ORIGINAL RESEARCH

Maternal and Pediatric Nutrition

CURRENT DEVELOPMENTS IN NUTRITION

Maternal Mediterranean Diet Adherence and Its Associations with Maternal Prenatal Stressors and Child Growth

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ABSTRACT

Background: Psychosocial and physiologic stressors, such as depression and obesity, during pregnancy can have negative consequences, such as increased systemic inflammation, contributing to chronic disease for both mothers and their unborn children. These conditions disproportionately affect racial/ethnic minorities. The effects of recommended dietary patterns in mitigating the effects of these stressors remain understudied.

Objectives: We aimed to evaluate the relations between maternal Mediterranean diet adherence (MDA) and maternal and offspring outcomes during the first decade of life in African Americans, Hispanics, and Whites.

Methods: This study included 929 mother–child dyads from the NEST (Newborn Epigenetics STudy), a prospective cohort study. FFQs were used to estimate MDA in pregnant women. Weight and height were measured in children between birth and age 8 y. Multivariable linear regression models were used to examine associations between maternal MDA, inflammatory cytokines, and pregnancy and postnatal outcomes.

Results: More than 55% of White women reported high MDA during the periconceptional period compared with 22% of Hispanic and 18% of African American women ($P < 0.05$). Higher MDA was associated with lower likelihood of depressive mood ($\beta = -0.45$; 95% CI: −0.90, −0.18; $P = 0.02$) and prepregnancy obesity ($\beta = -0.29$; 95% CI: −0.57, −0.0002; $P = 0.05$). Higher MDA was also associated with lower body size at birth, which was maintained to ages 3–5 and 6–8 y—this association was most apparent in White children (3–5 y: $\beta = -2.9$, $P = 0.02$; 6–8 y: $\beta = -3.99$, $P = 0.01$).

Conclusions: If replicated in larger studies, our data suggest that MDA provides a potent avenue by which effects of prenatal stressors on maternal and fetal outcomes can be mitigated to reduce ethnic disparities in childhood obesity. *Curr Dev Nutr* 2022;0:nzac146.

Keywords: Mediterranean diet, stressors, child weight, birth outcomes, maternal diet

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Abbreviations used: CES-D, Center for Epidemiological Studies—Depression scale; MDA, Mediterranean diet adherence; MDS, Mediterranean Diet Score; NEST, Newborn Epigenetics Study.

Introduction

According to the developmental origins of health and disease hypothesis, there are critical windows of exposure, such as pregnancy, during which health trajectories can be established (1, 2). Data from animal models and humans have shown that diet during pregnancy may mitigate the risk of some negative health outcomes (3, 4). In particular, a Mediterranean-style dietary pattern has been associated with a number of positive health outcomes, including lower levels of cardiovascular disease, cancer, and inflammation and greater longevity (5, 6). A Mediterranean diet is rich in plant-based foods, uses olive oil as the main source of added fat, and includes moderate to high consumption of fish and seafood, low consumption of red meat, and moderate intake of alcohol (7, 8). Although food intake and preferences in the United States do not mirror those from countries in the Mediterranean region, adherence to a Mediterranean or Mediterranean-style dietary pattern has also been shown to result in lower mortality (9) and lower risk of chronic disease (10, 11) in non-Mediterranean countries.

Maternal physiologic and emotional (or psychosocial) stressors, such as obesity and depression, during pregnancy can have detrimental effects on maternal and child health, including inflammation (12, 13) and increased risk of chronic diseases (11, 14, 15), and contribute to poor birth outcomes (16). Approximately 1 in 10 women of reproductive age suffers from depression (17) and 29% of women of

childbearing age are obese (18). Maternal stressors during pregnancy, such as depression, can activate inflammatory pathways (19), which can have harmful, possibly lifelong health consequences for mothers and their children (19), including metabolic perturbations and obesity (20). During pregnancy, depression has been associated with increased risk of stillbirth (21), low birth weight (16, 22), and preterm birth (16). Obesity before pregnancy and excess gestational weight gain during pregnancy have also been associated with poor child neurodevelopmental outcomes (23), child obesity (24), and maternal and child chronic disease later in life (25–27). A healthful diet and greater diet quality have been linked to better mental health and mood (28, 29) and lower risk of obesity or excessive gestational weight gain (30). Further, other studies using NEST (Newborn Epigenetics STudy) data have shown that maternal dietary patterns are associated with offspring behavior in 12- to 24-mo-old offspring, and suggest a possible link through epigenetic mechanisms (31, 32). However, a recent systematic review (33) and a meta-analysis (34) of the associations between maternal healthy diet and birth or childhood outcomes have reported inconsistent findings, which may be, in part, driven by social determinants of health and other factors, including structural racism, that drive differences by race/ethnicity.

Importantly, racial/ethnic disparities exist in the prevalence of chronic depression (35), obesity (18, 36, 37), diet quality (38), and associated negative health outcomes in mothers and children (39). Black/African American women report higher levels of stressful life events (40), are more likely to be obese before pregnancy (18) and report poor diet quality (38), and have a higher risk of health and pregnancy complications (41). In addition, infants born to Black/African American mothers are more likely to have a low birth weight or be born preterm (42, 43). These poor birth outcomes can carry lifelong consequences for families (44–46) and are costly to the health care system (47); thus, there is a need to gain a better understanding of modifiable factors that can help mitigate risk.

This study leveraged existing NEST data to assess maternal adherence to a Mediterranean-style dietary pattern [Mediterranean diet adherence (MDA)] and the association between maternal MDA and 3 maternal outcomes during pregnancy: *1*) depression (longitudinal association), *2*) prepregnancy BMI (in kg/m^2) (cross-sectional association), and 3) maternal gestational weight gain (longitudinal association). In addition, we assessed the association between MDA during pregnancy and the following child outcomes: *1*) birth weight, *2*) infant gestational age at birth, and *3*) child weight at ages <3 to 8 y. Because racial/ethnic disparities exist in the outcomes of interest, we assessed associations with diet by race.

Methods

Study participants

The NEST enrolled 1700 women during pregnancy (median gestational age at enrollment: 11–12 wk) between 2009 and 2011 at qualifying prenatal clinics in North Carolina. Women were followed through pregnancy and upon delivery, and their children have been followed through their eighth birthday. Details of study enrollment have been described elsewhere (48). In brief, the study included women who met the following criteria: 18 y of age or older, planned to deliver in 1 of 2 birthing facilities in Durham County, and English- or Spanish-speaking. Women were excluded if they planned to give up custody of their child or did not carry the pregnancy to term. Of the 1700 enrolled, 1304 remained after additional exclusions ($n = 115$ experienced a fetal death, $n = 281$ refused further participation or there was an inability to follow up with the participant). The current study includes 929 mother–child dyads who completed an FFQ and had nonmissing data on the exposures and outcomes of interest (**Supplemental Figure 1**). The women in the study sample had more years of education, were more likely to be nonsmokers, were older on average, and had lower prepregnancy BMI and lower depression scores than those excluded from the analysis (**Supplemental Table 1**). This study was approved by the Duke University Institutional Review Board (#Pro00014548).

Data collection

MDA.

Women's periconceptional diet was measured at enrollment using a modified Block FFQ (49), which captured intake over the past 3 mo. The FFQ collected data on intake frequencies of >150 food items and supplements. Women were asked to report the frequency with which they consumed a given food or group of foods and the typical portion size of each food when consumed. Visuals were included to aid with portion size reporting. Women's diets were scored using the Mediterranean Diet Score (MDS) (7), which assesses adherence to a Mediterranean-like dietary pattern, adjusting for caloric intake. The MDS assesses reported intake of foods and nutrients that are deemed to be beneficial: fruit, vegetables, fish, dairy, whole grains, legumes, nuts, and MUFAs (ratio of MUFAs to SFAs), and foods that are deemed detrimental: meat. Women who reported intake of a beneficial food at or above the study sample median received a score of 1 and 0 otherwise. Women who reported intake of detrimental foods below the median received a score of 1 and 0 otherwise. The MDS was calculated per 1000 kcal of intake. For the current study, alcohol was excluded from the MDS, because alcohol is not recommended during pregnancy and reported alcohol intake in our cohort was low. The MDS ranges from 0–9, with 0 representing the lowest possible adherence to a Mediterranean diet pattern and 9 representing the highest adherence to a Mediterranean diet pattern. Maternal MDA was assessed as a continuous variable.

Pregnancy-related outcomes.

Psychosocial stressors. Depression during pregnancy was assessed in women at enrollment using the Center for Epidemiologic Studies—Depression scale (CES-D) (50) measure. The CES-D includes 20 questions asking women to rate how often they experienced symptoms related to depression. Women were asked to provide responses in relation to the 2 wk before questionnaire completion. Responses were scored according to guidelines (50). For the current study, depression was treated as a continuous variable.

Physiologic stressors. Gestational weight gain and maternal BMI were obtained from medical records and assessed continuously. Maternal prepregnancy BMI estimates were based on measured height and self-reported weight 6 mo before pregnancy, and verified with medical records data (51). These were assessed as a continuous variable.

TABLE 1 Distribution of characteristics among study participants[1]

Characteristic	Black/African American ($n = 341$)	White ($n = 317$)	Hispanic ($n = 225$)	All ($n = 929$)
Mediterranean Diet Score	3.8 ± 1.8	5.2 ± 1.9	4.7 ± 1.5	4.5 ± 1.9
Maternal education level				
No high school	21.1	4.4	57.3	23.7
High school	21.1	7.6	21.3	17.5
College	47.8	84.2	16.4	53.5
Maternal age at delivery, y	26.5 ± 5.9	30.8 ± 4.7	28.4 ± 5.7	28.6 ± 5.7
Maternal smoking, yes	23.5	12.5	2.4	14.1
Maternal BMI, kg/m^2	30.5 ± 8.7	25.1 ± 5.3	26.9 ± 5.0	27.5 ± 7.1
Sex of child, male	54.0	52.0	54.2	54.0
Depression score	14.1 ± 9.2	10.1 ± 7.8	10.1 ± 8.1	11.8 ± 8.8
Birth weight, g	3005 ± 725	3312 ± 668	3283 ± 580	3190 ± 676
Gestational age at delivery, wk	37.7 ± 3.3	38.4 ± 2.1	38.5 ± 2.2	38.2 ± 2.6

[1]Values are mean ± SD or percentages. The "other" racial group ($n = 46$) was not included owing to insufficient sample size.

Peripartum and postnatal outcomes.

Data on infant birth weight and gestational age at birth were abstracted from medical records by trained personnel after delivery. Infant birth weight (g) and gestational age at birth (wk) were normally distributed and analyzed as continuous variables. Data on child weight (pounds; 1 lb = 0.454 kg) and height or length (inches; 1 inch = 2.54 cm) were obtained through a combination of medical records at ages 7 mo–8 y, as previously described (52). Weight-for-height or -length percentiles were calculated at each age using CDC standards (53). Children were grouped and categorized by age (<3 y, 3–5 y, 6–8 y).

Inflammatory cytokine IL-17A.

Based on suggestions that higher prenatal concentrations of IL-17A increased the risk of childhood obesity at age <3 to 8 y as previously described (48, 54), we used Milliplex Analyst version 5.1 to measure this cytokine in plasma obtained at a median age of 2.9 months of gestation.

Statistical analysis

Multiple linear regression models were used to evaluate the relation between MDS and both maternal and birth outcomes: maternal factors included maternal depression, prepregnancy BMI, and gestational weight gain, and infant factors included birth weight, gestational age at birth, and weight-for-height and BMI *z* score at ages <3 to 8 y. Each regression model included Mediterranean diet as an independent variable, adjusted for covariates. Covariates were chosen a priori based on substantive knowledge from the literature on maternal diet and maternal and child health outcomes (55–57). Models for maternal outcomes were adjusted for education level (to estimate socioeconomic status), maternal age at delivery, and maternal smoking. Models for offspring birth outcomes were adjusted for maternal education level, maternal smoking, gestational age, and sex of child. We in addition adjusted for children's age, breastfeeding, parity, maternal BMI, gestational age, and gender in models evaluating associations between prenatal MDSs and children's anthropometric measurements at age <3 to 8 y. Because income data to estimate socioeconomic status in addition were missing for 20% of the study population, we conducted a sensitivity analysis including income as a covariate in a subset of $n = 645$; these analyses did not alter the associations found when income was excluded (**Supplemental Table 2**). For postnatal outcomes, supplemental analysis that included child caloric intake and income as covariates was conducted (**Supplemental Table 3**); however, estimates did not change in direction or significance. The interaction term of Mediterranean diet × race/ethnicity was assessed and found to be significant ($P < 0.1$). Therefore, overall and racial/ethnic-stratified estimates are presented. In addition, we explored the use of cubic splines to allow for greater flexibility in modeling. Analysis was conducted in SAS version 9.4 (SAS Institute Inc.) and R version 4.1.0 (R Foundation for Statistical Computing).

Results

Study participants

Table 1 shows the distribution of variables among the 929 study participants: $n = 317$ White, $n = 341$ Black/African American, and $n = 225$ Hispanic women. These participants were comparable with respect to parity and gestational age at delivery ($P > 0.05$). However, African American and Hispanic women, on average, were younger, had lower levels of education, and were more likely to have a BMI > 30 before pregnancy than White women ($P < 0.05$). Consistent with previous reports (58), children of Black/African American women were more likely to have lower birth weight and shorter gestational age at delivery than those of Whites. The prevalence of depressive symptoms was 26% overall, and Black/African American women also reported a higher level of depressive symptoms than White and Hispanic women (mean CES-D score: 14.1, 10.1, and 10.1, respectively). Forty-nine percent of women in the study gained, on average, more weight during pregnancy than that recommended for their BMI classification. White women gained 15.3 kg, Black/African American women gained 13.7 kg, and Hispanic women gained 12 kg.

MDA during the perinatal period by race/ethnicity

Black/African American women had the lowest MDA compared with Hispanic and White women (mean diet score: 3.8, 4.7, and 5.2 out of 9, respectively) (Table 1). A greater proportion of Black/African American women reported diets that scored <5 than did women of all other races/ethnicities (**Figure 1**).

Exploration of sources of this variation revealed that whereas the majority of Black/African American and non-Hispanic White women (61.8% and 64.9%, respectively; $P < 0.0001$) reported fruit and vegetable

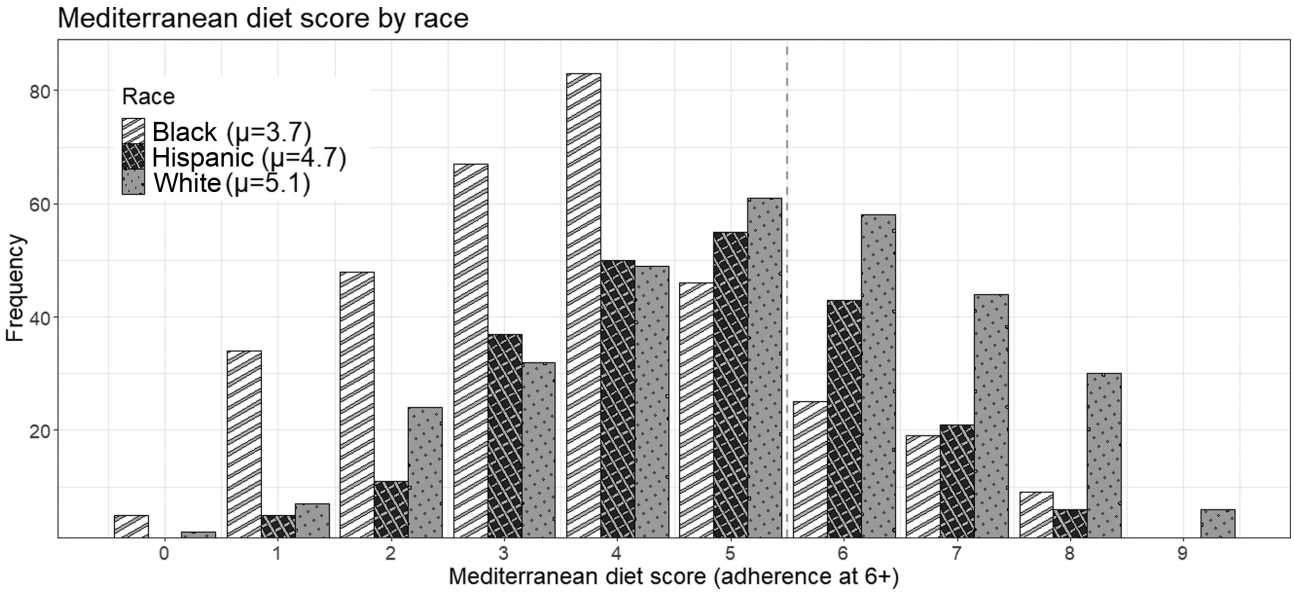

FIGURE 1 MDS by race. MDS, Mediterranean Diet Score.

consumption below the study medians of 150.7 and 82.2 g/1000 kcal (Table 2), Hispanic women consumed a greater amount of fruit and legumes than women of other races/ethnicities ($P < 0.0001$). Only 25.8% of Hispanic women consumed below the study median intake of 150.7 g fruit/1000 kcal and only 20.3% consumed below the study median of 15.2 g legumes/1000 kcal. Other major sources of variation between ethnic groups were intakes of nuts and dairy. For example, although overall nut and dairy consumption in this study was low, non-Hispanic White women consumed more nuts and dairy foods than did Black/African American and Hispanic women, because only 24.1% of non-Hispanic White women consumed below the study median of 0.7 g nuts/1000 kcal and only 28% of non-Hispanic White women consumed below the study median of 31.2 g dairy/1000 kcal ($P < 0.0001$).

Association between MDA and prenatal stressors

We evaluated the extent to which periconceptional MDA was cross-sectionally associated with lower risk of prepregnancy BMI, and longitudinally associated with depressive mood and gestational weight gain. Table 3 shows that, among all participants, a 1-unit increase in MDS was associated with a −0.29 difference in BMI periconceptionally ($\beta = -0.29$; 95% CI: −0.57, −0.0002; $P = 0.05$) and a −0.45-point difference in depression score in the first trimester of pregnancy ($\beta = -0.45$; 95% CI: −0.90, −0.18; $P = 0.02$). However, MDA did not influence gestational weight gain ($\beta = 0.07$; 95% CI: −0.25, 0.39; $P = 0.670$). The protective associations between MDA and depressive mood were greater among Hispanic women, with Hispanic women experiencing a −0.91 difference in depression score ($\beta = -0.91$; 95% CI: −1.71, −0.17; $P = 0.04$) and Black/African American women experiencing a

TABLE 2 Maternal Mediterranean diet adherence scores by race/ethnicity[1]

	MDS component score = 0[2]		
	Non-Hispanic Black women ($n = 341$)	Hispanic women ($n = 225$)	Non-Hispanic White women ($n = 317$)
Fruit	201 (61.8)	56 (25.8)	186 (60.6)
Vegetables	211 (64.9)	91 (41.9)	172 (56.0)
Fish	132 (40.6)	109 (50.2)	137 (44.6)
Dairy	196 (60.3)	128 (59.0)	86 (28.0)
Whole grain	186 (57.2)	146 (67.3)	80 (26.1)
Nuts	191 (58.8)	139 (64.1)	74 (24.1)
Legumes	251 (77.2)	44 (20.3)	137 (44.6)
MUFA:SFA	186 (58.2)	100 (46.1)	148 (48.2)
Meat	160 (49.2)	102 (47.0)	155 (50.5)

[1]Values are *n* (%). MDS, Mediterranean Diet Score.
[2]For beneficial food/nutrient groups (fruit, vegetables, fish, dairy, whole grains, nuts, legumes, MUFA:SFA), a component score of 0 indicates intake below the median for the study population; for detrimental foods (meats), a component score of 0 indicates intake at or above the median for the study population.

TABLE 3 Association between maternal Mediterranean diet adherence and maternal stressors during pregnancy[1]

	Black/African American, β (95% CI), *P* value	Hispanic, β (95% CI), *P* value	White, β (95% CI), *P* value	All,[2] β (95% CI), *P* value
Depression score (CES-D)[3]	$n = 254$ −0.44 (−1.35, 0.01) 0.194	$n = 156$ −0.91 (−1.71, −0.17) 0.041	$n = 270$ −0.19 (−0.67, 0.33) 0.455	$n = 716$ −0.45 (−0.90, −0.18) 0.017
Gestational weight gain[3]	$n = 278$ 0.01 (−0.65, 0.66) 0.980	$n = 191$ 0.19 (−0.41, 0.78) 0.534	$n = 262$ −0.03 (−0.46, 0.41) 0.910	$n = 770$ 0.07 (−0.25, 0.39) 0.668
Maternal obesity[4]	$n = 288$ −0.46 (−1.10, 0.17) 0.150	$n = 193$ 0.09 (−0.38, 0.56) 0.697	$n = 277$ −0.27 (−0.63, 0.08) 0.130	$n = 797$ −0.29 (−0.57, −0.0002) 0.050

[1]Adjusted for education (high school/no high school), maternal smoking, and maternal age at delivery. CES-D, Center for Epidemiological Studies—Depression scale.
[2]"All" group includes race/ethnicity as a covariate.
[3]Prospective association.
[4]Cross-sectional association.

−0.44 difference in depression score ($\beta = -0.44$; 95% CI: −1.35, 0.01; $P = 0.19$) with a 1-unit increase in MDS compared with White women ($\beta = -0.19$; 95% CI: −0.67, 0.33; $P = 0.46$). Intriguingly, in the $n = 127$ in whom cytokines and diet were measured, higher MDA was associated with higher concentrations of prenatal IL-17A, although this association was most apparent in Black/African American mothers, with a difference of 0.21 per 1-unit increase in MDA ($\beta = 0.21$; 95% CI: 0.01, 0.41; $P = 0.03$) (Supplemental Table 3).

Association between MDA and offspring outcomes

We evaluated the extent to which periconceptional maternal MDA was associated with birth and childhood outcomes. We found no evidence for associations between MDSs and birth weight ($\beta = -10.97$; 95% CI: −33.4, 11.5; $P = 0.34$) or gestational age ($\beta = -0.42$; 95% CI: −1.19, 0.35; $P = 0.28$) (**Table 4**), although associations for both White and Black women were in the hypothesized direction. However, periconceptional MDA was associated with weight-for-height percentiles at ages 2–8 y when stratified by race/ethnicity (**Table 5**). We found a −2.9 percentile difference in child weight-for-height per 1-unit increase in periconceptional MDA in children ages 3–5 y among White mother–child dyads ($\beta = -2.9$; 95% CI: −5.31, −0.46; $P = 0.02$). This trend continued in children 6–8 y of age with a −3.99 difference in weight-for-height percentile per 1-unit increase in periconceptional MDA ($\beta = -3.99$; 95% CI: −6.98, −1.0; $P = 0.01$). Conversely, among Hispanic mother–child dyads we observed a 3.96 difference in weight-for-height percentiles in association with a 1-unit increase in periconceptional MDA in children ages 3–5 y ($\beta = 3.96$; 95% CI: 0.63, 7.29; $P = 0.02$). This association was no longer statistically significant in children ages 6–8 y; however, estimates were in a consistent direction ($\beta = 1.73$; 95% CI: −2.55, 6.02; $P = 0.43$).

Supplemental analysis using cubic splines

We found that the use of cubic splines did not improve model fit for any outcomes except for gestational age (**Supplemental Table 4**). The results of our supplemental analysis suggest that a change from low maternal MDA to "mid-level" adherence was associated with a −1.11-wk difference in gestational age; however, a change from "mid-level" adherence to high adherence was associated with a 1.09-wk difference in gestational age (**Supplemental Table 5**).

Discussion

Accumulating evidence suggests that the Mediterranean diet confers numerous physical and mental health benefits. Our study adds to this evidence by showing associations between maternal MDA during the periconceptional period and lower prepregnancy BMI, lower depression scores, increased proinflammatory cytokine IL-17 during pregnancy, and weight-for-height percentiles among children at ages

TABLE 4 Associations between maternal Mediterranean diet adherence and infant birth outcomes[1]

	Black/African American, β (95% CI), *P* value	Hispanic, β (95% CI), *P* value	White, β (95% CI), *P* value	All,[2] β (95% CI), *P* value
Birth weight[3]	$n = 292$ −13.07 (−54.90, 28.78) 0.539	$n = 196$ 31.14 (−13.06, 75.34) 0.166	$n = 278$ −34.70 (−69.97, 0.57) 0.054	$n = 806$ −10.97 (−33.40, 11.50) 0.338
Gestational age at birth[3]	$n = 296$ −1.19 (−2.79, 0.41) 0.144	$n = 198$ −0.37 (−1.82, 1.07) 0.612	$n = 284$ −0.02 (−1.04, 0.99) 0.965	$n = 818$ −0.42 (−1.19, 0.35) 0.281

[1]Adjusted for education (high school/no high school), maternal smoking, high gestational age (yes/no), and infant gender.
[2]"All" group adjusted for race/ethnicity as a covariate.
[3]Prospective association.

TABLE 5 Associations of maternal adherence to a Mediterranean-style diet pattern with child weight-for-height percentiles by age group and race/ethnicity[1]

	Overall			Black/African American			Hispanic			Non-Hispanic White		
Age	*β*	95% CI	*P*	*β*	95% CI	*P*	*β*	95% CI	*P*	*β*	95% CI	*P*
<3 y	−0.30	(−1.78, 1.19)	0.70	−0.65	(−3.09, 1.79)	0.60	1.26	(−1.95, 4.47)	0.44	−1.30	(−3.82, 1.22)	0.31
3–5 y	0.30	(−1.2, 1.8)	0.69	0.90	(−1.54, 3.33)	0.47	3.96	(0.63, 7.29)	0.02	−2.89	(−5.31, −0.46)	0.02
6–8 y	−0.35	(−2.31, 1.62)	0.73	2.07	(−1.58, 5.71)	0.27	1.73	(−2.55, 6.02)	0.43	−3.99	(−6.98, −1.00)	0.01

[1]Adjusted for children's age, breastfeeding, parity, maternal BMI, gestational age, and gender.

3–8 y. In general, these effects were ethnic-specific. These data support European clinical trials data suggesting that Mediterranean-style diet is perhaps a potent avenue for preventing adverse maternal and offspring prenatal and early postnatal outcomes, including prenatal depressive mood and childhood obesity, which disproportionately affect Blacks/African Americans. In our study, MDA differed starkly by race/ethnicity, with non-Hispanic White mothers reporting the highest MDA and non-Hispanic Black mothers reporting the lowest MDA. The stark differences in MDA by race/ethnicity showcase the need for interventions to support healthy eating among populations of color in the United States.

The findings that a higher adherence to a Mediterranean-style diet was associated with lower depression scores, especially among Hispanic women, are consistent with the literature. For example, a recent study in women during pregnancy similarly found an association between diet quality and depression that appeared stronger among Hispanic women (59). The reasons for this are not clear, although they may be related to the greater consumption of fruits and legumes underpinning higher MDA among Hispanic women in our study, because these food groups contain a number of antioxidant compounds, including flavonoids and phenolic compounds (60, 61). Previous studies in nonpregnant populations have also reported associations between greater MDA and improvements in depressive symptoms and mood (62–64). Among these, a systematic review found a consistent link between the polyphenols present in the Mediterranean diet and decreases in depressive symptoms (65). Clinical trial findings in addition suggest that individuals who adhered to a Mediterranean-style diet and increased omega-3 intake [(EPA (20:5n–3) and DHA (22:6n–3)] had lower stress and negative emotions at 3 and 6 mo (62). Because links exist between depression and inflammatory pathways (66, 67), there is a need to prioritize a diet that can reduce inflammation, such as the Mediterranean diet. Additional research is needed to better understand the timing of Mediterranean diet consumption and depression and determine whether consumption of a Mediterranean diet can also prevent the onset of depression, and other psychosocial stressors common during pregnancy, including anxiety and stress, because research evidence is lacking in this area.

Our findings indicating an association between periconceptional maternal MDA and lower prepregnancy BMI are also consistent with existing literature in nonpregnant populations (68–70). In addition to an association with lower BMI, associations have been observed between consumption of a Mediterranean dietary pattern and improved cardiometabolic outcomes (69) and weight loss (68). The Mediterranean diet includes an abundance of plant-based and fiber-rich foods, which contribute to lower inflammation and weight status than a traditional Western diet.

Previous studies have assessed the association between maternal MDA and child growth outcomes, with inconsistent results. A study using the Rhea and Project Viva cohorts found that improving maternal MDA resulted in a lower BMI *z* score in children ages 4–10 y (71). A study using the INMA (Infancia y Medio Ambiente) cohort found no association between maternal MDA and BMI *z* scores at age 4 y, but did find an association between MDA and lower waist circumference among children at age 4 y (72). Our finding that children born to women who identify as White had a lower weight status at 3–5 y of age when their mothers reported greater MDA is intriguing, because it may point to the minimum "dose" of dietary intake contributing to beneficial effects, for which the score was highest among Whites. However, a greater MDA among Hispanic mothers was associated with a greater weight status at ages 3–5 y. It is possible that this association is related to more indulgent feeding practices, which have been associated with obesity among Hispanic children (73, 74).

Many of the benefits of a Mediterranean-style diet pattern are related to its inflammation-lowering properties. The mechanism by which Mediterranean-style diets decrease inflammation and chronic disease is an active topic of investigation. However, it is now established that in pregnant women, oxidative stress induced by prenatal stressors contributes to systemic inflammation—an established risk factor for maternal and fetal adverse outcomes, including gestational diabetes, preeclampsia, preterm delivery, depressive symptoms, and recurrent abortion (75), and changes to the maternal gut microbial diversity (76). Oxidative stress is an established risk factor for antioxidant depletion, DNA damage, pathologic aging, and systemic inflammation (77–79). Mechanistically, it is plausible that components of Mediterranean-style diets reduce free radicals and oxidative stress, leading to decreased concentrations of circulating proinflammatory cytokines and chemokines (80, 81) as seen in preclinical and clinical anti-inflammatory diet studies (82, 83). Polyphenols present in olive oil and other plant-based foods have received particular attention, and have shown promise as one of the active components in reducing inflammation as a result of consuming a Mediterranean diet (84). The anti-inflammatory properties of polyphenols and flavonoids have been studied in a number of animal (85, 86) and experimental studies (87, 88), and have been shown to reduce inflammatory markers and expression of genes regulating inflammation.

One exemplar is the PREDIMED (Prevención con Dieta Mediterránea) randomized clinical trial, which compared a Mediterranean-style dietary pattern supplemented with extra-virgin olive oil or nuts and a control (lower-fat) diet in nonpregnant adults. This study showed a 30% reduction in major cardiovascular events in the intervention arms (89) with lower rates of breast cancer (90) and incident diabetes (91). Remarkably, these findings persisted even among those

exposed to an established proinflammatory environmental contaminant, such as methylmercury common in fish, a prominent component in Mediterranean-style diets (92). In the CARDIA study comprising >1000 nonpregnant adult Blacks and Whites, higher MDA was associated with lower F_2-isoprostane concentrations—an established biomarker of oxidative stress (80, 81). Moreover, a meta-analysis comprising 17 studies of dietary patterns and inflammatory markers during pregnancy found that some diets (i.e., high-glycemic diets, high animal protein, and low fiber) were associated with higher concentrations of circulating proinflammatory markers, including CRP, IL-6, IL-1β, and TNF-α, than were Mediterranean-style diets (75).

Limitations

Our study benefits from many strengths, including the collection of biological samples during a sensitive time period in development, the use of validated questionnaires for data collection, the inclusion of a racially/ethnically diverse sample, and prospective measures of child BMI in the first 6 y of life. However, our study also has limitations that should be noted and the results should be interpreted with caution given these limitations. Our sample size is small, some of our analyses are cross-sectional, and we did not account for multiple comparisons; therefore, future studies are needed to confirm the findings of the current study. The sample included for analysis was different with respect to education, smoking, maternal age, and maternal prepregnancy BMI. Although we adjusted for these covariates in our analysis, we cannot rule out the possibility of residual confounding. In addition, participants in this study were recruited from clinics, early in pregnancy. Not all women seek care during pregnancy, and many do not initiate care until later in their pregnancy; therefore, selection bias may have affected our results, because care-seeking behaviors may be associated with both dietary patterns and outcomes of interest. Because our sample represents a local population from 1 state, our results cannot be generalized to the overall US population. We did not include income as a confounding variable in our main analysis owing to missing data; however, our sensitivity analysis showed that results did not change in significance or direction when we included income in our models. Diet measures were obtained through self-report and the diet score used for this analysis does not capture intakes of many added sugars and fats in the diet. In addition, the use of FFQs without validation through supplemental 24-h recalls or biomarkers may have introduced bias in our results, because FFQs tend to underestimate energy intake (93). Our diet score was energy-adjusted; however, there still may be residual bias. Finally, it is important to note that, although adherence to a Mediterranean-style diet pattern was assessed using a validated score, a "true" Mediterranean diet pattern may not be represented in the intakes of women in the current study. Researchers have argued that adaptation of the Mediterranean diet in other countries may be missing key components that are thought to convey health benefits, such as olive oil and other antioxidant compounds, because food preferences and availability differ between countries (94).

Conclusion

A Mediterranean-style diet pattern during the periconceptional period appears to convey psychosocial and physiologic health benefits to mothers and their unborn children, although racial/ethnic disparities exist in dietary intake. The racial/ethnic disparities seen in diet pattern are rooted in inequities related to the social determinants of health, because Black and Hispanic individuals in the United States are disproportionately affected by low economic stability and limited upward mobility, and are more likely to live in areas where access to healthy food is a challenge. Given the many benefits of adherence to a Mediterranean-style dietary pattern, interventions addressing these issues, in addition to studies of mechanism and racial/ethnic differences in outcomes, are needed.

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Data Availability

Data described in the article, code book, and analytic code will be made available upon request pending adequate permissions.

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