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Maternal diet quality in pregnancy and neonatal adiposity: The Healthy Start Study

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Abstract

Background and Objective—Poor maternal diet in pregnancy can influence fetal growth and development. We tested the hypothesis that poor maternal diet quality during pregnancy would increase neonatal adiposity (percent fat mass, %FM) at birth by increasing the fat mass (FM) component of neonatal body composition.

Methods—Our analysis was conducted using a pre-birth observational cohort of 1,079 mother-offspring pairs. Pregnancy diet was assessed via repeated Automated Self-Administered 24-hour dietary recalls, from which Healthy Eating Index-2010 (HEI-2010) scores were calculated for each mother. HEI-2010 was dichotomized into scores ≤ 57 and scores > 57, with low scores representing poorer diet quality. Neonatal %FM was assessed within 72 hours after birth with air displacement plethysmography. Using univariate and multivariate linear models, we analyzed the relationship between maternal diet quality and neonatal %FM, FM, and fat-free mass (FFM) while adjusting for pre-pregnancy body mass index (BMI), physical activity, maternal age, smoking, energy intake, preeclampsia, hypertension, infant sex, and gestational age.

Results—Total HEI-2010 score ranged between 18.2 and 89.5 (mean: 54.2, SD: 13.6). An HEI-2010 score ≤ 57 was significantly associated with higher neonatal %FM ($\beta = 0.58$, 95% CI 0.07, 1.1, $p<0.05$) and FM ($\beta=20.74$; 95% CI 1.49, 40.0; $p<0.05$) but no difference in FFM.

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ALBS conducted the research, analyzed data, and wrote the full draft of the manuscript as well as made revisions on subsequent drafts. BMR and DHG analyzed data and consulted on interpretation of statistical findings. JLK, TLC, APS, AMSR, and JMN made substantial contributions for the revision of manuscript drafts. LAB and JEF reviewed all manuscript drafts and made substantial contributions to the clinical and mechanistic interpretation of the study findings. DD designed the Healthy Start study, reviewed each manuscript draft and has primary responsibility for the final content of this manuscript. The Healthy Start research team collected all data, including diet data. Authors have no conflicts of interest to report.

Conclusions—Poor diet quality during pregnancy increases neonatal adiposity independent of maternal pre-pregnancy BMI and total caloric intake. This further implicates maternal diet as a potentially important exposure for fetal adiposity.

Introduction

In the United States over 60% of women of reproductive age are overweight or obese (1). A significant focus of the research on developmental origins of health and disease has been on the impact of maternal overweight and obesity during pregnancy on infant outcomes. Large prospective cohort studies have consistently shown maternal overweight and obesity during pregnancy to be significant risk factors for higher birth weight and neonatal adiposity (2-4) and for childhood obesity and later life metabolic dysregulation (5, 6). However, while effective interventions have been developed to promote healthy weight loss in the general adult population (7-9), it is challenging to implement interventions that can quickly and successfully help women to lose weight before pregnancy, due in large part to a significant number of pregnancies being unplanned. Therefore, a shift in research focus from reducing maternal weight before and during pregnancy to other interventions that could also impact fetal overgrowth and offspring adiposity, such as improving maternal diet and nutrition, is warranted.

Diet quality as measured by levels of macro- and micronutrients consumed, as well as by dietary patterns (e.g. Western, Mediterranean) during pregnancy has demonstrated significant relationships with birth outcomes implicating maternal nutritional exposures during pregnancy as important factors in fetal growth and development (10-14). Specifically, high-fat content in the diet during pregnancy has been shown to increase offspring birth weight and adiposity in several animal studies (15, 16). Evidence from nutrient-specific and dietary pattern analyses in human pregnancies remains inconsistent. Some studies report increased offspring adiposity given a maternal diet with a low protein-to-carbohydrate ratio (17). Other studies report growth restriction given a maternal "Western" dietary pattern (12), or no relationship between maternal dietary patterns and offspring growth (18, 19). This lack of consistency may be due in part to the difficulty in replicating data-driven dietary patterns, such as factor and cluster analysis, across different populations (20) and the use of different infant size and growth outcomes.

Measures of diet quality that are based *a priori* on national or international recommendations are a potential alternative for measuring the impact of nutrition during pregnancy on neonatal body composition. These standardized diet quality indices are generalizable across different cohorts (21). One such index, the Healthy Eating index, measures the inadequacy, adequacy or excess of recommended intakes of food groups (e.g. whole grains) and nutrients (e.g. sodium), therefore quantifying the quality of the total diet. In the few studies that have used a diet quality index in developed countries, higher diet quality scores were positively associated with growth parameters such as birth weight and birth length (22, 23). However, no studies have used markers of offspring body composition such as adiposity.

The present analysis aimed to fill this information gap using the Healthy Start cohort, a pre-birth, multi-ethnic cohort of 1,410 mother-offspring pairs. Our goal was to test the hypothesis that neonates born to women with low diet quality during pregnancy have increased adiposity compared to those born to women with higher diet quality. We also tested whether diet quality modifies the effect of pre-pregnancy BMI on neonatal adiposity.

Participants and Methods

Study Population

Mother-infant pairs included in this analysis were enrolled in the Healthy Start study, an observational, longitudinal pre-birth cohort study of ethnically diverse mothers. The Healthy Start study recruited 1,410 pregnant women ages 16 and older prior to 24 weeks gestation from the obstetrics clinics at the University of Colorado Hospital during 2010-2014. Women were excluded if they had prior diabetes, a history of prior premature birth or fetal death, asthma with active steroid management, serious psychiatric illness, or a current multiple pregnancy. The Healthy Start study protocol was approved by the Colorado Multiple Institutional Review Board, and all women provided written informed consent prior to the first study visit. The Healthy Start study was registered as an observational study at clinicaltrials.gov as NCT02273297.

As of July 2014, 1,410 women were enrolled in the Healthy Start cohort. Healthy Start participants were eligible for the current analysis if they had at least one dietary recall (N=1,366). Women who had been diagnosed with gestational diabetes mellitus (n=53) were excluded because these women are encouraged to adopt special diets after diagnosis. Neonates born at less than 32 weeks gestation or those without body composition measures at birth were also excluded from the eligible cohort to give a final sample size of 1,079 for the analytic cohort used in this report.

Comparison of the analytic cohort to those who were excluded revealed no significant differences in maternal race/ethnicity (p=0.35), maternal age at delivery (p=0.67), pre-pregnancy BMI (p=0.25), and household income (p=0.31). As expected, the analytical cohort had significantly higher birth weight compared to the excluded participants (3,255 g vs. 3,007 g, p<0.001) given the exclusion of infants born very preterm (gestational age <32 weeks).

Data Collection

Healthy Start mothers were invited to participate in two research visits during pregnancy. The first visit occurred between 8 and 24 weeks of gestation (median = 17 weeks) and the second between 24 and 32 weeks of gestation (median = 27 weeks). Maternal fasting blood samples were collected at each of the two pregnancy visits and demographic, behavioral, physical activity (energy expenditure) and dietary questionnaires were administered. A third visit occurred in the hospital, after delivery during which women were asked to complete questionnaires identical to those from the second pregnancy visit. Offspring's birth length, weight, head circumference, and skin-fold thickness were measured within 72 hours after delivery neonatal body composition, fat mass (FM) and fat-free mass (FFM) were estimated from total mass and volume using air displacement plethysmography (PEA POD). Body composition was measured twice for each neonate with a third measurement taken if the first two percent body fat values were greater than two percentage points apart. Values used in this report are the average of the two closest measures.

Maternal pre-pregnant body mass index (BMI) was calculated using maternal height measured at the first research visit and pre-pregnant weight obtained from medical records (83.7%) or self-reported at the first research visit (16.2%). Pre-pregnant BMI was categorized as normal weight (BMI<25 kg/m^2), overweight (25≤BMI<30 kg/m^2), and obese (BMI≥30 kg/m^2). Physical activity in pregnancy was measured using the Pregnancy Physical Activity Questionnaire (24) from which metabolic equivalent task (MET) values were estimated as described in detail elsewhere (24, 25).

Infant sex, birth weight, and gestational age at birth were abstracted from medical records. Race/ethnicity, household income, smoking during pregnancy, and gravidity (0 vs. prior pregnancies) were obtained from questionnaires administered to participants. Race/ethnicity was categorized into non-Hispanic white, non-Hispanic black, Hispanic, and other. Household income was categorized into five levels: < $20,000, $20,000 - $40,000, $40,000 - $70,000, income > $70,000, and “don't know”. Maternal age at delivery was calculated from offspring delivery date and maternal date of birth.

Dietary Assessment

Maternal diet was assessed several times throughout pregnancy using the Automated Self-Administered 24-hour Dietary Recall (ASA24), an online platform developed and hosted by the National Cancer Institute (ASA24-Beta and ASA24-2011, Bethesda, MD: National Cancer Institute). Healthy Start participants were asked to complete up to six ASA24 dietary recalls beginning at their first pregnancy visit (approximately one per month). On average participants completed 2 recalls over the pregnancy period (range: 1 - 8) with 76% (n = 1,038) of the eligible cohort (n = 1,366) having at least 2 diet recalls. Monthly calls were made by the University of North Carolina (UNC) at Chapel Hill to remind participants to complete their dietary recalls at home. Trained, bilingual study staff members administered recalls in-person for Spanish-speaking participants (n = 60) at study visits and over the phone between visits. Data from the ASA24 were collected (except for the Spanish interviews) and processed by UNC.

The Healthy Eating Index

The Healthy Eating Index-2010 (HEI-2010) is a diet quality scoring system developed by the United States Department of Agriculture, Center for Nutrition Policy and Promotion and the National Cancer Institute designed to assess adherence to the 2010 Dietary Guidelines for Americans. This tool is a valid and reliable measure of diet quality (29) and consists of twelve components (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories) (30). The twelve components are scored per 1,000 kcal to give a maximum possible total HEI-2010 score of 100.

We calculated average food group servings across the multiple ASA24 recalls for each participant for use in calculating the HEI-2010 component and total scores. Average intakes of total energy, saturated fat, mono- and polyunsaturated fats, and sodium across the repeated recalls were also used for calculation of the HEI-2010 scores. Alcohol was not included in the total HEI-2010 score because participants were all under 13 g/1,000 kcal of alcohol consumption for each recall which is the threshold for inclusion of calories from alcohol. Publically available NCI SAS macro-code from the NCI website (http://appliedresearch.cancer.gov/hei/tools.html) was used to generate the HEI-2010 total and component scores from the average food groups and nutrients values for each participant.

Statistical Analysis

Different studies have used varying ways to categorize the HEI-2010 total score. However, many analyses use quintile categorization (31-33). We plotted the observed mean neonatal %FM against the quintiles of the HEI-2010 total score (Q1: HEI-2010 ≤ 42; Q2: 42 < HEI-2010 ≤ 50; Q3: 50 < HEI-2010 ≤ 57; Q4: 57 < HEI-2010 ≤ 66; Q5: HEI-2010 > 66) and observed a clear, threshold effect of HEI-2010 total score on %FM that appeared between the lower three (HEI-2010 ≤ 57) and upper two quintiles (HEI-2010 > 57) (Figure 1). Based on the quintile plot we dichotomized the HEI-2010 total score at 57 for descriptive comparisons and all analyses reported hereafter.

Maternal and neonatal descriptive statistics were generated, and differences between the two HEI-2010 total score categories were tested using Satterthwaite t-tests for continuous variables and Cochran Mantel-Haenszel tests for categorical variables. Average predicted estimates of usual intake of macro- and micronutrients and average HEI-2010 component scores were compared between the HEI-2010 categories using t-tests to demonstrate the differences in nutrient and food group intakes related to the two levels of diet quality.

We fit a general linear multivariable model, and a planned, backwards stepwise approach to examine the effects of HEI-2010 total score category (≤ 57 versus > 57), maternal pre-pregnancy BMI category, and their interaction on neonatal %FM. Covariates for inclusion in all models were chosen based on the literature and included maternal age, race/ethnicity, infant sex, gestational age at birth, household income, usual daily energy intake (kcal/day), smoking in pregnancy, and average energy expenditure (METS per week) over the pregnancy period. We also adjusted for pregnancy complications that could impact neonatal body composition such as chronic hypertension (yes/no), gestational hypertension (yes/no) and preeclampsia (yes/no) as diagnosed by a physician and reported in the medical record. As a sensitivity analysis we included gestational weight gain as a covariate to test whether the relationship between diet quality and infant adiposity was independent of this pregnancy exposure.

Given that no significant interaction between HEI-2010 category and maternal pre-pregnant BMI was noted, we then tested the main effect of the two HEI-2010 categories, and the main effect of BMI categories, while controlling for covariates. This same modeling approach was applied for the general multivariate linear model that tested the effect of HEI-2010 and BMI categories on FM and FFM. An alpha-spending approach was used to control the overall Type I error. We used the Hotelling-Lawley test to assess the significance of the association between BMI and HEI-2010 with both FM and FFM at $p<0.03$, and, if the overall test was significant, we planned to use $p<0.01$ for each step-down test of association between BMI and HEI-2010, and FM and FFM, respectively.

Results

The HEI-2010 total score in the Healthy Start cohort ranged between 18 and 89 with a mean of 54.2 (SD=13.6). Maternal and neonatal characteristics are presented by HEI-2010 category in Table 1. Women with an HEI-2010 total score ≤ 57 (lower diet quality) were significantly more likely to be obese, to have reported smoking during pregnancy, and to have a household income of less than $20,000 ($p<0.001$ for all, respectively). Lower diet quality was also significantly related to younger maternal age ($p<0.001$), shorter length of gestation ($p=0.02$), higher gravidity ($p=0.01$), and higher energy expenditure ($p<0.001$). Furthermore, neonates born to women with an HEI-2010 total score ≤ 57 had significantly lower birth weight (3,226 g vs. 3,297 g, $p=0.01$) and FFM (2,804 g vs. 2,872 g, $p<0.01$). There was no difference in %FM (9.2% vs. 8.8%, $p=0.11$), birth head circumference ($p=0.09$), or birth length ($p=0.47$) between the two HEI-2010 groups.

The pattern of macro- and micronutrient average daily intakes (Table 2) as well as HEI-2010 component scores (Table 3) were as expected between the HEI-2010 categories. While small differences were seen between groups, the percent of total energy as fat ($p<0.001$) and as saturated fat ($p<0.001$) were significantly higher in the group with an HEI total score ≤ 57. As expected, average HEI-2010 component scores for all of the components were significantly lower in the group with an HEI-2010 total score ≤57 ($p<0.001$ for all, respectively). However, empty calories were significantly lower in this group ($p<0.001$), which was not expected.

Table 4 shows the results of the regression analyses assessing the relationship between HEI-2010 total score categories and neonatal body composition, adjusting for covariates. Having an HEI-2010 score ≤57 was significantly associated with higher %FM ($p<0.05$), independent of maternal BMI. Among women with an HEI-2010 total score ≤57 during pregnancy, the %FM of their neonate was on average 0.58 percentage points higher compared to neonates born to women with an HEI-2010 total score >57 ($\beta=0.58$, 95% CI 0.07, 1.1). Furthermore, the HEI-2010 score ≤ 57 was associated with significantly higher FM (grams) ($\beta=20.74$; 95% CI 1.49, 40.0; $p<0.05$) but not with significantly different FFM ($\beta=7.30$; 95% CI -29.71, 44.31; $p=0.97$), indicating that the increased %FM associated with lower maternal diet quality reflects an increase in neonatal FM rather than a decrease in FFM. This compartmentalization of the effect of diet quality on infant body composition is further supported by the non-significant effect of HEI-2010 total score category on overall birth weight ($\beta=27.86$; 95% CI -21.16, 76.89; $p=0.35$). Maternal pre-pregnancy BMI was a significant predictor of higher %FM, FM, FFM, and birth weight independent of maternal diet quality ($p<0.001$, $p<0.001$, $p<0.05$, and $p<0.001$, respectively). Other independent predictors of increased FM and/or %FM were older maternal age and lower household income, while gestational smoking was independently associated with lower %FM and FM. Interestingly, girls had higher FM (and %FM) but lower FFM, compared with boys while infants of non-Hispanic Black women (NHB) had both lower FM and FFM, compared with infants born to non-Hispanic white women (NHW). Additionally, our sensitivity analysis showed no significant change in the results when including gestational weight gain in the model.

Discussion

In this prospective, multi-ethnic, pre-birth cohort we have shown that diet quality has a significant impact on neonatal adiposity, and that this effect is independent of the mother's pre-pregnancy BMI. Furthermore, the association between poorer maternal diet quality and higher neonatal adiposity is primarily due to an effect of lower diet quality on the fat compartment of neonatal body composition.

While maternal nutrition during pregnancy has been previously studied in relation to birth outcomes, to the best of our knowledge this is the first study to investigate the effect of maternal diet quality during pregnancy on neonatal body composition. Furthermore, few studies of maternal diet during pregnancy have used the Healthy Eating Index. Additionally, these studies have not targeted neonatal adiposity as the outcome, specifically; rather they have used birth weight. For example, Rodriguez-Bernal and colleagues found that increasing quintiles of the Alternative Healthy Eating Index for Pregnancy (AHEI-P) score (34) was associated with higher birth weight in a cohort of Spanish women (23). However, in a similar study of pregnant Spanish women Gesteiro and colleagues did not see a significant difference in birth weight of infants born to mothers with an HEI-1995 total score ≤ 70 compared to those with an HEI-1995 total score > 70 (35). Geteiro and colleagues implemented the 1995 version of the Healthy Eating Index, therefore the inconsistency between findings may be due to differences between these versions. Poon and colleagues also did not see a significant association between maternal diet quality and infant birth weight or other markers of growth (19) using the AHEI-P.

The discrepancies may also be due to the timing of dietary assessment or a combination of differences in the methods of dietary assessment (use of a single Food Frequency Questionnaire versus repeated ASA-24 dietary recalls) and model adjustment for potential confounders. In the Spanish cohort used by Rodriguez-Bernal (2010) and Gesteiro (2012) diet was assessed only once and in the first trimester and Poon also measured diet once but in the third trimester, whereas the Healthy Start study assessed diet repeatedly (82% of sample used in this analysis had 2 or more diet recalls in pregnancy) to estimate the HEI-2010 total score over the observed pregnancy period. The degree to which we adjusted for additional potential confounders above that of these other studies may also explain differences in the findings. Given the lack of studies that parallel our dietary assessment methods and analysis, our findings warrant further investigation and replication in other large, diverse birth cohorts.

The HEI-2010 categorization used in this analysis to denote a “poorer quality diet” reflects what we would expect in terms of macronutrients for such a diet given the Institute of Medicine's report on Acceptable Macronutrient Distribution Ranges (36). Women with an HEI-2010 score ≤57 had higher total and saturated fat intake (Table 2). While total fat and saturated fat have been shown to effect offspring size and adiposity in animal studies (15, 16), their effect in studies of human development have not been demonstrated (17), suggesting a potentially different mechanism in humans. Together, our findings, that poorer diet quality is positively associated with infant adiposity and that higher intakes of total fat and saturated fat are characteristics of this poorer diet quality, suggest that the deleterious effect of these specific nutrients on human neonatal size and body composition may be the result of multiple nutrients interacting. This highlights the importance of using a measure of diet quality that reflects the whole diet, likely accounting for the synergistic effects of foods and nutrients on neonatal body composition that may not be explained by a single nutrition factor.

Maternal BMI is also an established risk factor for accelerated fetal growth and increased birth weight and size (2, 3, 37, 38). Further, our group recently reported that the %FM at birth of neonates born to women with a pre-pregnancy BMI in the overweight or obese categories was significantly higher than the %FM of neonates born to women in the normal BMI category, a finding that sustained when further adjusted by total energy and diet quality in this analysis, further supporting the link between maternal BMI and infant adiposity (4). The consistent and robust data supporting the independent effects of maternal diet during pregnancy (broadly measured) and maternal BMI on fetal growth and size provide clues to potential pathways and mechanisms that need to be further explored.

We purposefully did not include gestational weight gain as a covariate in our model, hypothesizing that it may be part of the causal pathway liking maternal diet quality to neonatal adiposity. Interestingly, sensitivity analyses adjusting for maternal weight gain during pregnancy resulted in similar findings, suggesting that the effect of maternal diet quality on neonatal adiposity is independent of gestational weight gain.

In our large pre-birth cohort we have demonstrated that lower maternal diet quality has a statistically significant impact on neonatal adiposity and that this effect is independent of pre-pregnancy BMI. While the clinical relevance of this finding is unclear at this time, it is important to note that neonates of women with lower diet quality had, on average, 24.9 g more fat mass, compared with those whose mothers had higher diet quality. This is just half that of the effect of maternal obesity (47.5 g higher in neonates of obese vs. normal weight mothers), and given the clinical emphasis on obesity in pregnancy, this suggests that maternal diet quality may be similarly important, clinically. Longitudinal follow up of this cohort, now ongoing, will provide much needed data on the clinical significance of increased adiposity at birth with respect to childhood obesity and other relevant outcomes.

Our analysis is not without limitations. Our use of the HEI-2010 precludes us from comparing our results to studies using other Healthy Eating Index versions (e.g. HEI-1995) due to the different national dietary standards used in the calculation of those Healthy Eating Index scores. However, the HEI-2010 was designed to reflect the Dietary Guidelines for Americans and therefore we are confident that our results are generalizable to the overall population in the United States and to the pregnant population in this country. Future studies of diet in pregnancy and neonatal outcomes should employ the Healthy Eating Index so to allow comparison across pregnant populations and for replication of the findings from this analysis.

In conclusion, our study suggests that poor overall diet quality, as assessed by the Healthy Eating Index-2010, during pregnancy may lead to increased neonatal adiposity regardless of maternal BMI. This highlights the potential importance of dietary interventions during pregnancy, which is likely a more accessible time for clinicians and public health practitioners to communicate the importance of healthy eating to pregnant women.

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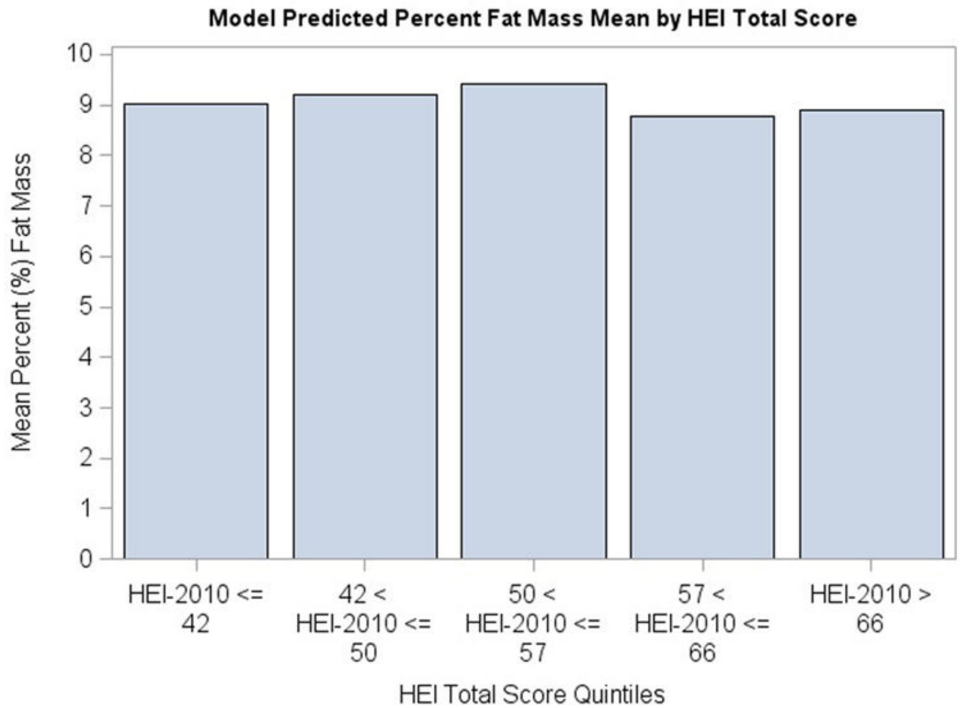

Figure 1.

Observed mean % FM by quintiles of HEI-2010 total score. HEI-2010 total score was dichotomized given the observed drop in %FM at a total score of 57.

Table 1

Characteristics of study participants by category of maternal HEI-2010 total score (*n* = 1,079)

	HEI-2010 Total Score		
	HEI-2010 ≤ 57 (n=647)	**HEI-2010 > 57 (n=432)**	***p*[1]**
Maternal			
Age at delivery in years, mean (SD)	26.3 (5.9)	30.0 (5.8)	<0.001
Race/ethnicity, n (%):			<0.001
NHW[2]	298 (46.1)	290 (67.1)	
Hispanic	174 (26.9)	90 (20.8)	
NHB[2]	133 (20.6)	30 (6.9)	
Other	42 (6.5)	22 (5.1)	
Gravidity, mean (SD)	1.4 (1.7)	1.2 (1.4)	0.01
Pre-pregnancy BMI, n (%):			<0.001
Normal	333 (51.5)	272 (63.0)	
Overweight	174 (26.9)	96 (22.2)	
Obese	140 (21.6)	64 (14.8)	
IOM recommended GWG, n (%):			0.09
Inadequate	146 (22.6)	100 (23.1)	
Adequate	162 (25.0)	143 (33.1)	
Excessive	339 (52.4)	189 (43.7)	
GA at birth (weeks), mean (SD)	39.4 (1.3)	39.6 (1.3)	0.02
Cesarean section, n (%)	138 (21.5)	81 (19.0)	0.26
Smoking in pregnancy, n (%)	90 (13.9)	6 (1.4)	<0.001
Household income, n (%):			<0.001
< $20,000	128 (19.8)	29 (6.7)	
$20,000 - $40,000	101 (15.6)	50 (11.6)	
$40,000 - $70,000	117 (18.1)	87 (20.1)	
> $70,000	150 (23.2)	212 (49.1)	
Don't know	151 (23.3)	54 (12.5)	
Energy expenditure (mets/week), mean (SD)	194.0 (92.1)	176.3 (68.8)	<0.001
Offspring			
Female, n (%)	333 (51.5)	196 (45.4)	0.05
Birth weight (g), mean (SD)	3226 (457)	3297 (450)	0.01

	HEI-2010 Total Score		
	HEI-2010 ≤ 57 (n=647)	**HEI-2010 > 57 (n=432)**	***p*[1]**
Head circumference (cm), mean (SD)	34.0 (2.1)	34.4 (2.1)	<0.01
Length (in), mean (SD)	19.4 (1.1)	19.4 (1.0)	0.53
% FM, mean (SD)	9.2 (4.0)	8.8 (3.9)	0.11
FM (g), mean (SD)	295 (156)	289 (149)	0.48
FFM (g), mean (SD)	2804 (354)	2872 (351)	<0.01

[1] p-value generated using a Satterthwaite t-test for continuous variables and Cochran Mantel-Haenszel test for categorical variables.

[2] NHW: non-Hispanic white; NHB: non-Hispanic black

Table 2
Diet characteristics by category of maternal HEI-2010 total score

	HEI-2010 Total Score		
Diet Characteristic, mean (SD)	**HEI-2010 ≤ 57 (n=647)**	**HEI-2010 > 57 (n=432)**	***p*[1]**
Total energy (kcal)	2128 (827)	1970 (551)	<0.001
% fat from total energy	35 (6)	34 (6)	<0.001
% saturated fat from total energy	13 (3)	11 (3)	<0.001
% carbohydrates from total energy	50 (8)	51 (7)	<0.01
% protein from total energy	16 (3)	17 (3)	<0.001
Monounsaturated fat (g)	31 (15)	27 (10)	<0.001
Polyunsaturated fat (g)	16 (9)	16 (7)	0.17
Cholesterol (mg)	309 (179)	270 (148)	<0.001
Protein:Carbohydrate ratio	0.33 (0.12)	0.34 (0.13)	0.07
Added sugar (tsp)	17 (11)	12 (7)	<0.001
Sodium (mg)	3717 (1550)	3253 (1008)	<0.001
Fiber (g)	15 (7)	22 (8)	<0.001
Calcium (mg)	1065 (537)	1149 (460)	<0.01
Folate (ug)	449 (230)	494 (196)	<0.001
Iron (mg)	17 (8)	17 (6)	0.57
Niacin (mg)	23 (10)	23 (7)	0.47

[1] p-value generated using Sattherwaite t-test.

Table 3

Mean component scores of the HEI-2010 by category of maternal HEI-2010 total score

	HEI Total Score	
HEI-2010 Components, mean (SD)[1]	**HEI-2010 ≤ 57 (n=647)**	**HEI-2010 > 57 (n=432)**
Total vegetables[3]	2.8 (1.3)	3.8 (1.1)
Greens and beans[3]	1.4 (1.8)	3.3 (1.9)
Total fruit[3]	2.9 (1.8)	4.4 (1.1)
Whole fruit[3]	2.2 (2.2)	4.1 (1.7)
Whole grains[2]	2.2 (2.2)	5.1 (3.0)
Dairy[2]	6.7 (2.9)	7.5 (2.5)
Total protein foods[3]	4.1 (1.2)	4.6 (0.8)
Seafood and plant protein[3]	1.9 (1.9)	3.9 (1.7)
Fatty acid ratio (unsaturated:saturated)[2]	3.0 (2.7)	4.6 (3.0)
Sodium[2]	3.3 (2.8)	4.1 (2.8)
Refined grains[2]	4.9 (3.1)	7.5 (2.5)
Empty calories[4]	9.5 (4.5)	14.8 (3.4)

[1] P-value <0.001 for all; p-value generated using Sattherwaite t-test.

[2] Component score maximum is 10.

[3] Component score maximum is 5.

[4] Calories from added sugars and solid fats. Component score maximum is 20.

Table 4

Multivariate regression model assessing the relationship between HEI-2010 total score and neonatal body composition and birth weight

	Neonatal Body Composition			
	FFM (g) β (95% CI)	**FM (g) β (95% CI)**	**% FM β (95% CI)**	**Birth Weight β (95% CI)**
HEI-2010 Total Score:				
≤ 57	7.30 (-29.71, 44.31)	20.74 (1.49, 40.0)[3]	0.58 (0.07, 1.1)[3]	27.86 (-21.16, 76.89)
>57	ref.	ref.	ref.	ref.
Pre-pregnancy BMI:				
Normal	ref.	ref.	ref.	ref.
Overweight	26.20 (-15.13, 67.53)	13.98 (-7.52, 36.48)	0.32 (-0.24, 0.90)	50.33 (-4.41, 105.07)
Obese	51.20 (3.75, 98.66)[3]	52.83 (28.14, 77.51)[1]	1.34 (0.69, 1.99)[1]	108.33 (45.48, 171.18)[1]
GA at birth (weeks)	134.33 (121.26, 147.40)[1]	25.93 (19.13, 32.73)[1]	0.40 (0.22, 0.58)[1]	167.11 (149.80, 184.43)[1]
Maternal age (years)	2.94 (-0.65, 6.54)	3.73 (1.86, 5.60)[1]	0.10 (0.05, 0.14)[1]	7.15 (2.38, 11.91)[2]
Smoking in pregnancy:				
Yes	-141.94 (-204.85, -79.03)[1]	-48.07 (-80.79, -15.34)[2]	-0.91 (-1.77, -0.05)[3]	-197.35 (-280.67,-114.03)[1]
No	ref.	ref.	ref.	ref.
Household income:				
< $20,000	81.82 (14.84, 148.8)[2]	52.61 (17.76, 87.45)[2]	1.21 (0.29, 2.12)[2]	129.27 (40.56, 217.99)[2]
$20,000 - $40,000	24.93 (-33.98, 83.85)	36.97 (6.32, 67.62)[3]	1.04 (0.23, 1.85)[3]	58.66 (-19.37, 136.67)
$40,000 - $70,000	9.60 (-40.82, 60.03)	19.61 (-6.62, 45.85)	0.54 (-0.15, 1.23)	24.53 (-42.25, 91.32)
> $70,000	ref.	ref.	ref.	ref.
Unknown	-18.80 (-82.93, 45.33)	19.03 (-14.33, 52.39)	0.55 (-0.32, 1.43)	-9.77 (-94.71, 75.16)
Race/ethnicity:				
NHW	ref.	ref.	ref.	ref.
Hispanic	7.87 (-40.30, 56.04)	-7.89 (-32.95, 17.16)	-0.27 (-0.93, 0.38)	-8.71 (-72.51, 55.09)
NHB	-149.88 (-205.60, -94.16)[1]	-31.91 (-60.89, -2.93)[3]	-0.46 (-1.22, 0.30)	-215.83 (-289.62, -142.03)[1]
Other	-38.88 (-112.56, 34.80)	-25.02 (-63.35, 13.30)	-0.71 (-1.72, 0.30)	-86.21 (-183.79, 11.37)
Infant sex:				
Male	ref.	ref.	ref.	ref.
Female	-184.09 (-217.84, -150.35)[1]	34.15 (16.59, 51.70)[1]	1.5 (1.04, 1.96)[1]	-149.4 (-194.1, 104.7)[1]
Average energy expenditure (mets/week)	0.0005 (-0.20, 0.20)	0.02 (-0.08, 0.12)	0.0003 (-0.002, 0.003)	0.0004 (-0.27, 0.27)
Preeclampsia:				
Yes	92.36 (-9.01, 193.73.0)	59.69 (6.95. 112.42)[3]	1.77 (0.39,3.16)[3]	128.20 (-6.05, 262.46)

	Neonatal Body Composition			
	FFM (g) β (95% CI)	FM (g) β (95% CI)	% FM β (95% CI)	Birth Weight β (95% CI)
No	ref.	ref.	ref.	ref.
Chronic hypertension:				
Yes	51.02 (-57.23, 159.27)	6.14 (-50.17, 62.45)	-0.14 (-1.62, 1.34)	82.89 (-60.47, 226.27)
No	ref.	ref.	ref.	ref.
Gestational hypertension:				
Yes	-36.69 (-106.84, 33.45)	12.32 (-24.16, 48.81)	0.27 (-0.68, 1.23)	-40.59 (-133.50, 52.31)
No	ref.	ref.	ref.	ref.

[1] $p<0.001$

[2] $p<0.01$

[3] $p<0.05$