. (2013)[38]	UK Cross-sectional study	n=6,979 British women ALSPAC[a] cohort White: 94.4%	Depressive sx[b] EPDS[c], 10 items Scores 0-30	Diet pattern FFQ[d], 43 items Factor analysis 2 diet patterns: healthy, unhealthy	32 wks	Path analysis **Control vars:** police involvement, substance use, partner cruelty, inadequate living conditions and housing, housing defects, poverty, single caregiver, early parenthood, and low education	**Adjusted:** Higher depressive sx were associated with higher 'unhealthy' dietary pattern scores (d=0.096, p<0.05) and lower 'healthy' dietary pattern scores (d=-0.059, p<0.05).
Baskin et al. (2017)[50]	Australia Cohort study	n=167 Australian women No racial breakdown	Depressive sx EPDS, 10 items, Scores 0-30	Diet quality FFQ, 100 items Factor analysis 2 diet patterns: healthy, unhealthy	T1: 16 wks T2: 32 wks	Path analysis (examined relationships in *both directions*) **Control vars:** age, pre-pregnancy BMI[e], education, income, parity, history of depression, exercise	**Adjusted:** Higher depressive sx at 16 wks significantly predicted lower 'unhealthy' dietary pattern scores at 32 weeks (β=-0.17, p<0.05, 95% CI (-0.32, -0.02)). **Adjusted:** Higher 'unhealthy' dietary pattern scores were related to higher depressive sx at 32 wks (β= 0.19, p<0.05, 95% CI (0.04, 0.34)).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Jiang et al. (2018)[52]	China Cohort study, cross-sectional analysis	n=3,698 (T1) n=2,343 (T2) n=2,162 (T3) Chinese women Zhoushan Pregnant Women Cohort Chinese women	Dietary Diversity Scale Dietary recall questionnaire, 21-items 9 food groups: cereal, soybean products, meat, egg, dairy products, fish/seafood, fat/oil, fruits, vegetables Scores ranged from 0-9 (aggregate score of all consumed food groups) Low dietary diversity: < 6 High dietary diversity: > 6	Self-Rating Depression Scale (SDS), 20-items Scores 20-80 Scores $\geq$ 53= depressed	T1: 10 weeks T2: 28 weeks T3: 36 weeks	T-test; Chi-square test Multiple linear and logistic regression models for each trimester **Control vars:** education, per capita income, occupation, BMI, maternal age, marital status, physical exercise, sleep quality, family care, morning sickness, medical problems in pregnancy, cigarette smoking and drinking before pregnancy, parity, and gravidity	**Adjusted:** Dietary diversity scores were inversely associated with depressive symptoms (higher dietary diversity scores were associated with lower depressive symptoms). [T1: β(se)= -1.16 (0.12), *P*= <0.0001 T2: β(se)= -1.12 (0.21), *P*= <0.0001 T3: -1.01 (0.22), *P*= <0.0001] High dietary status (>6) was negatively associated with depression status [T1: OR (95% CI)= 0.56 (0.46, 0.69) T2: 0.55 (0.36, 0.84) T3: 0.45 (0.31, 0.65)]

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Lobel et al. (2008)[11]	US Cohort study	n=279 White: 65.2% AA[f]: 11.8% Hispanic: 11.8%	Pregnancy-specific stress Prenatal Distress Questionnaire, Scores 0-18 Prenatal Life Events Scale: # of life events, Scores 0-28 Life events distress, Scores 0-84	Diet quality Prenatal Health Behaviors Scale, 6 items Healthy, unhealthy eating subscales, Scores 0-12	T1: 10-20 wks T2: 21-30 wks T3: 30+ wks	Structural equation modeling **Control var:** obstetric risk	**Adjusted:** Higher pregnancy-specific stress scores were associated with higher ‘unhealthy’ dietary pattern scores (β=0.29, p<0.05), and associated with lower ‘healthy’ dietary pattern scores (β=-.14, p<0.05)
Miyake et al. (2018)[39]	Japan Cross-sectional study	n=1,744 KOMCHS[g] cohort Japanese women	Diet patterns Diet History Questionnaire, 145 items Factor analysis 3 diet patterns: healthy, Japanese, & Western	Depressive sx CES-D[h] (Japanese version), 20 items Scores 0-60 Scores > 16 = presence of depressive sx	5-39 wks	Poisson regression **Control vars:** age, gestation, region of residence, # of children, family structure, history of depression, family history of depression, smoking, secondhand smoke exposure, employment, household income, education, and BMI	**Adjusted:** Compared to the lowest quartile of the ‘healthy’ dietary pattern scores, those in the 2nd, 3rd, or 4th quartiles of the healthy pattern were associated with a lower prevalence of depressive sx (PR 0.56, 95% CI (0.43, 0.73), p=0.0001). **Adjusted:** Compared to the lowest quartile of the ‘Japanese’ dietary pattern scores, those in the 3rd and 4th quartiles were associated with a lower prevalence of depressive sx (PR 0.76, 95% CI (0.58, 0.99) and 0.72, 95% CI (0.55, 0.94)), respectively; p=0.008.

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Molyneaux et al. (2016)[32]	UK Cohort study	n=13,314 ALSPAC cohort British women White: 97.3%	Depressive sx EPDS, 10 items, Scores 0-30 Scores > 12 at both 18 and 32 weeks gestation = elevated depressive sx	Diet patterns FFQ, 43 items Principal component analysis 5 diet patterns: Health conscious, Traditional, Processed, Confectionary, & Vegetarian	Depressive sx: 18 wks, 32 wks Diet: 32 wks	Linear regression; Multiple logistic regression **Control vars:** age, ethnicity, marital status, occupation, education, parity, singleton or multiple pregnancy, stressful life events, social support, alcohol consumption, tobacco smoking, drug use, physical activity	**Adjusted:** High depressive sx at 18 and 32 wks were significantly associated with higher 'confectionary' dietary pattern scores only (β=0.10, 95% CI (0.02, 0.17); p=0.014).
Omidvar et al. (2018)[47]	Iran Cross-sectional study	n=445 Iranian women	Pregnancy-specific stress Prenatal Distress Questionnaire, 12-items, Scores 0-48 Depressive sx Beck Depression Inventory-II, 21-items, Scores 0-63	Healthy nutrition Health-Promoting Lifestyle Profile (Persian version, nutrition domain), 9-items, Scores 9-36	Anytime in pregnancy (ranged from < 13-42 weeks)	ANOVA; Pearson's correlation Linear regression (unadjusted and adjusted models) **Control vars:** Age, education, and gestational age	**Adjusted:** Neither depressive symptoms nor pregnancy-specific stress were significantly associated with healthy nutrition scores in adjusted models (p>0.05).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Paskulin et al. (2017)[40]	Brazil Cross-sectional study	n=712 Brazilian women	Diet patterns FFQ, 88 items Cluster analysis 3 diet patterns: restricted, varied, & common-Brazilian Food groups that align with Food Guide for the Brazilian Population (fruit, beans, & sweets/sugars)	Prevalence of major depressive disorder PRIME-MD[i], Diagnosis of major depressive disorder	16-36 weeks	Poisson regression models **Control vars:** age, municipality of residence, violence in pregnancy, and monthly family income	**Adjusted:** Women with high 'common-Brazilian' dietary pattern scores had 43% higher prevalence of major depressive disorder compared to those with high scores on the 'varied' dietary pattern (PR 1.43, 95% CI (1.01, 2.02)). **Adjusted:** Women with low fruit and high sweets/sugars intake had a higher prevalence of major depressive disorder (PR 1.43, 95% CI (1.04, 1.95); p=0.03 and PR 1.91, 95% CI (1.91, 3.07); p=0.01), compared to those with high fruit and low sweets/sugar intake.

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Pina-Camacho et al. (2015)[51]	UK Prospective cohort study	n=7,814 British women ALSPAC cohort White: 95%	Depressive sx EPDS, 10 items Scores 0-30	Diet patterns FFQ, 43 items, used to create unhealthy diet score Unhealthy diet: continuous score (higher=worse)	Depressive sx: 18 wks, 32 wks Diet: 32 wks	Pearson's correlation **Control vars:** summed into an index parity, birth complications, police involvement, substance use, cruelty from partner, inadequate basic living conditions, inadequate housing, housing defects, poverty, being a single caregiver, early parenthood, and low educational attainment	**Correlation:** Higher depressive sx at 18 wks were associated with higher 'unhealthy' dietary pattern scores at 32 wks (r=0.024, p<0.05).
Wall et al. (2016)[41]	New Zealand Cross-sectional study	n=5,664 New Zealand women in the *Growing up in New Zealand* cohort European: 56% Māori: 13.2% Pacific: 12.8% Asian: 14.2% Other: 3.8%	Diet patterns FFQ, 44 items Principal components analysis 4 diet patterns: junk, health-conscious, traditional/White bread, and fusion/protein	Depressive sx EPDS, 10 items, Scores 0-30 Scores ≥ 13 = likely to be suffering symptoms of depression	29-40wks	Multivariable linear regression **Control vars:** ethnicity, household deprivation, pre-pregnancy BMI, pre-pregnancy self-rated health, folic acid supplementation, smoking and alcohol consumption, physical activity prior and during pregnancy, & dieting pre-pregnancy	**Adjusted:** Higher 'junk' dietary pattern scores were associated with having an EPDS score ≥13 (β=0.14, 95% CI (0.06, 0.23); p=0.0005).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Diet Quality (Indices)							
Fowles et al. (2011)[30]	US Cross-sectional study	n=118 Hispanic: 46.6% AA: 12.7% Low-income	Distress (index of stress & depressive sx) Prenatal Psychosocial Profile-Stress subscale, Scores 11-44 EPDS Scores ≥10= possible depression	Diet quality 24hr recall (x3) Diet Quality Index-Pregnancy, Scores 0-80 Scores ≥ 70 = desirable diet quality	≤14 wks	Path analysis **Control vars:** age, education	**Adjusted**: Higher distress scores were significantly associated with higher 'poor eating habits' scores (β=0.36, p<0.01), and directly (β=-0.23, p<0.05) and indirectly associated with lower diet quality index scores (β=-0.30, p<0.05).
Fowles et al. (2012)[34]	US Cross-sectional study	n=71 Hispanic: 48% AA: 14% Low-income	Stress, depressive sx Prenatal Psychosocial Profile-Stress subscale, Scores 0-33 EPDS Scores >10= possible depression Scores >13= probable depression	Diet quality 24hr recall (x3) Diet Quality Index-Pregnancy, Scores 0-80 Scores ≥ 70 = desirable diet quality	≤ 14 wks	Student's t-tests **Control vars:** none (sample size too small)	**Unadjusted:** Women with diet quality scores below the median (DQI-P=53.3) had higher depressive sx (9.6±5.1 vs. 6.7±5.1, p=0.02) and stress scores (22.1±5.4 vs. 19.3±4.8, p=0.03) than women with diet quality scores above the median.

Author(s), Year, Reference	**Country, Study Design**	**Sample Size, Racial Composition**	**IV, Assessment Tool(s)**	**DV, Assessment Tool(s)**	**Time-point in pregnancy**	**Statistical Tests, Covariates**	**Findings**
Saeed et al. (2016)[49]	Pakistan Cohort study	n=82 Pakistani women Middle-income	Depressive sx EPDS, 10 items, Scores 0-30 Score $\geq$ 9= "depressed"	Diet quality 24-hr recall (x1) Food Frequency Checklist, modified for cultural context Healthy Eating Index (modified)—only adequacy components, Scores 0-50 ($\geq$40=good diet)	Depressive sx:13 wks Diet: 13 wks, 36 wks	Correlations; Relative Risk (RR) and Attributable Risk **Control vars:** none (potential confounders—age, weight, BMI, and parity didn't differ between depressed vs. non-depressed women)	**Unadjusted:** Women with higher depressive sx had an increased risk of poor diet quality compared to women with lower depressive sx (RR=2.58, CI (1.60, 5.23), p<0.0001). 62% of poor diet quality could be attributed to exposure to high depressive sx.
Food Groups							
Chang et al. (2015)[36]	US Cross-sectional study	n=213 White: 48% AA: 47% Other: 5% Overweight/ obese, low-income, & Women, Infants, & Children (WIC) enrolled women	Stress, Depressive sx Perceived Stress Scale, 9 items, Scores 9-36 EPDS, 10 items, Scores 0-30 Scores 11-12 = possible minor depression Scores $\geq$ 13 = potential major depression	Fat, fruit, & vegetable intake Rapid Food Screener, 17 items Higher score = higher fat intake or more fruit and veggie intake	Any time during pregnancy (women in all three trimesters)	ANOVA, Chi-square, Pearson's correlation, Path analysis **Control vars:** none	**Unadjusted:** Higher stress was associated with lower fruit and vegetable intake in the 1st trimester (β=-0.56, p<0.05). Higher depressive sx were associated with higher fat intake in the 1st trimester, (β=0.67, p<0.05).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Chang et al. (2016)[45]	US Cross-sectional study	n=332 White: 58% AA: 42% Overweight/ obese, low-income, & Women, Infants, & Children (WIC) enrolled women	Stress, Depressive sx Perceived Stress Scale, 9 items, Scores 9-36 EPDS, 10 items, Scores 0-30	Fast food, fat, fruit, & vegetable intake Brief fast food screener, 12-items, Scores 0-96 Rapid Food Screener, 24-items (Fruit, vegetables, fat)	Any time during pregnancy (women in all three trimesters)	T-test, Chi squared, Path analysis **Control vars:** none	**Unadjusted:** Among overweight women, women who reported more depressive symptoms were more likely to eat fast foods, which led to more vegetable intake (p=0.01) and partially higher fat intake than women with less depressive symptoms (p=0.003).
Fowles et al. (2011)[35]	US Cross-sectional study	n=50 Hispanic: 50% White: 32% AA: 18%	Frequency of fast-food consumption 24-hr recall (x3)	Stress, depressive sx Prenatal Psychosocial Profile-Stress subscale, Scores 11-44 EPDS, 10 items, Scores 0-30 Scores $\geq$ 10 = possible depression	$\leq$ 14 wks	T-tests **Control vars:** none	**Unadjusted:** Eating from fast-food restaurants 3+ times/past week was associated with having higher stress (23.7$\pm$6.8 vs. 18.9$\pm$4.1; CI (-7.87, -1.70); p<0.05) and depressive sx (10.4$\pm$6.0 vs. 6.8$\pm$4.1; CI (-6.45, -0.71); p<0.05) compared to eating at fast-food restaurants 0-2 times/past week.

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Golding et al. (2009)[42]	UK Cross-sectional study	n=14,541 British women ALSPAC cohort Majority White (breakdown not provided)	Seafood intake FFQ, 13 food groups Fish, 3-items: White fish, dark or oily fish, and shellfish	Depressive sx EPDS, 10 items, Scores 0-30 Scores ≥ 13 = "high levels of depressive sx"	32 wks	Logistic regression **Control vars:** age, parity, outcome of immediately preceding pregnancy, education, housing tenure, crowding, mothers' life events in childhood scale, chronic stress, smoking, alcohol use, ethnicity, energy intake	**Adjusted:** Compared with women consuming more than 1.5 g omega-3 from seafood/ week, those consuming none were more likely to have higher depressive sx at 32 weeks' gestation (adjusted OR = 1.54; 95% CI (1.25,-1.89); p<0.0001).
Hurley et al. (2005)[12]	US Cross-sectional study	n= 134 85% White Well-educated middle-class	Stress, depressed mood Perceived Stress Scale Profile of Mood States-Depression subscale	Intake of food groups FFQ, frequencies for 7 food groups	Stress, depressive sx: 24 wks Diet: 28 wks	Pearson's correlations (adjustment via residual approach) **Control vars:** maternal age, parity, BMI, and education	**Adjusted**: Higher stress at 24 wks was associated with higher intake of breads (r=0.23, p<0.01) and foods from the fats, oils, sweets, and snack group at 28 wks (r=0.18, p<0.05). No significant relationship between depressed mood and food group intake.

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Malek et al. (2017)[31]	Australia Cross-sectional study Theory of Planned Behavior	n=455 Australian women	Stress Perceived Stress Scale, 4-items, Scores 0-16	Adherence to food group recommendations FFQ, 6-items Adherence to 5 food group recommendations	13-30 wks	Hierarchical multiple linear regression **Control vars:** metro area, education, household income, parity, third trimester, pre-pregnancy overweight/obesity, pre-pregnancy exercise, smoking during pregnancy, nutrition knowledge, and use of folic acid and iodine supplements during pregnancy	**Adjusted:** Perceived stress was not a significant predictor of adherence to food group recommendations (β=0.04, p>0.05).
Miyake et al. (2013)[43]	Japan Cross-sectional study	n=1,745 KOMCHS cohort Japanese women	Fish intake Diet History Questionnaire, 150 items Fish intake, g	Depressive sx CES-D (Japanese), 20 items, Scores 0-60 Scores $\geq$ 16 = depressive sx present	Any time during pregnancy Mean=19 wks 92% in 1^{st} or 2^{nd} trimester	Multiple logistic regression **Control vars:** age, gestation, region of residence, # of children, family structure, history of depression, family history of depression, smoking, secondhand smoke exposure at home and at work, job type, household income, education, and BMI	**Adjusted**: Compared to being in the lowest quartile, being in the highest quartile for fish intake was associated with a lower prevalence of depressive sx during pregnancy (adjusted OR between extreme quartiles= 0.61; 95% CI (0.42, 0.87); P =0.01).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Miyake et al. (2015)[44]	Japan Cross-sectional study	n=1,745 KOMCHS cohort Japanese women	Dairy intake Diet History Questionnaire, 150 items Dairy, 4-items: full-fat milk, low-fat milk, yogurt, cheese, and cottage cheese	Depressive sx CES-D (Japanese), 20 items, Scores 0-60 Score $\geq$ 16 = depressive sx present	Any time during pregnancy Mean=19 wks 92% in 1^{st} or 2^{nd} trimester	Multiple logistic regression **Control vars:** age, gestation, region of residence, # of children, family structure, history of depression, family history of depression, smoking, secondhand smoke exposure at home and at work, job type, household income, education, BMI, and fish intake	**Adjusted**: Compared to being in the lowest quartile, being in the highest quartile for yogurt intake were independently associated with a lower prevalence of depressive sx during pregnancy. Adjusted OR between extreme quartiles 0.69; 95% CI (0.48, 0.99); P= 0.03).
Miyake et al. (2018)[46]	Japan Cross-sectional study	n=1,745 KOMCHS cohort Japanese women	Soy product intake Diet History Questionnaire, 150 items Total soy product intake: sum of tofu, tofu products, fermented soybeans, boiled soybeans, miso, miso soup, and soymilk	Depressive sx CES-D (Japanese), 20 items, Scores 0-60 Scores $\geq$ 16 = depressive sx present	Any time during pregnancy Mean=19 wks 92% in 1^{st} or 2^{nd} trimester	Poisson regression **Control vars**: age, gestation, region of residence, number of children, family structure, history of depression, family history of depression, smoking, secondhand smoke exposure at home and at work, job type, household income, education, and BMI, intake of fish, yogurt, and seaweed.	**Adjusted**: Higher intake total soy products, tofu, tofu products, fermented soybeans, boiled soybeans, and miso soup was independently related to a lower prevalence of depressive symptoms during pregnancy: Adjusted PRs (95% CI, P for trend) between extreme quartiles were: 0.63 (0.47, 0.85, 0.002), 0.72 (95% CI: 0.54, 0.96, 0.007), 0.74 (95% CI: 0.56, 0.98, 0.04), 0.57 (95% CI: 0.42, 0.76, < 0.0001), 0.73 (95% CI: 0.55, 0.98, 0.03), and 0.65 (0.49, 0.87, 0.003) respectively.

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Sontrop et al. (2008)[37]	Canada Cross-sectional study	n=2,394 Prenatal Health Project (cohort) Canadian women (no racial breakdown)	Fish intake FFQ, 106-items Fish: 4-items (canned tuna; dark meat fish; other fish; and shrimp, lobster, or scallops)	Depressive sx CES-D, 20 items, Scores 0-60 Score $\geq$16 = probable depression	10-22 wks	Sequential multiple regression **Control vars:** age, marital status, education, household income, occupational status, smoking, physical activity, meeting Canada Food Guide to Healthy Living guidelines, and total energy intake	**Adjusted**: No relationship between fish intake and depressive sx after controlling for confounders (β=-0.2, 95% CI (-0.9, 0.4); p>0.05).

Authors, Year, Reference	Country, Study Design	Sample Size, Racial Composition	IV, Assessment Tool(s)	DV, Assessment Tool(s)	Time-point in pregnancy	Statistical Tests, Covariates	Findings
Takahashi et al. (2016)[48]	Japan Cross-sectional study	n=9,030 Japan Environment and Children's Study (JECS) cohort Japanese women	Fermented food consumption FFQ, 66-items Focused on intake of probiotics, prebiotics, and other fermented foods (i.e., yogurt, lactic acid beverages, fermented milk, cheese, milk, Japanese pickles, miso soup, fermented soybeans, and beans)	Psychological Distress Kessler Psychological Distress Scale (K6), 6-items, Scores 0-24	2nd and 3rd trimesters	Multivariate logistic regression analysis **Control vars**: parity, BMI, marital status, family structure, number of childbirths, mood after pregnancy was confirmed, history of infertility treatment, history of mental health disorders, age, gestation, academic history, employment, household income, physical activity, smoking status, husband's smoking status, secondhand smoking status, alcohol consumption, total intake, tea consumption, presence of health complications or disease, intimate partner violence, and social capital	**Adjusted**: The consumption of yogurt and other fermented foods was not associated with lower prevalence of psychological distress in pregnant women (p>0.05).

[a]ALSPAC= Avon Longitudinal Study of Children and Parents cohort
[b]Sx= symptoms
[c]EPDS= Edinburgh Postnatal Depression Scale
[d]FFQ=Food Frequency Questionnaire
[e]BMI=Body Mass Index
[f]AA= African-American
[g]KOMCHS= Kyushu Okinawa Maternal and Child Health Study
[h]CES-D= Center for Epidemiologic Studies-Depression Scale
[i]PRIME-MD= Primary Care Evaluation of Mental Disorders

Table 4.3 Risk of bias summary: review authors' judgments about each risk of bias item for each included study according to GRADE (Grading of Recommendations Assessment, Development, and Evaluation) 4 guidelines

Author(s), year, reference	**Appropriate eligibility criteria**	**Appropriate measurement of exposure and outcome**	**Adequately control confounding**	**Complete follow-up**
Barker et al. (2013)[38]	—[a]	+	+[b]	—
Baskin et al. (2017)[50]	—	+	+	+
Chang et al. (2015)[36]	—	—	?	—
Chang et al. (2016)[45]	—	—	?	—
Fowles et al. (2011)[30]	+	+	+	—
Fowles et al. (2011)[35]	+	+	—	—
Fowles et al. (2012)[34]	+	+	—	—
Golding et al. (2009)[42]	—	+	+	—
Hurley et al. (2005)[12]	+	+	+	—
Jiang et al. (2018)[52]	+	+	+	+
Lobel et al. (2008)[11]	—	—	+	+
Malek et al. (2017)[31]	—	+	+	—
Miyake et al. (2013)[43]	—	+	+	—
Miyake et al. (2015)[44]	—	+	+	—
Miyake et al. (2018)[39]	—	+	+	—
Miyake et al. (2018)[46]	—	+	+	—
Molyneaux et al. (2016)[32]	—	+	+	+
Omidvar et al. (2018)[47]	+	—	+	—
Paskulin et al. (2017)[40]	—	+	+	—
Pina-Camacho et al. (2015)[51]	—	+	+	+
Saeed et al. (2016)[49]	+	+	+	+
Sontrop et al. (2008)[37]	+	+	+	—
Takahashi et al. (2016)[48]	—	+	+	—
Wall et al. (2016)[41]	—	+	+	—

[a]— = high risk of bias; criteria not met in the study design.
[b]+=low risk of bias; criteria met in the study design.
[c]?=unclear risk of bias; authors failed to report whether criteria was met.

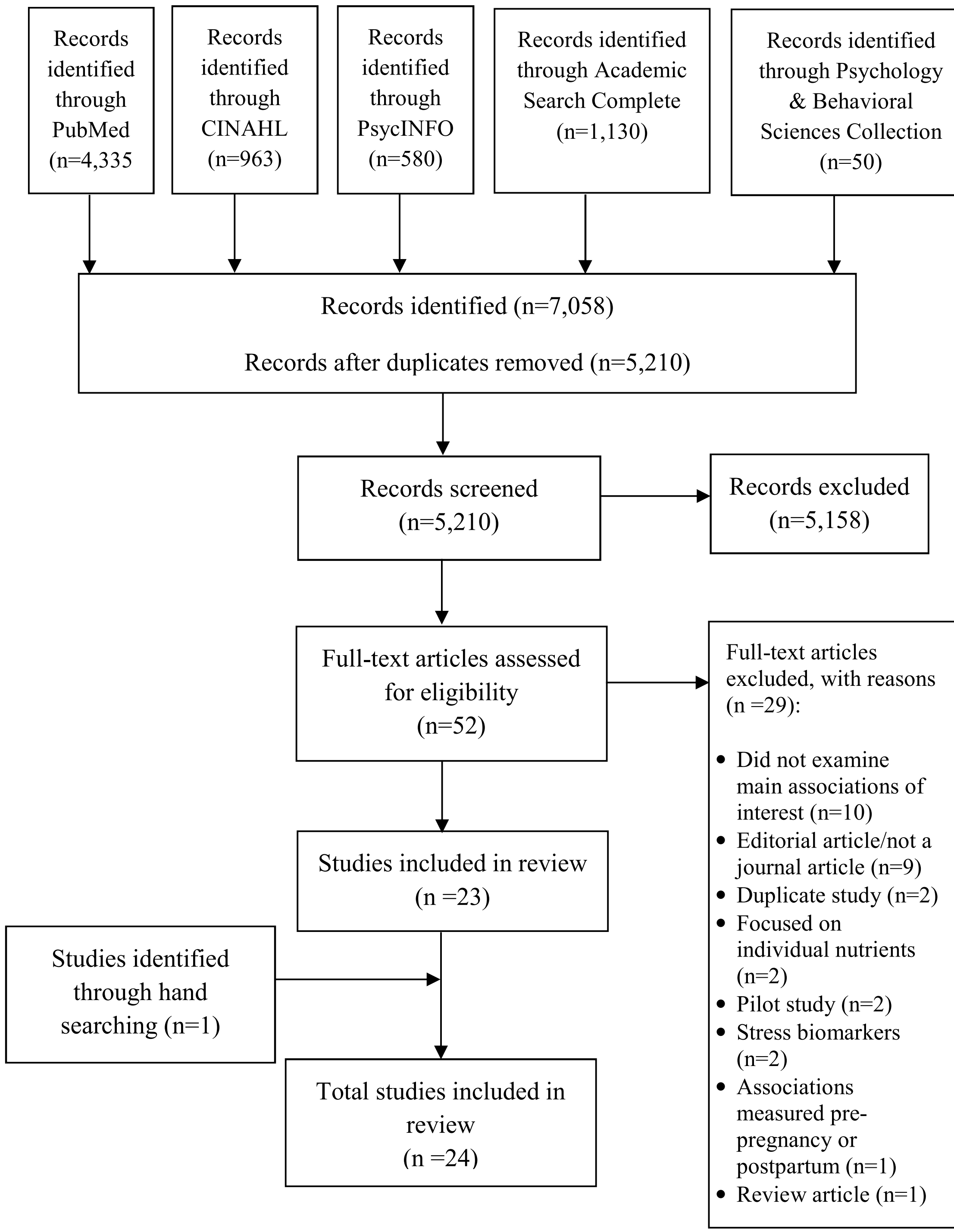

Figure 4.1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart for article selection process for systematic review assessing stress, depressive symptoms, and diet quality in pregnancy.

Maternal Mental Health and Diet Quality: Associations among Racially-Diverse Pregnant Women Participating in a Lifestyle Intervention[2]

[2] Boutté AK, Turner-McGrievy GM, Wilcox S, Liu J, Eberth JM, Kaczynski AT. To be submitted to *Maternal and Child Health Journal*.

Keywords: stress; depression; mental health; diet quality; pregnancy

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Author Disclosure Statement: No competing financial interests exist.

Note: This analysis does not reflect the full sample size of the HIPP study.

Abstract

Introduction: Poor mental health may be a barrier to optimal diet quality in pregnancy. This study aimed to 1) examine if stress and depressive symptoms are associated with poorer diet quality (via Healthy Eating Index (HEI)-2015 total scores and meeting HEI component recommendations) and 2) test whether race moderates the relationship between mental health and diet quality.

Methods: The Health in Pregnancy and Postpartum study is an ongoing randomized trial targeting excessive gestational weight gain among overweight/obese pregnant women (N=169). At baseline, participants provided demographic data and completed two 24-hour dietary recalls. Thirteen binary HEI components (met Dietary Guidelines recommendations vs. not) and HEI total scores were calculated. The Perceived Stress Scale was used to assess stress. The Edinburgh Prenatal/Postnatal Depression Scale was used to assess depressive symptoms. Multiple linear and logistic regression models were used to estimate HEI total scores and sub-component recommendations. Multiplicative interaction terms of stress or depressive symptoms with race were used to examine moderation.

Results: Participants' diet quality was suboptimal (M=55.9$\pm$10.6, range 28-76). Neither stress nor depressive symptoms were associated with HEI total scores. A one-unit increase in stress was associated with a 14% decrease in the odds of meeting Seafood & Plant Protein recommendations [adjusted (adj) OR: 0.86 (95% CI=0.77, 0.96)]. African-American (AA) women had more than 4 times the odds of meeting Fatty Acids recommendations [adj OR: 4.57 (95% CI=1.14, 18.25)] and approximately 3 times the odds of meeting Refined Grains recommendations [adj OR: 2.99 (95% CI=1.25, 7.13)] than White women. Race did not moderate the relationships between stress, depressive symptoms, and HEI total scores or meeting component recommendations.

Conclusion: Participants' diet quality was poor overall, highlighting the need for additional research on barriers and facilitators to achieving optimal diet quality during pregnancy. Future studies should examine the efficacy of interventions that incorporate stress management in conjunction with nutrition education to improve diet quality in this high-need population. Healthcare providers should examine the feasibility of screening stress, depressive symptoms, and diet quality during prenatal visits to identify women in need of additional dietary or mental health care and connect them with relevant resources.

Introduction

Diet quality is suboptimal in women around conception, with African-American (AA) pregnant women having the poorest diet quality compared to non-Hispanic White and Hispanic women.[1] Energy-dense, nutrient-poor diets in pregnancy may contribute to excessive gestational weight gain (GWG),[2] postpartum weight retention,[3] greater newborn adiposity,[4] and child overweight status.[5]

Approximately 55% of U.S. women begin pregnancy overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2),[6] which is associated with an increased risk of exceeding the Institute of Medicine's (IOM) 2009 GWG guidelines compared to healthy weight women.[7,8] Excessive GWG is associated with pre-eclampsia, cesarean delivery, and infants born large-for-gestational-age,[9–11] making excessive GWG a public health concern. Improving maternal diet quality may be one way to address excessive GWG,[12] so there is a need to better understand determinants of diet quality in pregnancy to reduce maternal obesity and optimize offspring health.[1]

Pregnancy is also a time when women experience increased stress due to the series of social, psychological, behavioral, and biological changes that accompany pregnancy.[13] Experiencing stress is closely linked with depressive symptoms,[14] both of which have been associated with poor diet quality in pregnancy.[15] Notably, stress and depressive symptoms are relatively understudied modifiable factors that may act as barriers to achieving proper diet quality in pregnancy.[16]

There has been variability in the assessment of diet quality, with much of the existing literature on the relationship between stress, depressive symptoms, and diet quality identifying dietary patterns through factor analysis[17,18] or other statistical techniques.[19,20] While these techniques produce dietary patterns that are customized to the study sample (e.g., 'Japanese', 'common-Brazilian', and 'Western'), it is challenging to compare findings across study populations.[18,20] Diet quality indices, such as the Healthy Eating Index-2015 (HEI), offer many benefits for assessing diet quality such as capturing the totality of one's diet, accounting for the synergistic relationship between dietary components, and adapting to fit personal and socio-cultural preferences.[21,22] Few studies have examined the relationship between stress, depressive symptoms, and diet quality in pregnancy using a standardized diet quality index, such as the HEI or Diet Quality Index-Pregnancy;[15,16,23] thus, researchers have called for high-quality studies that use standard methods of assessing diet quality.[24,25]

Of the limited research that has examined the relationship between mental health and diet quality in pregnancy, most studies focused on depressive symptoms.[17–20,23,26–30] Fewer studies have examined stress in relation to diet quality during pregnancy.[15,16,31–34] Additionally, minority women have been greatly underrepresented in study samples,[15,31] and even fewer studies have examined these relationships in racially-diverse samples of overweight/obese pregnant women.[31] Minority and overweight/obese pregnant women deserve attention due to the racial disparities in diet quality during pregnancy[1] and the consequences of maternal obesity on pregnancy complications (e.g., preeclampsia and gestational diabetes)[35] and delivery outcomes (i.e., cesarean section among women with induced labor).[35]

To address these gaps, the objectives of this study were to 1) examine if stress scores and depressive symptoms are associated with poorer diet quality (using the Healthy Eating Index-2015, or HEI) among a racially-diverse sample of overweight/obese pregnant women in South Carolina (SC), and 2) test whether race moderates the relationship between mental health and diet quality. We hypothesized that pregnant women with higher stress scores and depressive symptoms would have lower HEI total scores and lower odds of meeting HEI component recommendations. In terms of moderation, we hypothesized that as stress and depressive symptoms increased, AA women would have lower HEI total scores and lower odds of meeting HEI component recommendations compared to White women. This hypothesis was informed by Davis and colleagues' framework for stress reactivity and maternal obesity development in pregnancy, which posits that AA women experience disproportionate amounts of chronic stress due to social disadvantages (e.g., discrimination, single parenthood, and poverty).[36,37] Additionally, stress has been associated with consuming energy-dense, nutrient-poor foods (e.g., lower fruit and vegetable intake,[31] greater fast-food intake,[32] and greater intake of sweets and snacks) among pregnant women.[33]

Methods

The Health in Pregnancy and Postpartum (HIPP) study is a randomized controlled trial examining the efficacy of a theory-based behavioral lifestyle intervention to reduce excessive GWG among White and AA overweight/obese pregnant women, as compared to a standard care intervention. This paper reports a cross-sectional analysis of demographic, mental health, and dietary data measured at baseline to date (N=169). Baseline assessments for this analysis were conducted from January 2015 to March 2018.

A full description of HIPP study methods have been published elsewhere.[38] In brief, women were recruited to participate primarily through 13 obstetrics and gynecology (OB/GYN) clinics in the greater Columbia, SC area and adjacent counties, with some self-referrals in response to community and social media advertisements. Women were eligible if they: (a) were between 18-44 years of age, (b) self-identified as White or Black/AA, (c) could read and speak English, (d) had no plans to move outside of the geographic area in the next 18 months, (e) were $\leq$ 16 weeks gestation, and (f) had a pre-pregnancy body mass index (BMI) $\geq$ 25 kg/m^2 and a pre-pregnancy weight $\leq$ 370 pounds. Women were excluded if they had contraindications to physical activity during pregnancy.[39] Eligible women who met inclusion criteria and completed a baseline measurement visit were included in these analyses. Institutional Review Boards at our university and health care systems approved the study protocol. All participants provided written informed consent.

Measures

At the baseline visit, demographic data and anthropometric measures were collected. The demographic questionnaires, psychosocial questionnaires, and anthropometric measures were interviewer-administered, while the 24-hour dietary recalls were self-administered. Baseline demographic variables were categorized as follows: age (18-24 years, 25-29 years, or 30-34 years, 35-42 years), race (White or AA/Black), education (high school diploma/GED or less, some college, or college degree or higher), parity (nulliparous or multiparous), marital status (married or not married), enrollment in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (yes or no), and pre-pregnancy weight status (overweight or obese). Pre-pregnancy BMI was calculated from participants' self-reported pre-pregnancy height and weight.

Stress

Stress was measured using Cohen's 4-item Perceived Stress Scale (PSS), which is a global measure of perceived stress designed to assess the degree to which situations in the previous month were perceived as stressful.[40] Stress levels in the prior month are indicative of general trends in stress.[40] Items assessed the frequency of feeling overwhelmed (e.g., "In the last month, how often have you found that you could not cope with all the things you had to do?"). Responses were indicated on a 5-point Likert-type scale, ranging from 0 (never) to 4 (very often), with possible scores ranging from 0 to 16. Perceived stress was assessed as a continuous score with higher scores indicating more perceived stress. The 4-item PSS has acceptable internal consistency reliability (Cronbach's α=.79), good convergent validity with the Edinburgh Prenatal/Postnatal Depression Scale,[41] and has been validated in pregnant women.[41]

Depressive symptoms

Depressive symptoms were measured using the 10-item Edinburgh Prenatal/Postnatal Depression Scale (EPDS), a widely-used self-report scale that has been validated for use during pregnancy and postpartum.[42] The scale screens for depressive symptoms, such as blaming oneself unnecessarily or feeling anxious. Respondents rated how often in the past seven days they experienced the described thoughts or feelings on a 4-point Likert-type scale, ranging from 0 (never) to 3 (very often), with possible scores ranging from 0 to 30. Depressive symptoms were assessed as a continuous score with higher scores indicating more depressive symptoms. Satisfactory internal consistency reliability was previously reported (Cronbach's α=.80 to .87).[43]

Diet quality

Participants completed two unannounced 24-hour dietary recalls (one weekday and one weekend day, which included Fridays) at baseline through the National Cancer Institute (NCI)'s Automated Self-Administered 24-hour Dietary Recall (ASA24) online system.[44] The ASA24 is a web-based dietary assessment tool that provides complete nutrient analysis of all foods and beverages reported during the data collection timeframe.[44]

Based on the 24-hour dietary recall data, participants' diet quality was calculated using SAS code provided by the NCI to generate HEI scores, which measure adherence to the 2015 Dietary Guidelines for Americans (DGAs).[45] The HEI-2015 includes 13 components (Table 4.4), including nine adequacy components (i.e., Total Fruits, Whole Fruits, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids), which are dietary aspects that need to be increased. There are four moderation components (i.e., Refined Grains, Sodium, Added Sugars, and Saturated Fats), which are dietary aspects that need to be reduced. All components are scored on a density basis out of 1,000 calories, with the exception of Fatty Acids, which is a ratio of unsaturated to saturated fatty acids.[46]

For all components, higher scores reflect greater adherence to the 2015 DGAs. Achieving the maximum score for an HEI component reflects meeting the guidelines for that component. Component scores are summed to create a total score ranging from 0 to 100 points, with higher scores indicating better diet quality. HEI total scores were analyzed as a continuous variable; however, due to floor and ceiling effects of many HEI components,[47] components were analyzed as dichotomous outcomes of meeting the recommendations or not.

Statistical Analyses

Descriptive statistics (e.g., means, standard deviations (SD), and percentages) were used to summarize participants' sociodemographic characteristics, stress, depressive symptoms, and diet quality (i.e., HEI total scores and components) at baseline. Independent samples t-tests were used to test for mean differences in continuous variables (e.g., age, parity, gestational age, perceived stress, depressive symptoms, HEI total scores, HEI component scores) by race. The χ^2 test was used to examine differences in the proportion of categorical characteristics (e.g., marital status, education level, employment, and pre-pregnancy weight status) by race and to assess for differences in the percentage of women meeting HEI component recommendations by race.

Multiple linear regression models were used to predict HEI total scores. The independent variables were stress and depressive symptoms, which were modeled separately as continuous variables. Potential confounders were chosen a priori based on existing literature and included maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. WIC enrollment was used as a proxy for low-income since financial burden is a requirement to receive WIC benefits.[48] Multiplicative interaction terms of stress or depressive symptoms with race were used to examine if race moderated the relationship between stress, depressive symptoms, and diet quality in adjusted models. Beta coefficients and standard errors for both crude and adjusted models are presented.

To test the hypothesis that higher stress and depressive symptoms would be associated with lower odds of meeting HEI component recommendations, multiple logistic regression models were used to predict the odds of meeting HEI component recommendations for 12 out of the 13 HEI components as secondary outcomes. The Sodium component could not be analyzed due to the small cell size of participants who met the Sodium recommendation. Models adjusted for maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. Multiplicative interaction terms of stress or depressive symptoms with race were used to examine if race moderated the relationship between stress, depressive symptoms, and meeting HEI component recommendations in adjusted models. Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for crude and adjusted models are presented. For all analyses, a *P*-value <0.05 indicated statistical significance. Statistical analyses were performed using SAS® software, version 9.4.[49]

Results

Study population. A total of 169 participants completed baseline questionnaires and two 24-hour dietary recalls. Participants were racially-diverse (60% White, 40% AA), primarily married (67%), more than a third were 30-34 years old (37%), and almost a quarter of women (23%) were enrolled in WIC (Table 4.5). The sample was well-educated, since most women (61%) earned a college degree or higher. More than half of women had at least one child (56%) and approximately half (49%) were obese when they became pregnant. The mean gestational age at eligibility screening was 10.1 weeks ($\pm$2.4 weeks). In terms of mental health, participants had low levels of stress (M=4.8$\pm$3.3, range 0-14) and low levels of depressive symptoms (M=5.8$\pm$4.3, range 0-20).

When considering racial differences in demographic characteristics, White women were older (30.7±4.7 years vs. 27.9±5.4 years) and were earlier in their pregnancies at the time of eligibility screening (9.7±2.3 weeks vs. 10.6±2.5 weeks), compared to AA women. Additionally, a greater proportion of AA women were not married (61.2% vs. 14.7%) and were low-income, as indicated by higher WIC enrollment (41.8% vs. 10.8%), compared to their White counterparts. There were no significant racial differences in remaining demographic variables.

Diet quality overall and by race. Overall, HIPP participants' diet quality was suboptimal (M=55.9±10.6, range 28-76). Average HEI total scores did not significantly differ by race (Table 4.6). The only significant racial difference in HEI components was Refined Grains, where AA women had higher mean scores for Refined Grains (M=9.0±2.4 points vs. 8.0±2.9 points) compared to White women. Refined Grains is a moderation component with a recommended standard of having ≤1.8 oz equiv. of refined grains per 1,000 kcal. Results are interpreted such that on average, more AA women consumed refined grains in moderation compared to White women.

In terms of meeting HEI component recommendations, more than half of all participants met the recommendations for Greens and Beans, Whole Grains, and Refined Grains. Approximately half of participants met the recommendations for Whole Fruit and Seafood and Plant Proteins. Less than 10% of women met the recommendations for Total Vegetables, Fatty Acids, Sodium, and Saturated Fats. Similar to the average component scores, a significantly higher proportion of AA women met the recommendation for Refined Grains (79% vs. 59%) compared to White women. There were no other significant racial differences in average component scores or proportions of women meeting HEI component recommendations.

Diet quality, stress, and depressive symptoms. The first aim was to examine if stress scores and depressive symptoms were associated with lower HEI total and component scores. Table 4.7 presents the crude and adjusted linear regression models of the association between stress and HEI total scores. Overall, stress was not significantly related to HEI total scores in either the crude or adjusted analyses; however, estimated coefficients were in the direction of the hypothesized relationship for stress. As stress increased, HEI total scores tended to decrease, but did not reach statistical significance. Table 4.8 presents the adjusted logistic regression models of the association between stress and meeting HEI component recommendations. Stress was negatively associated with meeting Seafood and Plant Protein recommendations. The Seafood and Plant Protein component consists of seafood, nuts, seeds, soy products (excluding beverages), and legumes (beans & peas). A one-unit increase in stress was associated with a 14% decrease in the odds of meeting Seafood and Plant Protein recommendations [adjusted (adj) OR: 0.86 (95% CI=0.77, 0.96)], after adjusting for race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. Additionally, AA women had more than 4 times the odds of meeting Fatty Acids recommendations compared to White women [adj OR: 4.57 (95% CI=1.14, 18.25)]. The Fatty Acids recommendation examines the ratio of consuming unsaturated to saturated fatty acids.[46] AA women also had approximately 3 times the odds of meeting Refined Grains recommendations [adj OR: 2.99 (95% CI= 1.25, 7.13)], compared to their White counterparts. The racial difference for the Fatty Acids recommendation was only observed in the multivariable model as compared to the descriptive analysis.

In terms of depressive symptoms, Table 4.9 presents the crude and adjusted linear regression models of the association between depressive symptoms and HEI total scores. Overall, depressive symptoms were not significantly related to HEI total scores in either the crude or adjusted analyses. Table 4.10 presents the adjusted logistic regression models of the association between depressive symptoms and meeting HEI component recommendations. Depressive symptoms were not significantly associated with meeting HEI component recommendations; however, there were two significant racial differences. Similar to the stress models, AA women had significantly higher odds of meeting Fatty Acids recommendations [adj OR: 4.77 (95% CI= 1.17, 19.44)] and Refined Grains recommendations [adj OR: 2.81 (95% CI= 1.19, 6.64)], compared to their White counterparts.

Moderation analyses. The second aim was to examine whether race moderates the relationships between stress and diet quality or depressive symptoms and diet quality. Findings indicate that race did not moderate the relationship between stress or depressive symptoms and HEI total or component scores.

Discussion

Our first aim was to examine if stress and depressive symptoms were associated with poorer diet quality (indicated by lower HEI total scores and lower odds of meeting HEI component recommendations). Contrary to hypotheses, the present study found that stress and depressive symptoms were not associated with lower HEI total scores among HIPP participants; however, the data for stress trended in the anticipated direction. Other studies that have examined the relationship between mental health and diet quality scores in pregnancy have found that higher stress and/or depressive symptoms are associated with lower diet quality scores in pregnancy.[15,16,23] These studies used diet quality indices with different scales (i.e., DQI-P total score ranging from 0-80, modified HEI total score ranging from 0-50); therefore, it is challenging to determine if the current study had less variation in diet quality scores than these studies. Inadequate variability in stress and depressive symptoms among HIPP participants is a potential reason for observing a null association between mental health and diet quality. There were floor effects observed for stress and depressive symptoms, with participants having low average scores in both variables. It is possible that in a sample of pregnant women with more variability in stress and depressive symptoms scores, we might have observed significant associations in the relationship between increasing stress and depressive symptoms and lower HEI total scores. It is worth noting that the studies who observed significant associations had samples comprised of women from Pakistan[23] or majority Hispanic women in Texas.[15,16] AA women have been typically underrepresented in previous studies.[15,16,32] It is critical that AA women are adequately represented in future studies in order to gain a better understanding of the contextual factors that influence diet quality and develop culturally-appropriate interventions to improve diet quality.

In terms of HEI components, our results showed that an increase in stress was associated with significantly lower odds of meeting Seafood and Plant Protein recommendations among participants. The Seafood & Plant Protein recommendation is an important aspect of diet quality, especially during pregnancy due to seafood's iron, vitamin B_{12}, vitamin D, and polyunsaturated omega-3 fatty acids (i.e., docosahexaenoic acid [DHA]) content.[22] The average intake of seafood is low across all age-groups in the U.S., including women of reproductive age.[22]

In terms of the strength of the negative association, ORs can be compared to Cohen's *d* effect sizes using the cut-offs of $d < 0.2$ (small effect) when OR 0.5-0.9, and $d > 0.8$ (large effect) when OR $\leq$ 0.2.[50] The relationship between stress and lower odds of meeting Seafood and Plant Protein recommendations is a small effect since an OR of 0.86 is within the range of 0.5-0.9. A potential explanation of this association is the concept of eating energy-dense, nutrient-poor foods in response to stress. Research indicates that pregnancy-specific stress was associated with reduced protein intake overall;[33] however, this was not specific to seafood or plant-based protein. Previous studies that have examined the relationship between mental health and fish/seafood intake have focused on depressive symptoms, but not stress. Overall, they found an inverse relationship where higher fish/seafood intake was associated with lower depressive symptoms, suggesting seafood may have a protective effect on depressive symptoms.[27,29,51] A lack of studies investigating the relationship between stress and fish/seafood intake in pregnancy highlights the need for future research to confirm the present study's findings.

In terms of racial differences, our results indicate that AA women had significantly higher odds of meeting Fatty Acids and Refined Grains recommendations compared to their White counterparts in both the stress and depressive symptoms models. The associations between being AA and higher odds of meeting the recommendations for Fatty Acids and Refined Grains were moderate in strength. The OR for Fatty Acids (OR 4.57-4.77) and Refined Grains (OR 2.81-2.99) fall between the small and large effect size cut-offs of OR < 1.5 and OR > 5.[50] A previous study that evaluated meeting HEI component recommendations in a large sample of U.S. pregnant women found that White women met Fatty Acids and Refined Grains recommendations at a higher percentage than AA women,[1] which differs from the current study's findings. Study findings may differ due to differences in women's demographic characteristics, such as educational attainment. A greater proportion of HIPP participants have a college degree or higher (61% vs. 54%) compared to Bodnar et al.'s sample, which may influence the results. Additional research is needed to clarify racial differences in meeting HEI component recommendations and identify modifiable factors that are driving the relationships.

Our second aim was to examine whether race moderated the relationships between stress, depressive symptoms, and HEI total score or HEI component scores. Our results indicate that race did not moderate these relationships. The lack of moderation may be explained by the fact that AA and White women had equally low levels of stress and depressive symptoms and there were no significant differences by race. Davis' framework for stress reactivity and maternal obesity development in pregnancy posits that AA women experience disproportionate amounts of chronic stress due to social disadvantages (e.g., discrimination, single parenthood, and poverty).[36,37] Stress has been associated with consuming energy-dense, nutrient-poor foods (e.g., lower fruit and vegetable intake,[31] greater fast-food intake,[32] and greater intake of sweets and snacks[33]) among pregnant women. We may have observed significant interactions if there was greater variability in stress and depressive symptoms and notable differences in these variables by race. The majority of previous studies that examined the relationship between mental and diet quality had limited representation of AA women and did not examine race as a potential moderator.[15,26,33,34] This is a limitation in the existing literature that is addressed in the current study. Future studies could also examine chronic stress, which could have a different relationship with diet quality as compared to acute stress.

The present study addresses an important gap in the literature by examining stress and depressive symptoms as potential barriers to achieving optimal diet quality. These are relatively understudied risk factors in understanding overall diet quality, particularly among racially-diverse overweight/obese pregnant women. HIPP participants' overall diet quality fell below the 2015 DGAs recommendations, with a small percentage of women meeting the recommendations for Total Vegetables, Fatty Acids, Sodium, and Saturated Fat components. Using a graded approach, HIPP participants' average HEI total score of 55.9 receives a grade of "F", indicating poor diet quality.[54] The average HEI-2015 score for American adults (18-64 years) is 58, so participants' scores are below those of the average American adult.[55] This highlights the need for evidence-based interventions to help women improve their diet quality during pregnancy.

Limitations

In terms of limitations, HIPP participants' stress and depressive symptoms scores were low overall and had limited variability, which may have restricted our ability to detect significant associations with overall diet quality. As previously mentioned, AA and White women had comparable stress and depressive symptoms, with no significant differences by race. Together, the limited variability in stress and depressive symptoms scores and the lack of significant racial differences in stress and depressive symptoms may have influenced our ability to detect race as a moderator. Additionally, this study's cross-sectional design does not allow for the examination of mental health and diet quality at multiple time-points during pregnancy or for the direction of the association to be determined. While we found that stress is associated with lower odds of meeting Seafood and Plant Protein recommendations, it is plausible that mental health and diet quality have a bi-directional relationship.[19] This highlights the need for large-scale, longitudinal study designs that examine stress, depressive symptoms, and diet quality at multiple time-points to determine the temporal and directional nature of this association.[24] The study also used baseline data from a randomized trial, so the sample may not be representative of all overweight/obese pregnant women in SC.

Strengths

This study had multiple strengths including the population of women being studied and the methods used to assess diet quality in pregnancy. AA women experience several burdens including higher obesity prevalence,[56] worse diet quality,[57] increased risk of excessive GWG,[58] and increased likelihood of postpartum weight retention[58–62] compared to their White counterparts, yet have not been included in many pregnancy interventions to date. The authors are only aware of two other studies that have examined the relationship between stress, depressive symptoms, and diet quality in pregnancy with more than 20% of African-Americans represented in their sample;[31,63] however, their assessment of diet quality was limited to brief screeners assessing fat, fruit, vegetable, and fast-food intake through rapid screening tools compared to a comprehensive diet quality index score derived from multiple 24-hour recalls.

Previous authors have highlighted the need for high-quality studies that use standard definitions and methods of assessing diet quality and dietary patterns.[24,25,64] It is a strength that this study used the HEI-2015 to assess overall diet quality because it standardizes the methods used through density standards, characterizes diet quality while controlling for diet quantity, and is reliable and valid for all segments of the population for which the USDA Food Patterns are appropriate, which includes pregnant women.[65] Additionally, it allows for omnivorous, vegetarian, and vegan dietary patterns and captures a variety of ethnic and cultural eating patterns.[22,65]

Conclusions

Overall, HIPP participants' diet quality was poor, highlighting the need for additional research on barriers and facilitators to achieving optimal diet quality during pregnancy. Pregnancy can be a time of high-stress, which has been associated with poor diet quality in previous studies.[15,66] Future studies should examine the efficacy of interventions that incorporate stress management in conjunction with nutrition education to improve diet quality in overweight/obese pregnant women. Additionally, healthcare providers should examine the feasibility of screening stress, depressive symptoms, and diet quality during prenatal visits to identify women in need of additional dietary or mental health care. Once identified, providers could connect women with registered dietitians, mental health counselors, or support groups with other pregnant women. Such translational research is vital because pregnancy is an opportune time to improve diet quality and psychological well-being to address disparities in maternal and child health.

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Table 4.4 Description of Healthy Eating Index-2015 components.

HEI-2015 Component	Description
Adequacy	
Total Vegetables	Includes dark-green vegetables, all other vegetables, and legumes (beans & peas).
Greens and Beans	Includes dark-green vegetables and legumes (beans & peas).
Total Fruits	Includes whole fruit and fruit juice.
Whole Fruits	Includes only whole fruit.
Whole Grains	Includes whole grains.
Dairy	Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages. Includes only the nonfat fraction from these products.
Total Protein Foods	Includes meat, poultry, and eggs (lean fraction only); seafood; nuts, seeds, and soy products (other than beverages); and legumes (beans & peas).
Seafood and Plant Proteins	Includes seafood; nuts, seeds, and soy products (other than beverages); and legumes (beans & peas).
Fatty Acids	Fatty acids are included as a ratio of polyunsaturated and monounsaturated fatty acids to saturated fatty acids.
Moderation	
Sodium	Includes only sodium.
Refined Grains	Includes only refined grains.
Saturated Fats	Includes saturated fats from dairy and meat, poultry, and eggs.
Added Sugars	Includes added sugars.

Table 4.5 HIPP participants'(N=169) baseline demographic and psychosocial characteristics in early pregnancy

Characteristic	**Total (n=169), *n***	**%**	**White (*n*=102;60%)**	**African-American[a] (*n*=67; 40%)**	***p*-value**
Age, %					0.02
18-24	31	18.3	11.8	28.4	
25-29	45	26.6	24.5	29.8	
30-34	63	37.3	43.1	28.4	
35-42	30	17.8	20.6	13.4	
Marital Status, %					<0.0001
Married	113	66.9	85.3	38.8	
Not married	56	33.1	14.7	61.2	
Education level, %					0.09
High school or less	21	12.4	10.8	14.9	
Some college	45	26.6	21.6	34.3	
College degree/higher	103	61.0	67.6	50.8	
Total household income, %[b]					<0.0001
<$10K-34.9K	49	29.0	14.7	50.8	
$35K-49.9K	23	13.6	12.7	14.9	
$50K-74.9K	33	19.5	24.5	11.9	
$75K+	63	37.3	47.1	22.4	
WIC, %					<0.0001
Enrolled (parent and/or child receives food)	39	23.1	10.8	41.8	
Not enrolled	130	76.9	89.2	58.2	
Parity					0.16
Nulliparous	74	43.8	39.2	50.8	
Multiparous	95	56.2	60.8	49.2	
Pre-pregnancy weight status[c], %					0.98
Overweight (BMI 25.0-29.9 kg/m^2)	86	50.9	51.0	50.8	
Obese (BMI $\geq$ 30 kg/m^2)	83	49.1	49.0	49.2	
Group randomization, %					0.83
Intervention	85	50.3	51.0	49.2	
Standard Care	84	49.7	49.0	50.8	

Characteristic, Mean $\pm$ SD	**Total**	**White**	**African-American**	***p*-value**
Age (years), range 18-42	29.6 $\pm$ 5.1	30.7 $\pm$ 4.7	27.9 $\pm$ 5.4	0.0005
Gestational age (weeks at eligibility screening), range 5-16	10.1 $\pm$ 2.4	9.7 $\pm$ 2.3	10.6 $\pm$ 2.5	0.03
Perceived stress[d], range 0-14	4.8 $\pm$ 3.3	4.6 $\pm$ 3.0	5.2 $\pm$ 3.7	0.21
Depressive symptoms[d], range 0-20	5.8 $\pm$ 4.3	5.4 $\pm$ 3.9	6.3 $\pm$ 4.8	0.21

The χ^2 test was used to examine differences in the proportion of categorical characteristics by race.
Independent samples *t* tests were used to test for mean differences in continuous demographic characteristics by race.
$p < 0.05$ indicated statistical significance.
[a]Includes two participants who indicated both AA and White as their race.
[b]Percentages less than 100% due to a refused response.
[c]Based upon self-reported pre-pregnancy height and weight.
[d]Higher scores = greater perceived stress or depressive symptoms.

Table 4.6 HIPP participants' (N=169) baseline Healthy Eating Index-2015 total scores, component scores, and percentages of participants who met HEI component recommendations based on the Dietary Guidelines for Americans by race

			Participants' Component Scores			**Percentage who Met Recommendations**		
HEI-2015 Component	**Standard for Meeting Recommendations**	**Maximum Score**	**All**	**White**	**African-American**	**All**	**White**	**African-American**
			Mean score±SD			%		
Adequacy[1]								
Total Vegetables	≥1.1 cup equiv. per 1,000 kcal	5.0	2.1±1.6	2.3±1.5	1.9±1.6	9.5	8.8	10.5
Greens and Beans	≥0.2 cup equiv. per 1,000 kcal	5.0	3.8±1.9	3.8±1.9	3.9±1.9	68.1	66.7	70.2
Total Fruits	≥0.8 cup equiv. per 1,000 kcal	5.0	1.7±1.8	1.6±1.9	1.9±1.8	11.2	12.8	9.0
Whole Fruits	≥0.4 cup equiv. per 1,000 kcal	5.0	3.3±2.0	3.3±2.0	3.2±2.1	47.3	48.0	46.3
Whole Grains	≥1.5 oz equiv. per 1,000 kcal	10.0	7.0±4.0	6.7±4.1	7.5±3.9	60.4	56.9	65.7
Dairy	≥1.3 cup equiv. per 1,000 kcal	10.0	5.3±2.9	5.4±2.8	5.1±3.0	11.2	10.8	11.9
Total Protein Foods	≥2.5 oz equiv. per 1,000 kcal	5.0	2.6±1.9	2.8±1.8	2.4±1.9	26.0	26.5	25.4
Seafood and Plant Proteins	≥0.8 oz equiv. per 1,000 kcal	5.0	3.3±2.0	3.1±2.1	3.5±1.9	47.9	46.1	50.8
Fatty Acids	(PUFAs + MUFAs)/SFAs ≥2.5	10.0	4.4±3.1	4.2±2.8	4.7±3.4	8.3	4.9	13.4
Moderation[2]								
Sodium	≤1.1 gram per 1,000 kcal	10.0	1.9±2.4	1.9±2.2	1.7±2.6	0.6	0	1.5
Refined Grains	≤1.8 oz equiv. per 1,000 kcal	10.0	8.4±2.8	8.0±2.9	9.0±2.4*	66.9	58.8	79.1*
Saturated Fats	≤8% of energy	10.0	4.9±3.0	4.7±2.8	5.2±3.3	7.1	6.9	7.5
Added Sugars	≤6.5% of energy	10.0	7.1±2.8	6.9±2.9	7.5±2.7	23.1	18.6	29.9
Total Score			55.9±10.6	54.8±10.6	57.4±10.4			

[1]Adequacy components- dietary components that should be increased.

[2]Moderation components- dietary components that should be consumed in moderation.

***p* < 0.05**

Table 4.7 Adjusted linear regression models of baseline associations between perceived stress and Healthy Eating Index-2015 (HEI) total scores, HIPP study (N=169)

	Model 1 **b (SE)**	**Model 2** **b (SE)**	**Model 3** **b (SE)**
Stress[a]	-0.25 (0.25)	-0.23 (0.27)	-0.47 (0.37)
Black (ref: White)		2.72 (1.98)	0.22 (3.31)
Stress x race			0.49 (0.52)
Control variables			
Education level			
High school or less		-3.34 (2.88)	-3.60 (2.90)
Some college (ref: College degree or higher)		-2.31 (2.19)	-2.17 (2.19)
Age			
18-24 years		-0.45 (3.20)	-0.26 (3.20)
25-29 years		0.53 (2.66)	0.56 (2.66)
30-34 years (ref: 35-42 years)		3.01 (2.38)	3.18 (2.39)
Marital Status			
Not married (ref: Married)		-0.63 (2.27)	-0.23 (2.31)
Parity			
Multiparous (ref: Nulliparous)		-0.75 (1.84)	-0.56 (1.85)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)		3.71 (2.42)	3.42 (2.44)
Pre-pregnancy weight status			
Obese (ref: Overweight)		0.08 (1.66)	0.11 (1.66)

[a]Perceived stress scores are continuous, ranging from 0-14.
Linear regression models were used to examine the relationship between perceived stress scores and HEI total scores.
Model 1: crude model examining the relationship between stress and HEI total scores.
Model 2: adjusted model including covariates.
Model 3: adjusted model including stress*race interaction term and other covariates.
*= $p < 0.05$

Table 4.8 Adjusted logistic regression models of baseline associations between perceived stress and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	Adequacy components[a]				
	Total Vegetables	**Greens & Beans**	**Total Fruits**	**Whole Fruits**	**Whole Grains**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Stress	0.96 (0.81, 1.14)	0.90 (0.81, 1.01)	1.02 (0.87, 1.21)	0.94 (0.85, 1.04)	0.93 (0.84, 1.04)
Black (ref: White)	1.53 (0.44, 5.33)	1.30 (0.57, 2.95)	0.43 (0.12, 1.50)	1.12 (0.53, 2.38)	1.31 (0.60, 2.85)
Control variables					
Education level					
High school or less	2.32 (0.34, 15.73)	0.63 (0.20, 2.00)	1.73 (0.40, 7.54)	1.14 (0.38, 3.37)	0.55 (0.18, 1.73)
Some college	3.83 (0.98, 14.93)	0.79 (0.32, 1.95)	1.25 (0.35, 4.45)	0.68 (0.30, 1.57)	0.58 (0.24, 1.39)
(ref: College degree or higher)					
Age					
18-24 years	1.18 (0.17, 8.03)	0.91 (0.26, 3.23)	2.58 (0.37, 17.87)	0.69 (0.21, 2.35)	0.66 (0.19, 2.27)
25-29 years	0.68 (0.13, 3.39)	2.00 (0.68, 5.87)	1.46 (0.23, 9.37)	1.07 (0.40, 2.90)	1.51 (0.54, 4.18)
30-34 years (ref: 35-42 years)	0.51 (0.11, 2.31)	2.22 (0.86, 5.75)	1.67 (0.32, 8.79)	1.16 (0.48, 2.82)	1.95 (0.78, 4.89)
Marital Status					
Not married (ref: Married)	0.46 (0.10, 2.15)	0.72 (0.28, 1.87)	1.35 (0.36, 5.03)	0.73 (0.31, 1.73)	1.54 (0.61, 3.89)
Parity					
Multiparous (ref: Nulliparous)	1.13 (0.34, 3.77)	1.03 (0.48, 2.21)	0.89 (0.30, 2.66)	0.98 (0.49, 1.97)	1.05 (0.51, 2.16)
Proxy for income					
Enrolled in WIC (ref: Not enrolled)	0.43 (0.09, 2.12)	2.67 (0.94, 7.59)	1.32 (0.35, 5.01)	1.46 (0.58, 3.68)	2.37 (0.88, 6.40)
Pre-pregnancy weight status					
Obese (ref: Overweight)	0.79 (0.26, 2.39)	0.99 (0.49, 1.97)	1.43 (0.52, 3.94)	0.97 (0.51, 1.81)	1.15 (0.60, 2.22)

[a]Adequacy components- dietary components that should be increased.

* $p < 0.05$

Table 4.8 Continued. Adjusted logistic regression models of baseline associations between perceived stress and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	Adequacy components[a]			
	Dairy	**Total Protein Foods**	**Seafood & Plant Proteins**	**Fatty Acids**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Stress	1.03 (0.87, 1.22)	0.94 (0.84, 1.06)	0.86 (0.77, 0.96)*	0.95 (0.79, 1.14)
Black (ref: White)	1.25 (0.39, 4.07)	1.19 (0.51, 2.79)	1.64 (0.74, 3.65)	4.57 (1.14, 18.25)*
Control variables				
Education level				
High school or less	2.73 (0.64, 11.59)	3.64 (1.10, 12.08)*	0.65 (0.20, 2.08)	0.36 (0.03, 4.67)
Some college (ref: College degree or higher)	0.35 (0.06, 1.94)	1.21 (0.45, 3.24)	0.71 (0.30, 1.69)	0.60 (0.12, 3.05)
Age				
18-24 years	0.61 (0.08, 4.38)	1.01 (0.26, 3.84)	0.46 (0.13, 1.66)	1.52 (0.20, 11.49)
25-29 years	0.24 (0.03, 1.75)	0.44 (0.13, 1.44)	0.75 (0.27, 2.09)	0.28 (0.04, 1.91)
30-34 years (ref: 35-42 years)	1.58 (0.38, 6.56)	0.84 (0.31, 2.26)	1.27 (0.51, 3.19)	0.44 (0.09, 2.06)
Marital Status				
Not married (ref: Married)	0.64 (0.16, 2.62)	0.75 (0.27, 2.07)	1.06 (0.43, 2.63)	0.52 (0.11, 2.50)
Parity				
Multiparous (ref: Nulliparous)	0.33 (0.11, 1.04)	0.73 (0.33, 1.62)	1.33 (0.65, 2.76)	1.84 (0.47, 7.23)
Proxy for income				
Enrolled in WIC (ref: Not enrolled)	2.07 (0.43, 10.01)	0.54 (0.18, 1.61)	1.17 (0.44, 3.10)	1.19 (0.22, 6.31)
Pre-pregnancy weight status				
Obese (ref: Overweight)	1.11 (0.40, 3.07)	1.62 (0.78, 3.35)	1.03 (0.53, 1.97)	0.61 (0.18, 2.01)

[a]Adequacy components- dietary components that should be increased.
* $p < 0.05$

Table 4.8 Continued. Adjusted logistic regression models of baseline associations between perceived stress and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	← **Moderation components**[b]		→
	Refined Grains	**Saturated Fats**	**Added Sugars**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Stress	0.91 (0.81, 1.02)	0.96 (0.78, 1.18)	0.99 (0.88, 1.12)
Black (ref: White)	2.99 (1.25, 7.13)*	0.64 (0.12, 3.39)	1.72 (0.72, 4.07)
<u>Control variables</u>			
Education level			
High school or less	0.36 (0.11, 1.19)	0.52 (0.04, 6.30)	0.83 (0.21, 3.23)
Some college	0.64 (0.25, 1.65)	1.29 (0.26, 6.34)	1.25 (0.48, 3.26)
(ref: College degree or higher)			
Age			
18-24 years	0.97 (0.26, 3.60)	1.20 (0.07, 21.56)	0.60 (0.13, 2.65)
25-29 years	1.72 (0.59, 4.99)	1.51 (0.13, 18.12)	0.87 (0.26, 2.99)
30-34 years (ref: 35-42 years)	3.03 (1.13, 8.13)*	2.80 (0.30, 25.86)	1.17 (0.39, 3.53)
Marital Status			
Not married (ref: Married)	1.41 (0.50, 3.96)	0.61 (0.11, 3.51)	0.97 (0.36, 2.59)
Parity			
Multiparous (ref: Nulliparous)	1.56 (0.72, 3.39)	0.97 (0.22, 4.30)	0.50 (0.22, 1.16)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)	2.35 (0.79, 6.98)	8.91 (1.39, 57.06)*	1.52 (0.52, 4.40)
Pre-pregnancy weight status			
Obese (ref: Overweight)	0.75 (0.37, 1.53)	0.32 (0.08, 1.28)	0.96 (0.46, 2.03)

[b]Moderation components- dietary components that should be consumed in moderation.

* $p < 0.05$

Sodium component could not be analyzed due to the small cell size of participants who met the sodium intake recommendation.

Table 4.9 Adjusted linear regression models of baseline associations between depressive symptoms and Healthy Eating Index-2015 (HEI) total scores, HIPP study (N=169)

	Model 1 **b (SE)**	**Model 2** **b (SE)**	**Model 3** **b (SE)**
Depressive symptoms[a]	0.03 (0.19)	-0.02 (0.20)	0.03 (0.28)
Black (ref: White)		2.68 (1.99)	3.28 (3.14)
Depressive symptoms x race			-0.10 (0.39)
Control variables			
Education level			
High school or less		-3.81 (2.84)	-3.79 (2.85)
Some college (ref: College degree or higher)		-2.63 (2.16)	-2.70 (2.18)
Age			
18-24 years		-0.38 (3.21)	-0.46 (3.24)
25-29 years		0.86 (2.64)	0.80 (2.66)
30-34 years (ref: 35-42 years)		3.13 (2.38)	3.11 (2.39)
Marital Status			
Not married (ref: Married)		-0.55 (2.28)	-0.59 (2.29)
Parity			
Multiparous (ref: Nulliparous)		-0.68 (1.88)	-0.70 (1.89)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)		3.50 (2.43)	3.51 (2.43)
Pre-pregnancy weight status			
Obese (ref: Overweight)		0.05 (1.68)	0.05 (1.68)

[a]Depressive symptoms scores are continuous, ranging from 0-20.
Linear regression models were used to examine the relationship between depressive symptoms scores and HEI total scores.
Model 1: crude model examining the relationship between depressive symptoms and HEI total scores.
Model 2: adjusted model including covariates.
Model 3: adjusted model including depressive symptoms*race interaction term and other covariates.
*= $p < 0.05$

Table 4.10 Adjusted logistic regression models of baseline associations between depressive symptoms and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	Adequacy components[a]				
	Total Vegetables	**Greens & Beans**	**Total Fruits**	**Whole Fruits**	**Whole Grains**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Depressive symptoms	0.98 (0.86, 1.13)	0.95 (0.88, 1.03)	1.02 (0.90, 1.14)	0.97 (0.90, 1.05)	1.00 (0.93, 1.09)
Black (ref: White)	1.51 (0.43, 5.23)	1.30 (0.57, 2.94)	0.43 (0.12, 1.50)	1.12 (0.53, 2.37)	1.28 (0.59, 2.77)
Control variables					
Education level					
High school or less	2.13 (0.33, 13.64)	0.53 (0.17, 1.65)	1.78 (0.42, 7.63)	1.04 (0.36, 3.00)	0.47 (0.15, 1.45)
Some college	3.61 (0.96, 13.54)	0.71 (0.29, 1.71)	1.27 (0.36, 4.48)	0.64 (0.28, 1.45)	0.52 (0.22, 1.24)
(ref: College degree or higher)					
Age					
18-24 years	1.19 (0.17, 8.10)	0.89 (0.25, 3.15)	2.61 (0.37, 18.15)	0.68 (0.20, 2.31)	0.68 (0.20, 2.35)
25-29 years	0.70 (0.14, 3.48)	2.17 (0.75, 6.28)	1.42 (0.23, 8.92)	1.13 (0.42, 3.03)	1.67 (0.61, 4.57)
30-34 years (ref: 35-42 years)	0.53 (0.12, 2.37)	2.34 (0.91, 6.01)	1.64 (0.31, 8.64)	1.20 (0.49, 2.91)	2.01 (0.81, 5.01)
Marital Status					
Not married (ref: Married)	0.47 (0.10, 2.17)	0.75 (0.29, 1.94)	1.35 (0.36, 5.06)	0.74 (0.31, 1.75)	1.58 (0.63, 3.99)
Parity					
Multiparous (ref: Nulliparous)	1.10 (0.32, 3.79)	0.97 (0.44, 2.11)	0.91 (0.30, 2.74)	0.96 (0.47, 1.94)	1.09 (0.52, 2.27)
Proxy for income					
Enrolled in WIC (ref: Not enrolled)	0.43 (0.09, 2.10)	2.52 (0.90, 7.07)	1.33 (0.35, 5.02)	1.43 (0.57, 3.60)	2.18 (0.81, 5.86)
Pre-pregnancy weight status					
Obese (ref: Overweight)	0.81 (0.27, 2.43)	1.02 (0.51, 2.03)	1.41 (0.51, 3.88)	0.98 (0.52, 1.83)	1.14 (0.59, 2.21)

[a]Adequacy components- dietary components that should be increased.

* $p < 0.05$

Table 4.10 Continued. Adjusted logistic regression models of baseline associations between depressive symptoms and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	← Adequacy components[a] →			
	Dairy	**Total Protein Foods**	**Seafood & Plant Proteins**	**Fatty Acids**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Depressive symptoms	1.06 (0.94, 1.18)	0.96 (0.87, 1.05)	0.97 (0.90, 1.05)	0.93 (0.79, 1.09)
Black (ref: White)	1.18 (0.36, 3.87)	1.21 (0.52, 2.83)	1.59 (0.73, 3.45)	4.77 (1.17, 19.44)*
Control variables				
Education level				
High school or less	2.84 (0.69, 11.69)	3.40 (1.05, 11.02)*	0.49 (0.16, 1.52)	0.33 (0.03, 4.08)
Some college	0.36 (0.07, 1.98)	1.15 (0.43, 3.04)	0.59 (0.26, 1.37)	0.59 (0.12, 2.91)
(ref: College degree or higher)				
Age				
18-24 years	0.69 (0.09, 5.10)	0.96 (0.25, 3.68)	0.49 (0.14, 1.70)	1.35 (0.17, 10.56)
25-29 years	0.25 (0.03, 1.79)	0.46 (0.14, 1.48)	0.90 (0.33, 2.44)	0.25 (0.04, 1.79)
30-34 years (ref: 35-42 years)	1.61 (0.39, 6.67)	0.86 (0.32, 2.32)	1.36 (0.55, 3.34)	0.46 (0.10, 2.13)
Marital Status				
Not married (ref: Married)	0.63 (0.15, 2.62)	0.77 (0.28, 2.09)	1.10 (0.45, 2.66)	0.52 (0.11, 2.52)
Parity				
Multiparous (ref: Nulliparous)	0.36 (0.11, 1.15)	0.69 (0.31, 1.56)	1.34 (0.65, 2.76)	1.56 (0.38, 6.49)
Proxy for income				
Enrolled in WIC (ref: Not enrolled)	1.93 (0.40, 9.29)	0.53 (0.18, 1.58)	1.07 (0.41, 2.76)	1.23 (0.23, 6.52)
Pre-pregnancy weight status				
Obese (ref: Overweight)	1.07 (0.38, 2.98)	1.66 (0.80, 3.44)	1.02 (0.53, 1.94)	0.62 (0.18, 2.07)

[a]Adequacy components- dietary components that should be increased.

* $p < 0.05$

Table 4.10 Continued. Adjusted logistic regression models of baseline associations between depressive symptoms and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	Moderation components[b]		
	Refined Grains	**Saturated Fats**	**Added Sugars**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Depressive symptoms	1.00 (0.92, 1.09)	0.86 (0.70, 1.05)	1.04 (0.95, 1.13)
Black (ref: White)	2.81 (1.19, 6.64)*	0.64 (0.11, 3.61)	1.67 (0.70, 3.95)
Control variables			
Education level			
High school or less	0.29 (0.09, 0.97)	0.58 (0.05, 7.23)	0.78 (0.21, 2.97)
Some college	0.55 (0.22, 1.41)	1.42 (0.28, 7.33)	1.23 (0.48, 3.14)
(ref: College degree or higher)			
Age			
18-24 years	0.98 (0.27, 3.61)	1.06 (0.06, 19.18)	0.63 (0.14, 2.83)
25-29 years	1.94 (0.68, 5.55)	1.27 (0.10, 15.86)	0.94 (0.28, 3.18)
30-34 years (ref: 35-42 years)	3.08 (1.16, 8.18)*	2.99 (0.32, 27.95)	1.18 (0.39, 3.55)
Marital Status			
Not married (ref: Married)	1.45 (0.52, 4.05)	0.55 (0.09, 3.26)	0.99 (0.37, 2.65)
Parity			
Multiparous (ref: Nulliparous)	1.59 (0.73, 3.48)	0.73 (0.16, 3.32)	0.55 (0.23, 1.29)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)	2.13 (0.72, 6.26)	11.13 (1.58, 78.19)	1.41 (0.49, 4.08)
Pre-pregnancy weight status			
Obese (ref: Overweight)	0.75 (0.37, 1.53)	0.35 (0.09, 1.37)	0.92 (0.44, 1.96)

[b]Moderation components- dietary components that should be consumed in moderation.

* $p < 0.05$

Sodium component could not be analyzed due to the small cell size of participants who met the sodium intake recommendation.

The Relationship between Healthy Food Density and Diet Quality among Pregnant Women in South Carolina[3]

[3] Boutté AK, Turner-McGrievy GM, Eberth JM, Wilcox S, Liu J, and Kaczynski AT. To be submitted to *Preventive Medicine*.

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Abstract

Poor access to healthy food may be a barrier to improving diet quality during pregnancy; yet, few studies have examined the relationship between neighborhood healthy food density (% of healthy retailers out of the total number of retailers) and diet quality among African-American (AA) and White overweight/obese pregnant women. This study aimed to 1) examine if higher healthy food density (via the Modified Retail Food Environment Index [mRFEI]) is associated with better diet quality (via Healthy Eating Index [HEI]-2015 total scores and meeting HEI component recommendations) and 2) test whether residential location moderates the relationship between healthy food density and diet quality. The Health in Pregnancy and Postpartum (HIPP) study is an ongoing randomized trial targeting excessive weight gain among overweight/obese pregnant women in South Carolina (N=169). At baseline, participants provided demographic data, their home

addresses, and completed two 24-hour dietary recalls to calculate HEI scores. Binary codes for each of the 13 HEI components (met Dietary Guidelines recommendations vs. not) and HEI total scores (0-100) were calculated. Food retailer locations originated from ReferenceUSA. Retailer and participants' addresses were geocoded to the point/street address level. Healthy food density scores were calculated based on a 5-mile network buffer from participants' home addresses. Scores were calculated using the following ratio: (100 x [# of supermarkets/total # of supermarkets, convenience stores, drug stores, dollar stores, limited-service restaurants]). Multiple linear and logistic regression models were used to estimate HEI total scores and meeting HEI component recommendations respectively. Multiplicative interaction terms of healthy food density and residential location were used to examine moderation. Results indicated that participants' diet quality was suboptimal ($M=55.9 \pm 10.6$, range 28-76). There was a higher proportion of urban women who met the Total Protein Foods recommendation (29.5% vs. 10.0%) compared to rural women. As healthy food density increased, HEI total scores tended to increase, but the association did not reach significance. Residential location moderated the relationship between healthy food density and the odds of meeting the Whole Fruit recommendation. A one-unit increase in healthy food density was associated a 21% increase in the odds of meeting the Whole Fruit recommendation for urban women (adj OR: 1.21 [95% CI=1.04, 1.40]) compared to rural women (adj OR: 0.97 [95% CI=0.91, 1.03]). Overall, this study demonstrated that HIPP participants had poor diet quality; however, having better access to healthy food was associated with greater whole fruit consumption for participants living in urban but not rural areas. Future studies could analyze women's daily travel patterns via Global Position System (GPS) devices to better understand how women interact with their food environments during the important period of pregnancy to inform future diet quality interventions.

Introduction

Poor diet quality during pregnancy is an important public health problem due to its widespread nature and adverse effects on maternal and offspring health.[1] Energy-dense, nutrient-poor diets may be an important factor contributing to excessive gestational weight gain (GWG)[2,3] and postpartum weight retention in women,[4] and greater newborn adiposity[5] and overweight in childhood.[6] Diet quality among U.S. women during pregnancy falls short of national recommendations in the Dietary Guidelines for Americans (DGAs),[1,7] so there is a need to better understand the determinants of diet quality in pregnancy.

Over half of U.S. women (55%) begin pregnancy overweight or obese.[8] Overweight and obese women are nearly three times as likely to exceed the Institute of Medicine's (IOM) 2009 GWG guidelines compared to healthy weight women.[9,10] Excessive GWG is associated with an increased risk for pre-eclampsia, cesarean delivery, and infants born large-for-gestational-age.[11–13] Improving diet quality during pregnancy may be one strategy to address excessive GWG,[14] so additional research is needed to understand determinants of diet quality to reduce maternal obesity and make strides in achieving health equity in pregnancy outcomes.[1]

The neighborhood food environment has been increasingly investigated as a factor influencing dietary intake, overall diet quality, and obesity among the general U.S. population.[15–17] Research has found that individuals living in the lowest-ranked food environments are 22-35% less likely to have healthy diet quality, compared to those in the best-ranked food environments among non-pregnant adults;[18] however, there is a paucity of research investigating the relationship between the neighborhood food environment and diet quality in pregnant women.[19,20] It is theorized that individuals are more likely to engage in healthier behaviors when they are in supportive environments,[21] so poor access to healthy food may act as a barrier to improving diet quality during the important period of pregnancy.[20] Rural individuals face additional barriers that may negatively impact diet quality, such as traveling longer distances to buy groceries, having less independent access to a vehicle, greater reliance on car ownership/transportation to get to stores, lack of public transportation, grocery shopping less frequently, and shopping at one grocery store compared to multiple stores.[22,23] These factors influence the need to understand how one's food environment could be related to diet quality during pregnancy, and how the relationship could differ between urban and rural women.

Researchers have indicated the need to examine both environmental and individual-level factors to better understand how the food environment may impact diet quality.[17] Neighborhood food environments have been assessed either subjectively through the use of surveys, which capture individuals' perceptions of food availability, or objectively through the use of spatial analysis methods using geographic information systems (GIS).[24] Previous studies that have examined the relationship between neighborhood food environments and dietary intake using GIS-based measures have defined food access based on retail store density or proximity.[24] Density is typically defined as the number of retailers in an administratively defined area (e.g., census tract) or a researcher-specified area (e.g., street-network buffer).[24] Proximity can be measured by straight-line distance (i.e., Euclidean distance) or travel time (i.e., amount of time needed to travel to the nearest and/or utilized retailer through the street-network).[24] A limitation of previous studies that have examined the density of food retailers is that they often examined the exposure of a single type of food retailer independently (e.g., grocery stores/supermarkets, convenience stores, or fast-food restaurants).[15,18,20,25] Alternatively, a food environment index, such as the Centers for Disease Control and Prevention's Modified Retail Food Environment Index (mRFEI), holds value since it examines the proportion of healthy retailers (e.g., grocery stores/supermarkets) in an area while simultaneously accounting for the presence of less healthy retailers (e.g., convenience stores, limited-service restaurants).[26]

To address these gaps, the aims of the current study were to 1) examine if higher healthy food density (via the CDC's Modified Retail Food Environment Index (mRFEI)) is associated with better diet quality (via Healthy Eating Index (HEI)-2015 total scores and meeting HEI component recommendations) and 2) test whether residential location moderates the relationship between healthy food density and diet quality. We hypothesized that an increase in healthy food density would be associated with higher HEI total scores and higher odds of meeting HEI component recommendations overall and for urban compared to rural women. Residential location was tested as a moderator since individuals living in rural areas may face additional barriers (e.g., poorer quality produce, longer travel distances, lack of public transportation, and less frequent grocery shopping) that could negatively impact diet quality.[22,23]

Methods

The Health in Pregnancy and Postpartum (HIPP) study is a randomized controlled trial examining the efficacy of a theory-based behavioral lifestyle intervention to reduce excessive GWG among White and African-American (AA) overweight/obese pregnant women, as compared to a standard care intervention. This paper reports a cross-sectional analysis of demographic, food environment, and dietary data measured at baseline to date (*N*=169). Baseline assessments were conducted from January 2015 to March 2018.

A full description of HIPP study methods have been published elsewhere.[27] In brief, women were recruited to participate in the study primarily through 13 obstetrics and gynecology (OB/GYN) clinics in the greater Columbia, South Carolina (SC) area and adjacent counties, with some self-referrals in response to community and social media advertisements. Women were eligible if they: (a) were between 18-44 years of age, (b) self-identified as White or Black/AA, (c) could read and speak English, (d) had no plans to move outside of the geographic area in the next 18 months, (e) were $\leq$ 16 weeks gestation, and (f) had a pre-pregnancy body mass index (BMI) $\geq$25 kg/m^2 and a pre-pregnancy weight $\leq$ 370 pounds. Women were excluded if they had contraindications to physical activity during pregnancy.[28] Institutional Review Boards at our university and health care systems approved the study protocol. All participants provided written informed consent.

Measures

At the baseline visit, demographic data, home addresses, and anthropometric measures were collected. The demographic questionnaires and anthropometric measures were interviewer-administered, while the 24-hour dietary recalls were self-administered. Baseline demographic variables were categorized as follows: age (18-24 years, 25-29 years, 30-34 years, or 35-42 years), race (White or AA/Black), education (high school diploma/GED or less, some college, or college degree or higher), parity (nulliparous or multiparous), marital status (married or not married), enrollment in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (yes or no), pre-pregnancy weight status (overweight or obese), and self-reported distance traveled in miles to buy groceries. Pre-pregnancy BMI was calculated from participants' self-reported pre-pregnancy height and weight.

Neighborhood food environment

Food retailers were acquired from ReferenceUSA, a commercial database of U.S. businesses.[29] Food retailer addresses for SC were obtained from the database in December 2017. Retailers were categorized based on North American Industry Classification System (NAICS) codes. The categories of interest included: grocery stores/supermarkets (Group 445110), convenience stores (445120), gas stations with food marts (447110), drug stores (446110), discount merchandise stores (452319), and limited-service restaurants (722513). Drug stores and discount merchandise stores (e.g., Walgreens & Dollar General) were included since they typically sell a limited variety of food products such as milk, bread, soda, and snacks.[30] Limited-service restaurants are where customers order and pay before eating, the food is typically served quickly after ordering, and the food is kept cold, cooked in advance, and/or reheated.[31] This category included fast-food restaurants, fast-casual restaurants, limited-service family restaurants, pizza delivery shops, delicatessen restaurants, and takeout eating places. Food retailers and participants' home addresses were geocoded to the point or street address level using the ArcGIS Online World Geocoding Service address locator in ArcGIS Pro, version 1.2 (Esri, Inc., Redlands, CA, 2016).[32]

The neighborhood food environment was determined by calculating the 5-mile network distance from participants' homes using the "Network Analyst" tool. The 5-mile distance was based on the average distance participants reported traveling to buy groceries across urban and rural areas. Five-mile network buffers were created around each participant's home. Food retailers that were contained in each buffer were clipped and summed for use in the mRFEI formula (Figure 1). Within the 5-mile network areas, grocery stores (n=182), convenience stores (n=457), drug stores (n=84), discount merchandise stores (n=150), and limited-service restaurants (n=580) were geocoded to the point or street address level, resulting in a total of 1,453 retailers that were included in the analyses.

Healthy food density was assessed by the mRFEI, which has been significantly associated with health and dietary outcomes (i.e., lower odds of obesity[33] and higher objectively-measured fruit and vegetable consumption[34]) among the general population. The mRFEI combines the concepts of food deserts (i.e., areas with poor access to supermarkets) with the concept of food swamps (i.e., areas with a high amount of unhealthy food) into a single score at the census-tract level.[26] The original mRFEI score represents the percentage of food retailers considered healthy, out of the total number of food retailers considered healthy and less healthy in a census tract; however; the current study calculated healthy food density scores at the *individual-level* based on HIPP participants' home addresses. Healthy food density scores were calculated by dividing the total number of healthy food retailers by the total number of healthy and less healthy food retailers, and then multiplying by 100 to get a percentage (Figure 1). mRFEI scores range from zero (no food retailers that typically sell healthy food) to 100 (only food retailers that sell healthy food). The designation of healthy and less healthy retailers was based on the CDC's definition,[26] where healthy food retailers included grocery stores/supermarkets and less healthy food retailers included limited-service restaurants, convenience stores, drug stores, gas stations with food marts, and discount merchandise stores. Drug stores and discount merchandise stores were not included in the original CDC formula but were added since they sell a limited variety of food items similar to a convenience store.[30] Full-service restaurants are not included in mRFEI scores.

Urban and rural areas were determined by the Census Bureau's 2017 Urban Areas Boundary file. The Census defines two categories of urban areas—urbanized areas (50,000 people or more) and urban clusters (at least 2,500 people and less than 50,000 people). Rural areas include all populations and areas not included within an urban area.[35] Participants' addresses were spatially joined to associated urban area boundaries. Participants' addresses that fell within urban areas were categorized as urban and those outside urban areas were categorized as rural.

Diet quality

Participants completed two unannounced 24-hour dietary recalls (one weekday and one weekend day, which included Fridays) at baseline through the National Cancer Institute (NCI)'s Automated Self-Administered 24-hour Dietary Recall (ASA24) online system.[36] The ASA24 is a web-based dietary assessment tool that provides complete nutrient analysis of all foods and beverages reported during the data collection timeframe.[36] Based on the 24-hour dietary recall data, participants' diet quality was calculated using SAS code provided by the NCI to generate HEI scores, which measure adherence to the 2015 DGAs.[37]

The HEI-2015 includes 13 components, including 9 adequacy components (i.e., Total Fruits, Whole Fruits, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids), which are dietary components that need to be increased. There are four moderation components (i.e., Refined Grains, Sodium, Added Sugars, and Saturated Fats), which are dietary components that need to be reduced. All components are scored on a density basis out of 1,000 calories, with the exception of Fatty Acids, which is a ratio of unsaturated to saturated fatty acids.[38] The HEI components are described in Table 4.11. For each component, higher scores reflect greater adherence to the DGAs. Achieving the maximum score for an HEI component reflects meeting the guidelines for that component. Component scores are summed to create a total score ranging from 0 to 100 points, with higher scores indicating better diet quality. HEI total scores were analyzed as a continuous variable; however, due to floor and ceiling effects of many HEI components, components were analyzed as dichotomous outcomes of meeting the recommendations or not.

Statistical Analyses

Descriptive statistics (i.e., means, standard deviations (SD), and percentages) were used to summarize participants' sociodemographic characteristics, food environment variables (proximity to food retailers, self-reported distance for grocery shopping, and healthy food density scores), and diet quality (i.e., HEI total scores and components) at baseline. Independent samples t-tests were used to test for mean differences in continuous variables (e.g., age, parity, gestational age, healthy food density scores, HEI total scores, HEI component scores) by residential location. The χ^2 test was used to examine differences in the proportion of categorical characteristics (e.g., marital status, education level, and pre-pregnancy weight status) by residential location and to assess for differences in the percentage of women meeting HEI component recommendations by residential location.

Multiple linear regression models were used to predict HEI total scores. The independent variable was the healthy food density score, which was analyzed as a continuous variable. Potential confounders were chosen *a priori* based on existing literature and included race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. WIC enrollment was used as a proxy for low-income status since financial burden is a requirement to receive WIC benefits.[39] A multiplicative interaction term of healthy food density and residential location was used to examine if urban vs. rural status moderated the relationship between healthy food density and diet quality in adjusted models. Beta coefficients and standard errors for both crude and adjusted models are presented.

To test the hypothesis that higher healthy food density scores would be associated with higher odds of meeting HEI component recommendations, multiple logistic regression models were used to predict the odds of meeting HEI component recommendations for all of the HEI components as secondary outcomes, with the exception of sodium. The Sodium component could not be analyzed due to the small cell size of participants who met the Sodium recommendation. Models adjusted for maternal race, educational attainment, age, marital status, parity, WIC enrollment, and pre-pregnancy BMI. A multiplicative interaction term of healthy food density and residential location was used to examine if urban vs. rural status moderated the relationship between healthy food density and diet quality in adjusted models. Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for crude and adjusted models are presented. For all analyses, a *P* value <0.05 indicated statistical significance. Statistical analyses were performed using SAS® software, version 9.4 (SAS Institute, Inc., Cary, NC, 2013)[40].

Results

Study population

A total of 169 women completed baseline questionnaires and two 24-hour dietary recalls. Participants were racially-diverse (60% White, 40% AA), primarily married (67%), more than a third were 30-34 years old (37%), and almost a quarter of women (23%) were enrolled in WIC (Table 4.12). The sample was well-educated, since most women (61%) earned a college degree or higher. More than half of women had at least one child (56%) and approximately half (49%) were obese when they began pregnancy. The mean gestational age at eligibility screening was 10.1 weeks (±2.4 weeks). Additionally, most women (82%) lived in urban areas at baseline.

There were no significant differences in demographic characteristics by residential location (Table 4.12); however, there were significant urban vs. rural differences in food environment characteristics. As shown in Table 4.13, rural women lived significantly farther away from the nearest grocery store (3.1±2.1 miles vs. 1.0±0.7 miles, $p<.0001$), farther away from the nearest convenience store (1.7±1.1 miles vs. 0.7±0.5 miles, $p<.0001$), and farther away from the nearest limited-service restaurant (2.8±1.9 miles vs. 0.8±0.6 miles, $p<.0001$) compared to urban women. Additionally, rural women reported driving significantly farther to buy groceries (9.8±7.1 miles vs. 4.5±3.4

miles, $p<.001$) compared to urban women. There was no difference in 5-mile healthy food density scores by residential location.

Diet quality

Overall, HIPP participants' diet quality was suboptimal (M=55.9±10.6, range 28-76). Urban women's average HEI total scores did not differ from rural women's total scores (56.3±11.0 vs. 53.9±8.4, $p=.27$) (Table 4.14). Additionally, average HEI component scores did not differ by residential location. In terms of meeting HEI component recommendations, more than half of all participants met the recommendations for Greens and Beans, Whole Grains, and Refined Grains. Approximately half of participants met the recommendations for Whole Fruit and Seafood and Plant Proteins. Less than 10% of women met the recommendations for Total Vegetables, Fatty Acids, Sodium, and Saturated Fats. The only significant urban vs. rural difference in meeting HEI component recommendations was for Total Protein Foods. There was a higher proportion of urban women who met the Total Protein Foods recommendation (29.5% vs. 10.0%) compared to rural women. There were no other significant differences in the proportions of women meeting HEI component recommendations by residential location.

Healthy food density and HEI Scores

The first aim was to examine if higher healthy food density scores were associated with higher HEI total scores and higher odds of meeting HEI component recommendations. Table 4.15 presents the crude and adjusted linear regression models of the association between healthy food density and HEI total scores. Overall, healthy food density was not significantly related to HEI total scores in either the crude or adjusted analyses; however, estimated coefficients were in the direction of the hypothesized relationship. As healthy food density increased, HEI total scores tended to increase, but the association did not reach statistical significance.

Table 4.16 presents the adjusted logistic regression models of the association between healthy food density and meeting HEI component recommendations. Healthy food density was not significantly associated with meeting HEI component recommendations in main effect models; however, urban status moderated the relationship between healthy food density and the odds of meeting the Whole Fruit recommendation. A one-unit increase in healthy food density was associated a 21% increase in the odds of meeting the Whole Fruit recommendation for urban women (adj OR: 1.21 [95% CI=1.04, 1.40]) but not rural women (adj OR: 0.97 [95% CI=0.91, 1.03]).

Discussion

Overall, this study found that HIPP participants had poor diet quality, and urban status moderated the relationship between healthy food density and meeting the Whole Fruit recommendation. Additionally, as healthy food density increased, HEI total scores tended to increase, but the association was not significant. Previous studies that have examined the relationship between food retailer density and diet quality have conflicting findings across pregnant and non-pregnant samples.[15,18,20]

The current study is consistent with the null findings of Laraia et al. (2004), who examined the relationship between the density of multiple food outlets (i.e., supermarkets, grocery stores, and convenience stores) and diet quality measured by the Diet Quality Index for Pregnancy in a sample (n=918) pregnant women.[20] They found no significant association between food outlet density and diet quality scores. Conversely, previous research that examined supermarket density and fast-food restaurant density independently found more favorable results in non-pregnant individuals. For example, Moore and colleagues (2008) examined the relationship between supermarket density and diet quality measured by the Alternate Healthy Eating Index (AHEI) in a large sample (n=2,384) of non-pregnant adults aged 45-84 years from the Multi-Ethnic Study of Atherosclerosis (MESA) cohort. They found that individuals with no supermarkets near their homes were 25% less likely to have a healthy diet (scoring in the top quintile of the AHEI), compared to those in the highest category of supermarket density, after adjusting for sociodemographic factors.[18] The same research group used data from the MESA cohort to examine the relationship between fast-food outlet density and diet quality measured by the AHEI.[15] Authors found that higher fast-food outlet density was associated with 3-17% lower odds of consuming a healthy diet (top quintile of the AHEI) among a large sample (n=5,633) of non-pregnant adults.[15] Given the conflicting findings across pregnant vs. non-pregnant samples and differences in how food density was measured, further research could help clarify relationships for pregnant women.

A possible explanation for the lack of association is inadequate variation in healthy food density scores among HIPP participants. Half of participants' healthy food density scores fell between the range of 10-13 (meaning out of the food retailers in their neighborhood, 10-13% are healthy retailers). There was also no difference in healthy food density scores between participants living in urban vs. rural areas. Another potential contributing factor could be how neighborhoods were conceptualized. Conceptualizing neighborhoods has been challenging for researchers to define, which has resulted in wide variation in the definitions of neighborhoods that are used to examine neighborhood food exposure.[41] There is currently lack of consensus regarding the appropriate buffer size to use around an individual's home to define their "neighborhood";[42,43] however, this study used a tailored approach and based neighborhood size on participants' self-reported distance traveled for grocery shopping across urban and rural areas. Regardless of buffer size, individuals have their own ideas of what constitutes their neighborhood; therefore, future studies should examine Global Position System (GPS) devices to capture detailed space-time information related to people's behavior.[44]

We found that healthy food density was not significantly associated with HEI total scores; however, the results trended in the expected direction. Failure to find significant associations may be due to limited variability in 5-mile healthy food density scores overall and between urban and rural participants.

In terms of HEI components, residential location moderated the relationship between healthy food density and the odds of meeting the Whole Fruit recommendation, benefitting urban women compared to rural women. This means the relationship between higher healthy food density and meeting the Whole Fruits recommendation differed based on whether participants lived in an urban area or rural area. Results suggest that higher healthy food density can increase one's likelihood of consuming the recommended amount of whole fruits for individuals living in an urban area compared to a rural area. ORs can be compared to Cohen's d effect sizes using the cut-offs of $d < 0.2$ (small effect) when OR < 1.5 and $d > 0.8$ (large effect) when OR > 5.[45] The observed association is moderate in strength since the OR for Whole Fruits among participants in urban areas (OR: 1.21) does not exceed the small effect size cut-off of OR < 1.5.[45] Previous studies that have examined the relationship between healthy food density (density of grocery stores, produce stores) and fruit and vegetable intake have also shown mixed results.[46–49]

Previous studies have found that a higher density of supermarkets and produce stores is associated with more frequent vegetable consumption among non-pregnant Australian women (n=1,399) living in urban areas.[46] Similarly, Powell and Han (2011) found that higher supermarket density was significantly associated with slightly higher weekly vegetable consumption among low-income non-pregnant adolescents (n=1,134).[48] The current study's significant finding was for whole fruit consumption; therefore, does not directly complement these previous studies who found significant associations for vegetable consumption. Alternatively, there are previous studies that have found no association between grocery store or produce store density and fruit and vegetable consumption among non-pregnant Japanese young women[47] and non-pregnant Australian women.[49] It is worth noting that pregnant women were not included in any of these previous samples; highlighting the need for additional research.

A potential explanation for the significant association between higher healthy food density and higher odds of consuming more whole fruits for participants in urban areas could be the perishable nature of fresh produce and grocery shopping frequency. Since whole fruits are perishable food items, they would likely need to be purchased more frequently than shelf-stable items, like whole grains. Previous literature shows that individuals living in rural areas travel farther to do their grocery shopping compared to those in urban areas.[50] This pattern was also observed among HIPP participants, with participants in rural areas traveling approximately twice as far (9.8 vs. 4.5 miles) as participants in urban areas to buy groceries. Traveling a farther distance may result in less frequent grocery shopping for individuals in rural areas compared to those in urban areas. Additionally, there are differences in the quality of fresh produce sold in rural grocery stores that can have a detrimental impact on produce purchasing and subsequent consumption.[51] Qualitative research has shown that spoiled fruits and vegetables are an important barrier that constrains food options for rural populations.[50] Perceived quality and freshness of produce are factors that can influence food choice and are positively associated with fruit and vegetable consumption.[52]

Limitations

The current study is not without limitations. First, the exact location of where participants shopped for groceries was not collected. Since participants reported grocery shopping an average of 5.5 miles away from home, we estimated they might do their grocery shopping at one of the included stores; however, the possibility exists for participants to do their grocery shopping elsewhere. While we found that higher healthy food density was associated with increased odds of meeting Whole Fruit recommendations for participants living in urban areas, there are likely additional individual- and environmental-level factors that may contribute to diet quality that were beyond the scope of this study. Some individual-level factors include social support,[53] smoking before[54] and during pregnancy,[54] stress,[55] depressive symptoms,[55] physical activity during pregnancy,[19,54] pregnancy intention,[56] and nausea during pregnancy.[19] Additional environmental-level factors include availability of public transportation and aspects of the consumer food environment, such as quality/freshness of the produce,[57] variety of fresh produce,[58] and price of foods.[58] Furthermore, there are social factors that influence store choice such as store characteristics (e.g., customer service, cleanliness, and non-food merchandise availability),[59,60] sharing the same race/ethnicity, income, and education as fellow shoppers, accommodation of physical disabilities, and the ability to integrate shopping with other daily activities.[61] Future studies could analyze women's daily travel patterns via Global Position System (GPS) devices to better understand how women interact with their food environments, along with examining the consumer food environment (e.g., grocery store audit of quality, cost, variety) to better understand factors influencing diet quality in pregnancy.

The present study obtained food retailer data from a single database. While most sources of secondary data have the potential to introduce bias into the analysis,[62] using multiple sources could improve the accuracy/completeness of the data and is encouraged.[62] In addition, this study's cross-sectional design does not allow for the examination of healthy food density and diet quality at multiple time-points during pregnancy; therefore, the direction of the association cannot be determined. Geocoding can be inaccurate due to the inherent error in the geo-referencing process;[63] however, all of the food outlets in the current study were matched to the point- or street-address level. The locations of the food retailers were obtained in December 2017, while the HIPP baseline assessments were conducted from January 2015 to March 2018; therefore, there is the possibility that some retailers included in the study could have closed or new ones could have opened during that time frame. "Ground-truthing" is a way to verify the location and determine if the business is still in operation, but can be very labor-intensive.[62] Lastly, the study used baseline data from a randomized trial, so the sample may not be representative of all overweight/obese pregnant women in SC.

Strengths

This study has multiple strengths, including the use of objective GIS-based methods to determine healthy food access at the individual-level, the use of a food environment index, the use of a standardized diet quality index, the examination of residential location as a moderator, and the population of women being studied. Using GIS-based methods allowed for an objective and tailored measure of the availability of multiple food retailers in relation to participants' homes. Previous studies have examined food store density as a count of stores within a specified buffer; however, multiple store types were not accounted for simultaneously.[15,18,20,25] This study's use of the CDC's mRFEI allowed for the calculation of healthy food retailers *relative* to unhealthy retailers. Better healthy food density (via mRFEI) has been significantly associated with lower odds of obesity[33] and greater objectively-measure fruit and vegetable consumption (skin carotenoids)[34] among the general US population, both of which have implications for diet quality. Few studies have examined the ratio of healthy food retailers to less healthy retailers in relation to diet quality at the individual-level.[64,65]

Additionally, this study's use of the HEI-2015 is a strength since it captures overall diet quality as opposed to focusing on individual nutrients, scores diets based on adherence to federal dietary recommendations, allows for a variety of ethnic and cultural eating patterns, and is reliable for all segments of the population for which the USDA Food Patterns are appropriate, which includes pregnant women.[66] The examination of residential location as a moderator in the relationship between healthy food density and diet quality was a strength because it illustrated that the relationship between healthy food density and meeting the Whole Fruit recommendation was contingent upon women living in an urban vs. rural area. Furthermore, this analysis was conducted in a racially-diverse sample of overweight/obese pregnant women, which is a high-priority sample of women who have not been included in much research to date.

Conclusions

Overall, HIPP participants had poor diet quality; however, having better access to healthy food was associated with greater whole fruit consumption for participants living in urban but not rural areas. It is hypothesized that food-purchasing behaviors are a potential mechanism through which food environments influence dietary outcomes.[67] Future studies could expand upon the current findings by using Global Position System (GPS) devices to track daily travel patterns of participants to obtain accurate locations of food retailers that participants visit throughout the course of a day/week.[68] Additionally, investigators could examine aspects of the consumer food environment within stores (availability/quality, price, placement, and promotion of food within stores)[67] to gain a more comprehensive understanding of how store environments may influence food purchases and ultimately diet quality in pregnancy. Longitudinal studies that collect home address and dietary intake data from women across multiple time-points in pregnancy can examine differences in women's healthy food access and diet quality if women move to different neighborhoods during pregnancy. Given the adverse effects of poor diet quality on maternal and child health outcomes,[3,5] additional research in needed to better understand how women interact with their food environments during the important period of pregnancy to inform future diet quality interventions.

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Table 4.11 Description of Healthy Eating Index-2015 components.

HEI-2015 Component	Description
Adequacy	
Total Vegetables	Includes dark-green vegetables, all other vegetables, and legumes (beans & peas).
Greens and Beans	Includes dark-green vegetables and legumes (beans & peas).
Total Fruits	Includes whole fruit and fruit juice.
Whole Fruits	Includes only whole fruit.
Whole Grains	Includes whole grains.
Dairy	Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages. Includes only the nonfat fraction from these products.
Total Protein Foods	Includes meat, poultry, and eggs (lean fraction only); seafood; nuts, seeds, and soy products (other than beverages); and legumes (beans & peas).
Seafood and Plant Proteins	Includes seafood; nuts, seeds, and soy products (other than beverages); and legumes (beans & peas).
Fatty Acids	Fatty acids are included as a ratio of polyunsaturated and monounsaturated fatty acids to saturated fatty acids.
Moderation	
Sodium	Includes only sodium.
Refined Grains	Includes only refined grains.
Saturated Fats	Includes saturated fats from dairy and meat, poultry, and eggs.
Added Sugars	Includes added sugars.

Table 4.12 HIPP participants'(N=169) baseline demographic and psychosocial characteristics in early pregnancy by residential location

Characteristic	Total (n=169), *n*	%	Urban (*n*=139; 82.2%)	Rural (*n*=30; 17.8%)	*p*-value
Race, %					0.54
White	102	60.4	59.0	66.7	
African-American[a]	67	39.6	41.0	33.3	
Age, %					0.69
18-24	31	18.3	18.0	20.0	
25-29	45	26.6	25.9	30.0	
30-34	63	37.3	36.7	40.0	
35-42	30	17.8	19.4	10.0	
Marital Status, %					
Married	113	66.9	65.5	73.3	0.52
Not married	56	33.1	34.5	26.7	
Education level, %					0.76
High school or less	21	12.4	11.5	16.7	
Some college	45	26.6	26.6	26.7	
College degree/higher	103	61.0	61.9	56.6	
WIC, %					0.81
Enrolled (parent and/or child receives food)	39	23.1	23.7	20.0	
Not enrolled	130	76.9	76.3	80.0	
Parity					0.42
Nulliparous	74	43.8	45.3	36.7	
Multiparous	95	56.2	54.7	63.3	
Pre-pregnancy weight status[c]*, %*					0.55
Overweight (BMI 25.0-29.9 kg/m^2)	86	50.9	49.6	56.7	
Obese (BMI $\geq$ 30 kg/m^2)	83	49.1	50.4	43.3	
Group randomization, %					0.55
Intervention	85	50.3	48.9	56.7	
Standard Care	84	49.7	51.1	43.3	

Characteristic, Mean $\pm$ SD	**Total**	**Urban**	**Rural**	***p*-value**
Age (years), range 18-42	29.6$\pm$5.1	29.8$\pm$5.2	28.8$\pm$4.8	0.36
Gestational age (weeks at eligibility screening), range 5-16	10.1$\pm$2.4	10.0$\pm$2.4	10.4$\pm$2.2	0.42

The χ^2 test was used to examine differences in the proportion of categorical characteristics by urban status. Independent samples *t* tests were used to test for mean differences in continuous demographic characteristics by urban status.
$p < 0.05$ indicated statistical significance.
[a]Includes two participants who indicated both AA and White as their race.
[b]Percentages less than 100% due to a refused response.
[c]Based upon self-reported pre-pregnancy height and weight.

Table 4.13 Summary of food environment characteristics by residential location among HIPP participants (*N*=169).

	Total (*n*=169) Mean±SD (Range)	Urban (*n*=139) Mean±SD	Rural (*n*=30) Mean±SD	*p*-value
Distance to nearest grocery store, miles	1.4±1.4 (0.1-8.2)	1.0±0.7	3.1±2.1	<.0001
Distance to nearest convenience store, miles	0.9±0.8 (0.0-4.2)	0.7±0.5	1.7±1.1	<.0001
Distance to nearest limited-service restaurant, miles	1.2±1.2 (0.1-7.8)	0.8±0.6	2.8±1.9	<.0001
Self-reported distance for grocery shopping, miles	5.5±4.7 (1.0-37.0)	4.5±3.4	9.8±7.1	<.001
5-mile healthy food density[a], %	12.1±5.9 (0.0-50.0)	12.0±3.0	12.3±12.7	0.91

[a]Healthy food density represents the percentage of healthy food retailers out of the total number of retailers (both healthy and less healthy).

Table 4.14 HIPP participants'(N=169) baseline Healthy Eating Index-2015 total scores, component scores, and percentages of participants who achieved maximum component scores by residential location.

			Participants' Component Scores			**Percentage who Achieved Maximum Scores**		
HEI-2015 Component	**Standard for Maximum Score**	**Maximum Score**	**All**	**Urban**	**Rural**	**All**	**Urban**	**Rural**
			← Mean score±SD →			← % →		
Adequacy[1]								
Total Vegetables	≥1.1 cup equiv. per 1,000 kcal	5.0	2.1±1.6	2.2±1.5	1.9±1.5	9.5	9.3	10
Greens and Beans	≥0.2 cup equiv. per 1,000 kcal	5.0	3.8±1.9	3.7±2.0	4.2±1.7	68.1	66.2	76.7
Total Fruits	≥0.8 cup equiv. per 1,000 kcal	5.0	1.7±1.8	1.8±1.9	1.3±1.7	11.2	12.2	6.7
Whole Fruits	≥0.4 cup equiv. per 1,000 kcal	5.0	3.3±2.0	3.2±2.0	3.4±2.1	47.3	46.0	53.3
Whole Grains	≥1.5 oz equiv. per 1,000 kcal	10.0	7.0±4.0	6.8±4.0	7.7±3.9	60.4	57.5	73.3
Dairy	≥1.3 cup equiv. per 1,000 kcal	10.0	5.3±2.9	5.3±2.9	5.1±3.1	11.2	10.8	13.3
Total Protein Foods	≥2.5 oz equiv. per 1,000 kcal	5.0	2.6±1.9	2.7±1.9	2.2±1.6	26.0	29.5*	10.0
Seafood and Plant Proteins	≥0.8 oz equiv. per 1,000 kcal	5.0	3.3±2.0	3.3±2.0	2.9±2.2	47.9	49.6	40.0
Fatty Acids	(PUFAs + MUFAs)/SFAs ≥2.5	10.0	4.4±3.1	4.6±3.1	3.4±2.7	8.3	9.3	3.3
Moderation[2]								
Sodium	≤1.1 gram per 1,000 kcal	10.0	1.9±2.4	1.8±2.4	1.9±2.4	0.6	0.72	0.0
Refined Grains	≤1.8 oz equiv. per 1,000 kcal	10.0	8.4±2.8	8.3±2.9	9.1±2.0	66.9	64.0	80.0
Saturated Fats	≤8% of energy	10.0	4.9±3.0	5.0±3.1	4.5±2.6	7.1	7.2	6.7
Added Sugars	≤6.5% of energy	10.0	7.1±2.8	7.3±2.8	6.3±3.1	23.1	25.9	10.0
Total Score		100	55.9±10.6	56.3±11.0	53.9±8.4			

[1]Adequacy components- dietary components that should be increased.
[2]Moderation components- dietary components that should be consumed in moderation.
Independent samples *t* tests were used to test for mean differences in HEI component scores by urban status.
The χ^2 test was used to examine differences in the proportion of individuals who achieved maximum HEI component scores by urban status.
***$p < 0.05$**

Table 4.15 Adjusted linear regression models of baseline associations between 5-mile healthy food density and Healthy Eating Index-2015 (HEI) total scores, HIPP study (N=169)

	Model 1 **b (SE)**	**Model 2** **b (SE)**	**Model 3** **b (SE)**
5-mile healthy food density[a]	0.07 (0.14)	0.09 (0.14)	-0.03 (0.16)
Urban (ref: Rural)		2.02 (2.18)	-4.58 (4.84)
Healthy food density x urban			0.56 (0.36)
Control variables			
Education level			
High school or less		-3.94 (2.88)	-3.02 (2.93)
Some college (ref: College degree or higher)		-2.61 (2.16)	-2.24 (2.16)
Race			
Black (ref: White)		2.74 (1.99)	2.87 (1.98)
Age			
18-24 years		0.14 (3.23)	0.17 (3.22)
25-29 years		1.19 (2.65)	1.44 (2.64)
30-34 years (ref: 35-42 years)		3.31 (2.39)	3.42 (2.39)
Marital Status			
Not married (ref: Married)		-0.83 (2.29)	-1.33 (2.30)
Parity			
Multiparous (ref: Nulliparous)		-0.52 (1.85)	-0.41 (1.84)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)		3.21 (2.43)	2.23 (2.50)
Pre-pregnancy weight status			
Obese (ref: Overweight)		-0.14 (1.68)	0.34 (1.70)

[a]Healthy food density represents the percentage of healthy food retailers out of the total number of retailers (both healthy and less healthy).
Healthy food density scores are continuous, ranging from 0-50.
Linear regression models were used to examine the relationship between 5-mile healthy food density and HEI total scores.
Model 1: crude model examining the relationship between healthy food density and HEI total scores.
Model 2: adjusted model including covariates.
Model 3: adjusted model including healthy food density*urban interaction term and other covariates.
*= $p < 0.05$

Table 4.16 Adjusted logistic regression models of baseline associations between 5-mile healthy food density and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	Adequacy components[a]				
	Total Vegetables	**Greens & Beans**	**Total Fruits**	**Whole Fruits**	**Whole Grains**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
5-mile healthy food density	1.01 (0.92, 1.11)	1.01 (0.95, 1.08)	1.01 (0.93, 1.11)	1.01 (0.96, 1.07)	1.01 (0.95, 1.08)
Urban (ref: Rural)	1.02 (0.25, 4.19)	0.56 (0.21, 1.48)	2.36 (0.46, 12.14)	0.75 (0.33, 1.69)	0.40 (0.16, 1.04)
Control variables					
Education level					
High school or less	2.00 (0.30, 13.12)	0.46 (0.14, 1.48)	1.90 (0.42, 8.59)	0.93 (0.31, 2.74)	0.41 (0.13,1.31)
Some college (ref: College degree or higher)	3.55 (0.95, 13.30)	0.66 (0.27, 1.61)	1.35 (0.38, 4.88)	0.62 (0.27, 1.40)	0.48 (0.20, 1.16)
Race					
Black (ref: White)	1.52 (0.44, 5.28)	1.32 (0.58, 3.00)	0.41 (0.12, 1.46)	1.12 (0.53, 2.36)	1.34 (0.61, 2.95)
Age					
18-24 years	1.24 (0.18, 8.55)	0.87 (0.24, 3.10)	2.93 (0.41, 20.72)	0.69 (0.20, 2.36)	0.58 (0.16, 2.06)
25-29 years	0.71 (0.14, 3.56)	2.14 (0.74, 6.19)	1.51 (0.24, 9.52)	1.13 (0.42, 3.03)	1.50 (0.54, 4.14)
30-34 years (ref: 35-42 years)	0.51 (0.11, 2.34)	2.15 (0.83, 5.57)	1.72 (0.33, 9.10)	1.15 (0.47, 2.80)	1.83 (0.73, 4.62)
Marital Status					
Not married (ref: Married)	0.46 (0.10, 2.16)	0.78 (0.30, 2.02)	1.30 (0.35, 4.90)	0.75 (0.32, 1.79)	1.70 (0.66, 4.37)
Parity					
Multiparous (ref: Nulliparous)	1.13 (0.33, 3.86)	1.02 (0.48, 2.17)	0.95 (0.31, 2.86)	0.98 (0.49, 1.97)	0.99 (0.48, 2.06)
Proxy for income					
Enrolled in WIC (ref: Not enrolled)	0.41 (0.08, 2.02)	2.37 (0.84, 6.69)	1.23 (0.32, 4.77)	1.36 (0.54, 3.43)	2.33 (0.84, 6.42)
Pre-pregnancy weight status					
Obese (ref: Overweight)	0.80 (0.27, 2.39)	0.98 (0.49, 1.96)	1.38 (0.50, 3.83)	0.95 (0.51, 1.78)	1.17 (0.60, 2.27)

[a]Adequacy components- dietary components that should be increased.

* $p < 0.05$

Table 4.16 Continued. Adjusted logistic regression models of baseline associations between 5-mile healthy food density and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	← Adequacy components[a] →			
	Dairy	**Total Protein Foods**	**Seafood & Plant Proteins**	**Fatty Acids**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
5-mile healthy food density	1.00 (0.93, 1.08)	0.96 (0.87, 1.04)	1.00 (0.95, 1.06)	1.03 (0.89, 1.18)
Urban (ref: Rural)	0.68 (0.19, 2.46)	4.53 (1.19, 17.23)*	1.46 (0.63, 3.41)	2.53 (0.30, 21.36)
Control variables				
Education level				
High school or less	2.79 (0.66, 11.74)	4.21 (1.20, 14.81)*	0.49 (0.15, 1.53)	0.25 (0.02, 3.24)
Some college	0.36 (0.06, 1.98)	1.21 (0.45, 3.28)	0.59 (0.26, 1.36)	0.54 (0.11, 2.79)
(ref: College degree or higher)				
Race				
Black (ref: White)	1.29 (0.40, 4.17)	1.10 (0.46, 2.63)	1.57 (0.72, 3.39)	4.61 (1.13, 18.80)
Age				
18-24 years	0.56 (0.08, 4.17)	1.26 (0.32, 5.00)	0.54 (0.15, 1.91)	1.95 (0.25, 14.95)
25-29 years	0.21 (0.03, 1.54)	0.57 (0.17, 1.88)	0.99 (0.36, 2.68)	0.36 (0.05, 2.41)
30-34 years (ref: 35-42 years)	1.43 (0.34, 6.01)	1.03 (0.37, 2.86)	1.41 (0.57, 3.49)	0.50 (0.11, 2.38)
Marital Status				
Not married (ref: Married)	0.64 (0.15, 2.63)	0.74 (0.26, 2.07)	1.07 (0.44, 2.60)	0.51 (0.11, 2.41)
Parity				
Multiparous (ref: Nulliparous)	0.32 (0.10, 1.01)	0.85 (0.38, 1.92)	1.47 (0.72, 2.98)	1.97 (0.51, 7.56)
Proxy for income				
Enrolled in WIC (ref: Not enrolled)	2.27 (0.48, 10.85)	0.46 (0.15, 1.46)	1.01 (0.39, 2.61)	1.00 (0.19, 5.37)
Pre-pregnancy weight status				
Obese (ref: Overweight)	1.11 (0.39, 3.14)	1.61 (0.76, 3.38)	0.97 (0.51, 1.85)	0.56 (0.17, 1.88)

[a]Adequacy components- dietary components that should be increased.

* $p < 0.05$

Table 4.16 Continued. Adjusted logistic regression models of baseline associations between 5-mile healthy food density and achieving maximum Healthy Eating Index-2015 (HEI) component scores, HIPP study (N=169)

	← **Moderation components**[b]		→
	Refined Grains	**Saturated Fats**	**Added Sugars**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
5-mile healthy food density	1.02 (0.95, 1.09)	1.00 (0.88, 1.13)	1.03 (0.95, 1.11)
Urban (ref: Rural)	0.33 (0.11, 0.97)*	1.16 (0.21, 6.29)	3.05 (0.84, 11.07)
Control variables			
Education level			
High school or less	0.23 (0.07, 0.81)	0.45 (0.04, 5.36)	0.78 (0.20, 3.12)
Some college	0.48 (0.18, 1.27)	1.21 (0.25, 5.78)	1.21 (0.46, 3.17)
(ref: College degree or higher)			
Race			
Black (ref: White)	3.14 (1.29, 7.68)*	0.63 (0.12, 3.32)	1.77 (0.74, 4.24)
Age			
18-24 years	0.81 (0.22, 3.07)	1.18 (0.06, 21.30)	0.71 (0.16, 3.22)
25-29 years	1.74 (0.60, 5.08)	1.64 (0.14, 19.28)	1.01 (0.30, 3.44)
30-34 years (ref: 35-42 years)	2.84 (1.05, 7.66)*	2.83 (0.31, 26.12)	1.28 (0.42, 3.92)
Marital Status			
Not married (ref: Married)	1.55 (0.54, 4.43)	0.63 (0.11, 3.51)	0.88 (0.33, 2.37)
Parity			
Multiparous (ref: Nulliparous)	1.43 (0.65, 3.11)	1.01 (0.23, 4.47)	0.52 (0.22, 1.22)
Proxy for income			
Enrolled in WIC (ref: Not enrolled)	2.31 (0.76, 7.07)	8.79 (1.36, 56.82)	1.43 (0.48, 4.25)
Pre-pregnancy weight status			
Obese (ref: Overweight)	0.75 (0.36, 1.54)	0.31 (0.08, 1.26)	0.90 (0.42, 1.93)

[b]Moderation components- dietary components that should be consumed in moderation.

* $p < 0.05$

Sodium component could not be analyzed due to the small cell size of participants who met the sodium intake recommendation.

$$mRFEI = 100 \times \frac{\#\ \text{Healthy Food Retailers}}{\#\ \text{Healthy Food Retailers} + \#\ \text{Less Healthy Food Retailers}}$$

Figure 4.2 Modified Retail Food Environment Index Formula

Chapter 5: Conclusions and Implications

5.1 Summary of Major Findings

The high prevalence of energy-dense, nutrient-poor diets during pregnancy is an important public health challenge due to the many associated adverse maternal and child health outcomes, such as excessive gestational weight gain (GWG),[54] postpartum weight retention,[224] greater newborn adiposity,[225] and child overweight.[226] AA women are a high-priority group since they have the highest rates of obesity among the general population,[7] the poorest diet quality during pregnancy compared to White and Hispanic women,[8] and have an increased risk for postpartum weight retention compared to their White counterparts.[227,228] Improving diet quality is one important modifiable risk factor to address excessive GWG[6,54] and an important factor influencing infant development.[55] There is a growing body of evidence suggesting that mental health (i.e., stress and depression) and one's neighborhood food environment are important factors influencing dietary intake, overall diet quality, and obesity among the general U.S. population.[22,23,129] This study addresses an important gap in the literature since racially-diverse overweight/obese pregnant women have been underrepresented in studies examining the relationships between mental health, neighborhood food access, and diet quality in pregnancy.[14,19] This study 1) systematically reviewed previous literature on the relationship between mental health and diet quality in pregnancy, 2) examined the relationship between mental health and diet quality among HIPP participants, and 3) examined the relationship between healthy food density and diet quality among HIPP participants. This final chapter summarizes the main findings from the three specific aims of the study and discusses how the findings relate to previous studies. Finally, the chapter concludes by discussing implications for public health research and practice, addressing study limitations, and presenting ideas for future research to advance the field.

Specific Aim 1 1) synthesized findings of original, peer-reviewed studies that examined the associations between stress and/or depressive symptoms, and diet quality during pregnancy; 2) reviewed the measurement tools used to assess stress, depressive symptoms, and diet quality; 3) identified current gaps in the extant literature; and 4) offered recommendations for future research. Overall, higher stress and depressive symptoms were generally associated with unhealthy eating patterns and poorer diet quality scores in pregnancy. Findings were mixed regarding the relationship between stress, depressive symptoms, and food groups related to diet quality and frequency of fast-food consumption. Variability in the assessment tools, timing of assessments, and use of covariates likely contribute to the inconsistency in study findings. Gaps in the literature include limited use of longitudinal study designs; limited use of comprehensive diet quality indices; underrepresentation of minority women; and lack of multi-level theoretical frameworks.

Previous reviews have identified similar relationships between mental health and diet quality[92,229]; however, previous studies have focused on the impact of nutrient deficiencies (e.g., zinc, iron, and omega-3 fatty acids),[59,75] outcomes not specific to pregnancy (i.e., entire perinatal period),[75,92,229] or have focused on how diet quality impacts child health and dietary outcomes (e.g., height, blood pressure, and fruit and vegetable intake).[230–233] Given the cross-sectional nature of previous studies, there is a need for large-scale, prospective cohort studies that assess stress, depressive symptoms, and diet quality across multiple time-points in pregnancy to help determine the direction of the relationship.[92]

Specific Aim 2 1) examined if stress and depressive symptoms were associated with poor diet quality [using Healthy Eating Index-2015 (HEI) total and component scores] among HIPP participants, and 2) tested whether race moderated the relationship between mental health and HEI scores. Results showed that neither stress nor depressive symptoms were associated with HEI total scores. Additionally, an increase in stress was associated with a slight decrease in the odds of meeting Seafood & Plant Protein recommendations. AA women seemed to have healthier diets related to unsaturated fatty acid consumption and limited refined grain consumption compared to White women; however, diet quality was poor for participants overall. Furthermore, race did not moderate the relationships between stress, depressive symptoms, and HEI total score or component scores.

Previous studies that have examined the relationship between mental health and diet quality scores in pregnancy have found that higher stress and/or depressive symptoms are associated with lower diet quality scores in pregnancy.[14,15,17] On average, HIPP participants had low stress and depressive symptoms. Both stress and depressive symptoms had limited variation, which could have influenced the lack of association. In terms of HEI components, the current study's findings differ from a previous study which found that more White pregnant women met the recommendations for Fatty Acid and Refined Grains compared to AA women.[8] HIPP participants have higher educational attainment, which could have influenced the results. This study did not support the hypothesis that race would moderate the associations between stress and diet quality, and associations between depressive symptoms and diet quality. This could be due to the low levels of stress and depressive symptoms across all participants, regardless of race.

Specific Aim 3 1) examined whether healthy food density [via the Centers for Disease Control's Modified Retail Food Environment Index (mRFEI) within 5-miles of participants' homes] was associated with HEI total and component scores; and 2) tested whether residential location moderated the relationship between healthy food density and HEI scores. There was a higher proportion of urban women who met the Total Protein Foods recommendation compared to rural women. As healthy food density increased, HEI total scores tended to increase, but the association did not reach statistical significance. Residential location moderated the relationship between healthy food density and the odds of meeting the Whole Fruit recommendation, indicating that an increase in healthy food density was associated with higher odds of meeting the Whole Fruit recommendation for urban participants but not rural participants.

There are previous studies that complement[20] and contradict[130] the present study's results. Conflicting findings may be attributed to differences in sample characteristics (e.g., pregnant vs. non-pregnant women), differences in how food density was measured (e.g., different size buffers to define neighborhood), and limited variation in healthy food density among HIPP participants. The significant association between higher healthy food density and higher odds of consuming more whole fruits among urban but not rural participants could be due the perishable nature of fresh produce and grocery shopping frequency. Rural participants reported traveling twice as far as urban participants for grocery shopping, which may have had a negative impact on their consumption of fresh produce. Future research could examine potential differences in food shopping frequency and food purchasing behavior between pregnant women in rural compared to urban areas.

Some important themes were observed across the project's aims. First, the systematic review highlighted the fact that there is considerable variation in the way diet quality has been assessed across previous studies. For example, some studies assessed diet quality by identifying dietary patterns unique to the study sample through statistical techniques such as factor analysis,[167,234] while others examined the consumption of specific food groups,[126,235] or comprehensive diet quality scores.[14,17] This variability in diet quality methodology makes it challenging to compare findings across different study populations. Moving forward, more standardized methods should be used to increase consistency and comparability of diet quality, which is a sentiment expressed by multiple researchers.[92,105,107]

Second, the current project is interdisciplinary and integrated concepts from psychology, nutrition, maternal and child health, and used GIS methodology, which has roots in geography and epidemiology. The research team on this project consisted of researchers with expertise in clinical psychology, nutrition, perinatal epidemiology, geospatial methods, and the built environment. In order to conduct research and practice that targets multiple levels of influence, it's necessary to have team members from across different disciplines that can help design innovative methods for improving diet quality during the important time of pregnancy.

Third, the concept of place was important in this study. The fact that most people do not do their grocery shopping at the closest store to their house is an important factor to consider in this work.[236–238] Rural participants traveled twice as far to buy groceries compared to urban women, which could be a factor that can negatively impact diet quality given the added time constraints many women feel in balancing professional and household duties.[239] The relationship between time scarcity and associated food choices can be investigated in future research along with potential differences by residential location. Overall, study findings contribute to the growing body of literature that is examining the relationship between neighborhood healthy food density via GIS-based methods and diet quality at the individual-level.

5.2 Implications for Public Health Research and Practice

In terms of mental health and diet quality concerns during pregnancy, the current study has implications for prenatal care practice. While the current study did not find significant associations between mental health and overall diet quality, there's a growing body of literature supporting this relationship, and diet quality was poor among HIPP participants. Clinical health professionals should consider implementing standardized screening practices to identify women with high stress, high depressive symptoms, and poor diet quality during the first prenatal care visit to identify those who may need targeted dietary or mental health interventions. Once identified, providers could connect women with additional resources, such as registered dietitians, mental health counselors, or support groups with other pregnant women. Previous researchers have identified the feasibility of universal screening for depression during pregnancy and postpartum using the Edinburgh Prenatal/Postnatal Depression Scale as an initial screening followed by mental health referral for further diagnostic evaluation and treatment.[240] This approach is important because high depressive symptoms during pregnancy are a known risk factor for postpartum depression.[241]

Additionally, research shows that women who screened positively for high depressive symptoms during pregnancy were significantly more likely to connect with mental health services compared with women who screened positively in postpartum,[240] highlighting the importance of early detection and treatment. The assessment of both diet and depressive symptoms during prenatal care has been suggested by other authors.[167] Future research could examine the feasibility of assessing diet quality during a prenatal care visit and monitor changes in diet quality throughout pregnancy after the woman receives dietary counseling and support.

Regarding the food environment, this study has implications for future research focused on defining neighborhood food environments. The current study took a tailored approach and defined the neighborhood food environment based on the average self-reported distance participants traveled to do their grocery shopping; however, previous research highlights the fact that individuals live and work in multiple geographic areas,[242] and are therefore exposed to both healthy and unhealthy food in multiple environments (e.g., home, work, school).[243,244] Examining food exposure across multiple environments may help improve the understanding of the association between the built environment and diet quality.

Additionally, GIS methods are commonly used in public health practice, at local health departments, state, and federal public health agencies. Many of these agencies have GIS analysts who utilize spatial analytic methods for public health assessment and planning. The network buffers and healthy food density measure used in the current study could be used by public health agencies to identify areas of low and high healthy food access in various counties, regions, states, and nationwide. Identifying areas of low healthy food density could help agencies prioritize their use of resources (e.g., establishing a new farmer's market or community supported agriculture program) to increase access to healthy food. Furthermore, similar GIS methods can be employed to investigate a variety of public health challenges. Related to the current study, GIS methods could also be used by an agency to investigate disparities in access to prenatal care, WIC services, or mental health services. Overall, the current study has implications that could be relevant for prenatal care practice, future food environment research, and public health practice through GIS methods.

5.3 Limitations

This project was subject to a few limitations. Regarding the systematic review, only English-language papers were included, which may limit the generalizability of findings. Since this is a growing area of research, there are limited sources of data which resulted in multiple studies using the same cohort data for their analysis. For example, four studies came from the ALSPAC cohort in England,[125,245–247] three studies came from the KOMCHS cohort in Japan,[234,248,249] and three studies came from the same research group in Texas.[14,15,123] This may limit the generalizability of results for other study populations. Furthermore, the variability in how diet quality was assessed, and which dietary components were studied make it challenging to come to a conclusion in such a complex area. For *Aim 2*, stress and depressive symptoms scores were low overall and had limited variability, which may have restricted our ability to detect significant associations with overall diet quality. For *Aim 3*, the exact location of where participants shopped for groceries was not collected, so grocery store utilization was estimated based on their self-reported distance for grocery shopping. The present study obtained food retailer data from a single database and locations were obtained in December 2017, so there is the possibility that some retailers included in the study could have closed or new ones could have opened since then. Additionally, there are likely additional individual- and environmental-level factors that may contribute to diet quality that were beyond the scope of this study. This study used a cross-sectional design, so the direction of the associations between mental health, healthy food density, and diet quality cannot be determined. Lastly, the study used baseline data from a randomized trial, so the sample may not be representative of all SC pregnant women.

5.4 Future Directions

The results of the present study suggest multiple directions for future research. Regarding mental health, future research could examine the role of pregnancy-specific stress in relation to diet quality as opposed to generalized stress that could arise from other life circumstances. Pregnancy-specific stress is defined as stress that is derived from a variety of pregnancy-specific concerns (e.g., physical symptoms, parenting concerns, relationship strains, and apprehension about labor and delivery).[250,251] Previous research suggests that pregnancy-specific stress may be a stronger predictor of birth outcomes compared to general stress;[252] however, the relationship between pregnancy-specific stress and diet quality has not been thoroughly examined. Additionally, future studies should examine the efficacy of interventions that incorporate stress management in conjunction with nutrition education to improve diet quality among pregnant women. A recent feasibility study found that two novel 8-week stress-reduction interventions were able to facilitate meaningful reductions in stress and depressive symptoms and improve eating behaviors among a sample of multi-ethnic, low-income overweight/obese pregnant women.[253] Future studies could also investigate the effectiveness of stress management interventions in improving diet quality during pregnancy on a larger-scale through randomized controlled trials. These recent findings offer promise in the benefit of targeting stress management to improve maternal diet quality during pregnancy.

Regarding the food environment, future studies should address the limitation of not knowing the exact location of where participants did their grocery shopping by using Global Position System (GPS) devices to track daily activity patterns of participants to obtain accurate locations of food retailers that participants visit throughout the course of a day/week.[257] Not only would this provide detailed information on grocery store selection, but it would also provide information on how often they purchased food from a fast-food or full-service restaurant. Additionally, the daily activity patterns could provide insight on whether participants are doing their grocery shopping closer to their workplace versus their home.

Additionally, investigators could examine aspects of the consumer food environment within stores (availability/quality, price, placement, and promotion of food within stores)[21] to gain a more comprehensive understanding of how store environments may influence food purchases and ultimately diet quality in pregnancy. These factors could be investigated through in-depth interviews or focus groups, which would allow for more detailed and nuanced explanations of how women interact with their food environment during pregnancy. Lastly, longitudinal studies that collect home address and dietary intake data from women across multiple time-points can examine differences in women's healthy food access and diet quality over time for women who end up moving to different neighborhoods during pregnancy. Overall, future studies could build upon the current study in many ways to address the important gaps in the literature on the relationships between mental health, the food environment, and diet quality during pregnancy.

5.5 Conclusion

Mental health and access to healthy food in one's neighborhood have been identified as important determinants of diet quality;[92,254] however, they have not been investigated thoroughly in the context of pregnancy.[19,20] Overall, this study demonstrated that diet quality among pregnant women in SC is poor and deserves further investigation. Study findings highlight the need for additional research in the areas of stress management interventions, analyzing women's daily activity patterns to better understand how they interact with their food environment, and examining aspects of the consumer food environment within grocery stores to improve diet quality and increase the chances of positive maternal and child health outcomes.

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Appendix A: Perceived Stress Scale

Perceived Stress

Instructions: The next set of questions ask you about your feelings and thoughts during the last month. In each case, please tell me how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather, choose the answer that seems like a reasonable choice. For each, your choices are [read cue card answers].

In the last month...	Never	Almost never	Sometimes	Fairly often	Very often
1. How often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
2. How often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
3. How often have you felt that things were going your way?	0	1	2	3	4
4. How often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Appendix B: Edinburgh Prenatal/Postnatal Depression Scale

As you are pregnant [or have recently had a baby], we would like to know how you are feeling.
Please choose the answer that comes closest to how you have felt **IN THE PAST 7 DAYS**, not just how you feel today. The choices are [read cue card answers].

In the past 7 days……….

1. I have been able to laugh and see the funny side of things

__ As much as I ever did
__ Rather less than I used to
__ Definitely less than I used to
__ Hardly at all

2. I have looked forward with enjoyment to things

__ As much as I ever did
__ Rather less than I used to
__ Definitely less than I used to
__ Hardly at all

3. I have blamed myself unnecessarily when things went wrong

__ Yes, most of the time
__ Yes, some of the time
__ Not very often
__ No, never

4. I have been anxious or worried for no good reason

__ No, not at all
__ Hardly ever
__ Yes, sometimes
__ Yes, very often

5. I have felt scared or panicky for no very good reason

__ Yes, quite a lot
__ Yes, sometimes
__ No, not much
__ No, not at all

6. Things have been getting on top of me

__Yes, most of the time I haven't been able to cope at all
__ Yes, sometimes I haven't been coping as well as usual
__ No, most of the time I have coped quite well
__ No, I have been coping as well as ever

7. I have been so unhappy that I have had difficulty sleeping

__ Yes, most of the time
__ Yes, sometimes
__ Not very often
__ No, not at all

8. I have felt sad or miserable

__Yes, most of the time
__ Yes, quite often
__ Not very often
__ No, not at all

9. I have been so unhappy that I have been crying

__Yes, most of the time
__ Yes, quite often
__ Only occasionally
__ No, never

10. The thought of harming myself has occurred to me

__Yes, quite often
__ Sometimes
__ Hardly ever
__ Never