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Associations between perinatal factors and adiponectin and leptin in 9-year-old Mexican-American children

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Abstract

Objectives—To 1) determine whether perinatal factors (including maternal anthropometry and nutrition and early life growth measures) are associated with adiponectin and leptin levels in 9-year-old children, and 2) assess relationships between adiponectin, leptin and concurrent lipid profile in these children.

Methods—We measured plasma adiponectin and leptin for 146 mother - 9-year-old child pairs from the ongoing longitudinal birth cohort followed by the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS). Data on perinatal factors, including sociodemographics, maternal anthropometry and nutrition, and early life child growth were collected during pregnancy, birth and 6-month visits.

Results—Greater rate of weight and length gain during the first 6 months of life were associated with lower adiponectin in 9-year-olds (β=−2.0, P=0.04; β=−8.2, P=0.02, respectively) adjusting for child BMI. We found no associations between child adipokine levels and either maternal calorie, protein, total fat, saturated fat, fiber, sugar-sweetened beverage consumption during pregnancy or children's concurrent sugar-sweetened beverage and fast food intake. Lipid profile in 9-year-old children closely reflected adiponectin but not leptin levels after adjustment for child BMI. Additionally, we report that child adipokine levels were closely related to their mothers' levels at the 9-year-visit.

Conclusion—Overall, our results support the hypothesis that early life factors may contribute to altered adipokine levels in children.

Keywords

obesity; adipokines; lipid profile; diet; fetal programming; growth rate

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Introduction

Data from the National Health and Nutrition Examination Survey (NHANES) show a 2.5-fold increase in the prevalence of childhood obesity from 1976-1980 to 2007-2008 for youth of all ethnicities[1]. Further, the obesity epidemic disproportionately affects minority populations. In NHANES 2009-2010, Mexican-American children aged 2-19 had significantly higher obesity prevalence compared to their white counterparts (21.2% vs. 14.0%). This disparity was apparent among the youngest age group, with Mexican-American infants and toddlers having the greatest prevalence of high weight-for-recumbent-length of any US ethnicity (15.7%)[2]. While the obesity epidemic is on the rise, critical questions about its etiology, potential early life programming, and maternal contribution remain difficult to address.

Studies show that obesity development is accompanied by changes in important metabolism-related hormones, adiponectin and leptin – also known as adipokines[3, 4]. Adiponectin, a protein hormone secreted almost exclusively by adipose tissue, acts to increase the uptake and catabolism of fatty acids and carbohydrates, promoting insulin sensitivity. In children, hypoadiponectinemia has been associated with the metabolic syndrome and type 2 diabetes[5, 6]. Leptin, a hormone synthesized primarily by adipose tissue but also by the placenta, stomach, bone marrow, skeletal muscle and liver,[7, 8] acts on the hypothalamus to convey satiety, thereby regulating the body's energy intake and expenditure[3]. Both obese children and adults have been documented to have 'leptin resistance' – a state of hyperleptinemia without leptin's beneficial regulatory control[9, 10]. Whether adiponectin or leptin disturbance precedes obesity development or is merely a reflection of adipose tissue amount remains unknown. However, there is increasing evidence that adiponectin and leptin may be prenatally determined by the *in utero* environment[11-15]. Examining whether candidate factors during pregnancy are associated with later life adipokine levels may provide deeper insight into molecular mechanisms of obesity.

Existing studies have focused on relationships between maternal parameters during pregnancy and adipokine levels at birth. Mothers with gestational and type 1 diabetes, respectively, tended to have infants with lower adiponectin and higher leptin levels in umbilical cord blood[11, 12, 14-16]. Additionally, one study examined effects of maternal nutrition with respect to cord adipokines, showing that maternal protein intake was inversely related with both leptin ($\beta=-0.22$, $P=0.03$) and adiponectin ($\beta=-0.25$, $P=0.03$) at birth[13]. Further, comparing adipokine levels between maternal serum collected during pregnancy and cord blood, Weyermann et al (2006) reported a small but highly significant correlation for leptin ($r=0.16$, $P<0.0001$) and a weaker association for adiponectin ($r=0.07$, $P=0.07$)[17]. There remains a data gap on relationships between maternal and/or early life factors and adiponectin or leptin levels in children as they age[18]. Finally, while certain perinatal characteristics, including maternal gestational weight gain and infancy growth rate, have been consistently associated with greater later life body mass index (BMI), few data are available on their relationship with child adipokines at older ages[19, 20].

To further characterize the maternal and early life contribution to the child metabolic health, we examined whether: 1) maternal anthropometric measures or 2) child growth measures during infancy are associated with children's adiponectin and leptin levels at 9 years of age. We also aimed to confirm relationships between lipid profiles and adiponectin and leptin levels in 9-year-old children. We examine these associations in the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS), a Mexican-American cohort with a high prevalence of child overweight and obesity.

Materials and Methods

Subjects and study design

The CHAMACOS study is a longitudinal birth cohort designed to assess the health effects of pesticides and other exposures on child growth and development[21, 22]. Mothers were enrolled during pregnancy, with 537 mother-infant pairs in the study at delivery and 327 remaining at the 9-year visit. We selected a random sub-sample of 146 mother-child pairs for analysis of adiponectin and leptin. Mothers in the study were primarily young (mean age of 26.3±5.1 years), married, low-income, Mexican-born, Spanish-speaking women from farmworker households. No differences were seen comparing maternal and child socioeconomic (SES) and lifestyle factors, anthropometric measures or lipid profile between the sub-sample in these analyses and the overall CHAMACOS cohort.

Women were interviewed at ~13 weeks gestation, ~26 weeks gestation, shortly after delivery, and when their children were 6 months, and 1, 2, 3½, 5, 7 and 9 years of age. Developmental assessments of children, including anthropometrics, were conducted at birth and at the time of each maternal interview. All interviews and assessments were conducted inSpanish or English by bilingual, bicultural interviewers. Details are provided below.

Questionnaire data

Sociodemographic information, including maternal age at pregnancy (18 through 29 years and ≥ 30 years), years of living in US prior to pregnancy (<1 year, 1-10 years, >10 years) and education (≤6th grade, 7-12 grade, and ≥high school) was gathered at the initial prenatal visit (~13 weeks gestation). Additionally, women were asked to report their pre-pregnancy weight at the 13-week visit. At the second pregnancy visit (~26 weeks gestation), we used a previously validated food frequency questionnaire (FFQ) to estimate maternal calorie, protein, total fat, saturated fat, fiber and sugar-sweetened beverage consumption during pregnancy[23, 24]. The FFQ is based on the Spanish-language Block 98 Questionnaire which was specifically modified for this Mexican-American population, including focus groups to gather information on local foods and food use[25]. Participant mothers were asked about how often they ate a particular food item in the previous 3 months and what the usual portion was using a 72-item questionnaire. This information was then converted into average daily energy and nutrient intake using values from the USDA Nutrient Database for Standard Reference[26]. The FFQ used here is described in detail in Harley et al (2005)[24].

Maternal sugar-sweetened beverage consumption was calculated based on answers in the FFQ and includes number of drinks per week of 100% orange, grapefruit, apple, grape, or other real 100% fruit juice; fruit drinks (Tampico, Sunny D, lemonade, Kool-Aid); or soda. This variable was categorized into tertiles of 0-8, 9-16 and 17+ drinks per week. Additionally, we assessed child fast food and sugar-sweetened beverage intake when the children were 9 years of age. Household food security (food secure, low food security, and very low food security) was assessed at the 9-year visit using the USDA Spanish short form food security measure[27, 28].

Data on pregnancy weight gain, child birth weight, length, and gestational age were obtained from delivery medical records abstracted by a registered nurse. Children were categorized as small-for-gestational age if their birth weight was <10th percentile for gestational age, adjusting for ethnicity, parity and infant sex from national data[29]. Children were considered to be ‘at term’ if they were born at or after 37 weeks of gestation.

Information about smoking during pregnancy was obtained at each pregnancy interview. Since 140 of the 146 mothers reported no use of tobacco at the prenatal visits, associations of maternal smoking during pregnancy on with adipokines were not examined.

Anthropometric measurements

An electronic scale (Tanita Mother-Baby Scale Model 1582, Tanita Corp.) was used to measure recumbent infant weight at the 6-month visit and child and mother weight at the 9-year visit. Infant length and child height were measured in triplicate using a measuring mat and stadiometer, respectively, and the average of measurements was used. BMI was calculated as mass in kilograms divided by height in meters squared. Children were categorized as normal weight, overweight or obese using the sex and age-specific BMI cut-offs (85^{th} and 95^{th} percentile, respectively) provided by the 2000 Centers for Disease Control and Prevention (CDC) child growth data.

Monthly rate of weight gain during the first 6 months of life was calculated as weight at the 6-month visit minus birth weight divided by exact age in months at the 6-month visit and reported in 100 grams/month. This approach to examining infancy weight gain has been previously used and validated by Stettler et al (2002)[30]. Monthly rate of length gain during the first 6 months was calculated similarly as length at the 6-month visit minus birth length divided by exact age at the 6-month visit and expressed in centimeters/month. Child 9-year systolic and diastolic blood pressure (SBP and DBP, respectively) were measured at rest in triplicate using a Dinamap 9300 sphygmomanometer.

Plasma adiponectin and leptin measurements

Plasma adiponectin and leptin were measured in banked, non-fasting blood samples collected from 146 mother-child pairs at the time of the 9-year visit using enzyme-linked immunoassay (ELISA) RayBio Human Adiponectin and Human Leptin kits. The manufacturer recommended protocol was used with two exceptions: 1) the standard curve for adiponectin was narrowed to smaller values for better resolution while 2) the standard curve was widened for leptin. These changes were necessary to tailor the ELISAs towards the adipokine levels observed in this population. The minimum detectable concentrations for adiponectin and leptin ELISAs were 10 pg/ml and 6 pg/ml respectively. All samples were run in duplicate and the values were averaged. The intra- and inter-plate coefficients of variance (CV) were 4% and 12%, respectively, for adiponectin and 3% and 15%, respectively, for leptin.

Fasting blood lipid profile measurements

A subgroup of 56 of the 146 children also volunteered to provide an additional fasting blood sample for measurement of blood glucose, cholesterol, triglycerides, very low-density lipoprotein (VLDL), low-density lipoprotein (LDL) and high-density lipoprotein (HDL) at 9 years of age. These samples were collected from a convenience sample of volunteers who agreed to return for a second visit during health fairs held between August 2010 and February 2011. Fasting blood was drawn early in the morning and 1ml aliquots of serum were sent to Quest Diagnostics (Salinas, CA) for glucose and lipid profile measurement.

Statistical analyses

Adiponectin levels were normally distributed, but leptin levels were right-skewed. Thus, analyses using leptin levels as the dependent variable report geometric means or use base-ten log-transformed values. We used analysis of variance (ANOVA) to examine differences in child adipokine levels by child's sex, weight status and maternal descriptive characteristics (Table 1). We then used multivariate linear regression to characterize associations between perinatal factors and child adipokine levels (Table 2) and between child adipokines and lipid profiles (Table 3), controlling for 9-year child BMI. P-values < 0.05 were considered statistically significant. All statistical analyses were conducted using STATA 12 (College Station, TX) for Windows.

Results

Maternal and child characteristics

Of the 146 9-year-old children in this study, there were a similar number of girls (N=74) and boys (N=72) (Table 1). Children were primarily delivered at term (≥37 weeks, N=138) and appropriate for gestational age (N=119). Few children were small for gestational age (<10th percentile, N=9) There was a very high prevalence of obesity (41%) in children and overall 54% were overweight or obese (Table 1). Additionally, we observed a bimodal distribution for child BMI categories, with most children either normal weight (46%) or obese (41%). The average age of the mothers was 26.3 years. Nearly half (47%) had ≤6th grade education and, at the time of their pregnancy, 77% had resided in the US 10 years or less. Low or very low food security was documented in 37% of families.

Child adipokines by study cohort characteristics

Overall, mean child adiponectin concentrations were 44.2 μg/ml (95% CI 41.1, 47.2) ranging between 8.2 and 92.5 μg/ml. Mean child leptin concentrations were 7.6 ng/ml (95% CI 6.3, 9.2), ranging between 0.3 and 93.3 ng/ml. Boys tended to have slightly lower adiponectin (42.9 vs. 45.4 μg/ml, p=0.43) and leptin levels (6.4 vs. 9.1 ng/ml, p=0.07) compared to girls. Neither adipokine was different across gestational age categories. There was a suggestion that appropriate for gestational age children had the highest levels of adiponectin (P=0.08). As expected, we observed significantly lower adiponectin (P<0.001) and higher leptin (P<0.001) over increasing BMI categories in 9-year-old children. Children's adiponectin and leptin levels were not related to maternal age, years in US, education, sugar-sweetened beverage consumption during pregnancy or household food security measured at the 9-year visit. Additionally, other maternal dietary variables during pregnancy, including calorie, protein, total fat, saturated fat, and fiber consumption or 9-year child fast food or sugar-sweetened beverage intake were also not associated with child adiponectin or leptin (data not shown).

Associations of pregnancy and early life parameters with 9-year-old child adipokines

Relationships between maternal and early life anthropometric parameters and child adipokines at 9 years are summarized in Table 2. While birth weight and length were not associated with adipokine levels, increased weight and length gain in the first 6 months of life were negatively related to adiponectin (β=−2.8, P=0.007; β=−9.7, P=0.007, respectively) but not leptin levels in 9-year-olds. After adjustment for 9-year child BMI, these associations with adiponectin were slightly attenuated but remained significant (β=−2.0, P=0.04; β=−8.2, P=0.02).

Higher maternal pre-pregnancy BMI was associated with both lower adiponectin (β=−0.8, P=0.006) and higher leptin (β=0.03, P<0.001) in 9-year-old children. However, adjusting these relationships for child BMI eliminated these associations (β=−0.3, P=0.28; β=0.001, P=0.84, for adiponectin and leptin, respectively). We found no associations between maternal weight gain during pregnancy and either adiponectin or leptin in the 9-year-olds.

Additionally, mother's adiponectin and leptin levels (measured at the 9-year visit) were strongly related to concurrent measures of their child's adiponectin (β=0.4, P<0.001) and leptin (β=0.42, P<0.001) levels, respectively, and these associations remained significant after adjustment for 9-year child BMI (β=0.3, P=0.001, β=0.23, P=0.002, respectively) (Table 2).

Relationships between adiponectin, leptin and lipid profile in children

Table 3 shows the mean, standard deviation and range for lipid profile and blood pressure measurements for the 9-year-olds. The mean levels were within recommended guidelines for children: glucose (89±6 mg/dL), cholesterol (151±30 mg/dL), triglycerides (83±42 mg/dL), VLDL (17±8 mg/dL), LDL (82±26 mg/dL), HDL (52±12 mg/dL), SBP (97.4±11.1 mmHg) and DBP (53.4±5.9 mmHG).

As expected, 9-year child BMI was positively associated with triglycerides (β=4.8, P<0.001), VLDL (β=1.0, P<0.001), SBP (β=1.6, P<0.001), DBP (β=0.5, P<0.001), and negatively related to HDL (β=−1.5, P<0.001) (not shown). We did not find any differences in lipid profile between sexes, except that boys had slightly higher fasting blood glucose compared to girls (90.9 vs. 87.6 mg/dL, P=0.05).

Increased adiponectin levels were associated with lower triglycerides, VLDL, systolic and diastolic blood pressure and higher HDL in crude analyses. After adjusting for 9-year child BMI, associations of adiponectin with triglycerides (β=−0.5, P=0.03), VLDL (β=−0.1, P=0.03) and HDL (β=0.1, P=0.02) persisted (Table 3). Increased leptin was associated with higher triglycerides, VLDL cholesterol, systolic and diastolic blood pressure and lower HDL cholesterol in crude analyses. After controlling for child BMI, the associations with SBP (β=7.6, P<0.001) and DBP (β=3.6, P=0.02) remained.

Discussion

In this Mexican-American cohort with a high prevalence of obesity, we aimed to fill the data gap on relationships between maternal and early life parameters on 9-year-old child adiponectin and leptin. Our analyses show that children with an increased rate of weight or length gain in the first 6 months of life tend to have lower levels of adiponectin at 9 years and these associations remained after adjusting for 9-year child BMI. Data on relationships between infancy growth rate and later life adipokines are limited and our results are in agreement with one of the only studies currently available. Larnkjaer et al (2010). showed that increased weight gain during the first 3 or 9 months of life was negatively associated with adiponectin, but not leptin, in 17 year olds, adjusting for body fat (N=60)[31]. Taken together, these findings add support to the hypothesis that early life growth rate may be an important contributor to altered adiponectin levels at older ages.

However, it remains a challenge to determine whether such associations are due to direct effects on adipokine levels or merely reflective of underlying obesity and increased fat mass. Further, the biological mechanisms linking infancy growth rate and later life adipokine levels are poorly understood. Early life programming of energy balance and regulation may underlie both increased size gain and alterations in adipokine levels which persist into childhood and additional research is needed to elucidate these relationships[32]. Finally, it is important to note that in our study, calculation of weight gain is in accordance with methods used in previous publications and is not adjusted for accompanying length gain[20, 30]. Whether it is excess weight gain relative to length gain during infancy that may affect future adipokine levels remains an important question to answer.

While several reports show weak or no correlation between maternal and fetal adipokines, we found a strong relationship between maternal (at the 9-year visit) and 9-year-old child adiponectin and leptin levels in the CHAMACOS cohort[17, 33, 34]. In addition, large studies (HERITAGE, Framingham Heart and the National Heart, Lung and Blood Institute Family cohorts) have consistently reported heritability of obesity or obesity-related traits to be in the 40-80% range[35-37]. Currently, data on adiponectin and leptin heritability in Mexican-American children are available from only one cross-sectional cohort, showing a moderate

heritability of leptin (36%) and high heritability of adiponectin (97%)[38]. Given that heritability of BMI may vary with age, it is important to examine the relative genetic, developmental programming and environmental/cultural contributions to adipokine levels over childhood[39].

We did not find significant associations between birth weight or length and adipokine levels in 9-year-old Mexican-American children. While several studies have focused on the relationship between birth weight and adipokine levels in cord blood, few data are available tracking the relationship of birth size on adiponectin and leptin through childhood. Bozzola et al (2010) found that both small and appropriate for gestational age infants had statistically similar adiponectin levels over the birth to 1-year-old period[40]. However, two other studies have shown a positive relationship between cord adiponectin and birth weight[34, 41]. These conflicting results suggest that the relationship between child weight and adipokine levels may change over childhood, from no or weak associations at birth to strong correlations at later years, as observed in this report.

Previously, several large prospective cohorts have identified a relationship between excess maternal gestational weight gain and increased risk of obesity in their offspring[19, 42]. While we did not find similar associations with adipokines in 9-year-old children, this may be due to the specific characteristics of the CHAMACOS cohort or related to the relatively modest sample size. Additionally, pre-pregnancy weight was self-reported and likely an underestimate of true weight[43]. This would skew gestational weight gain to larger values, potentially biasing effect estimates toward the null.

We found no significant associations between maternal sugar-sweetened beverage, calorie, protein, total fat, saturated fat or fiber intake and adipokine levels in 9-year-old children. Available evidence shows that malnutrition during pregnancy increases risk of obesity in the offspring but data on child adipokines are limited[44]. To date, only one study is available, reporting that maternal protein consumption was associated with marginally lower adiponectin and leptin levels at birth[13]. An earlier report on CHAMACOS 5-year-old children found no associations between either soda or fast food intake and child weight status[45]. Echoing this, we found that neither children's sugar-sweetened beverage use nor fast food consumption at 9 years were related to their adipokine levels. Overall, we suggest that the complex biological and environmental interactions in older children may mask the relatively smaller effects of diet on adipokines.

In our cohort, leptin levels in children were tightly linked to participant body weight while adiponectin was more reflective of metabolic parameters. Results from our analyses on associations between adipokine levels, lipid profile and blood pressure are similar to findings from several other studies[46, 47]. Data from the Viva la Familia cohort showed that adiponectin was inversely associated with the homeostasis model of insulin resistance (HOMA-IR) and triglycerides/HDL ratio. With respect to leptin, reports indicate that its relationships with lipid profile are largely mediated by BMI[47, 48].

In summary, in this cohort of Mexican-American children with a high prevalence of obesity, greater infancy weight and length gain were associated with lower levels of adiponectin at 9 years, adjusting for child BMI. In turn, decreased adiponectin was related to an adverse lipid profile. Additionally, we report that child adiponectin and leptin were closely related to their mothers' levels at the 9-year visit. A strength of this study is the unique nature of the CHAMACOS birth cohort, having gathered extensive biological, anthropometric and questionnaire-based data on Mexican-American children from the prenatal period into puberty. Limitations include: 1) it remains uncertain whether the early life anthropometric measures examined are independent risk factors for later life adipokine changes and 2) this

study was conducted on a cohort of largely first generation, immigrant, relatively low SES Mexican-American families from an agricultural community and results may not be fully generalizable to other populations.

To further characterize obesity and metabolic disturbance etiology, it is critical to extend adipokine analyses to earlier ages. Key future directions include determining whether children are on set adipokine trajectories from birth, how the child weight – adipokine relationship changes over childhood and whether select maternal parameters are independent risk factors for abnormal levels of adipokines in children.

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What is already known about this subject

- Mexican-American children are at particularly high risk of obesity.
- Features of the perinatal environment, including maternal nutrition, anthropometry, glucose tolerance, and growth rate during infancy are implicated in programming of obesity in the offspring.

What this study adds

- Greater rate of weight or length gain in the first 6 months of life is associated with lower 9-year child adiponectin levels, adjusting for 9-year child BMI.
- 9-year-old child adipokine levels are strongly related to those of their mothers'.

Table 1

Study cohort characteristics and 9-year-old child adiponectin and leptin levels (N = 146)

		9 Year Child			
		Adiponectin (μg/ml)		Leptin (ng/ml)	
	N (%)	Mean (95% CI)	P	Mean[1] (95% CI)	P
Child Sex					
Boy	72(49)	42.9(38.2,47.6)		6.4 (4.9, 8.2)	
Girl	74 (51)	45.4 (41.3,49.4)	0.43	9.1(6.8,12.1)	0.07
Child Gestational Age at Birth					
34-37 Weeks	8(5)	37.3(26.1, 48.5)		9.0(4.2,19.1)	
≥37 Weeks	138(95)	44.6 (41.4,47.8)	0.29	7.5 (6.2, 9.2)	0.69
Child Birth Size					
Small for gestational age (< 10th %ile)	9(6)	35.1(18.0, 52.3)		6.3(1.9, 21.1)	
Appropriate for gestational age	119 (82)	45.S (42.5,49.1)		7.6 (6.2, 9.4)	
Large for gestational age (>90th %ile)	18(18)	37.S (28.7, 46.9)	0.08	8.4 (4.5,15.6)	0.84
Child BMI at 9 Years [2]					
Normal (≤ 85th %ile)	67 (46)	49.2 (45.6, 52.7)		3.3(2.7,3.9)	
Overweight (> 85th, < 95 %ile)	19(13)	52.1 (42.0, 62.3)		7.8 (5.3,11.4)	
Obese (≥ 95 %ile)	60 (41)	36.1(31.0,41.1)	<0.001	19.4(15.3,24.6)	<0.001
Maternal Age at Pregnancy					
18-23 Years Old	46(32)	44.S (38.8, 50.7)		8.7(6.2,12.2)	
24-29 Years Old	63 (43)	46.5 (42.0, 51.0)		6.9 (5.2, 9.2)	
30-41 Years Old	37(25)	39.4(33.4,45.5)	0.19	7.6 (4.9,11.8)	0.59
Maternal Yrs in US at Pregnancy					
<1	31(21)	44.9(38.0,51.7)		7.5 (4.8,11.5)	
1-10	81 (56)	46.1 (42.0, 50.2)		7.2(5.6, 9.3)	
>10	34 (23)	38.9(32.2,45.7)	0.17	8.8(5.5,13.9)	0.72
Maternal Education at Pregnancy					
≤6th Grade	68 (47)	45.3(40.6,49.9)		7.5 (5.6, 9.9)	
7-12 Grade	50(34)	43.3(38.1, 48.5)		7.4 (5.2,10.6)	

		9 Year Child			
		Adiponectin (μg/ml)		Leptin (ng/ml)	
	N (%)	Mean (95% CI)	P	Mean[1] (95% CI)	P
≥ High School	28(19)	43.0(35.5, 50.4)	0.8	8.4(5.6,12.5)	0.89
Maternal Sugar Sweetened Beverage Use in Pregnancy					
0-8 Drinks/Week	44(31)	44.S (38.5, 51.0)		8.3(5.8,12.0)	
9-16 Drinks/Week	51(35)	44.5(39.9,49.2)		6.8 (4.7, 9.7)	
17+ Drinks/Week	49 (34)	43.6(37.9,49.4)	0.96	8.0(5.9,10.8)	0.66
Household Food Security [3]					
Food Secure	92(63)	43.1(39.5, 46.7)		6.6(5.2, 8.5)	
Low Food Security	41(28)	46.4(39.3,53.6)		9.0(6.3,12.9)	
Very Low Food Security	13(9)	44.5(34.8, 54.1)	0.64	11.7(6.7,20.4)	0.15

[1] Geometric mean.

[2] Child's weight status was determined using age and sex adjusted body mass index cut offs for 85th and 95th percentiles from CDC child growth charts.

[3] At 9 year visit.

Table 2

Associations of maternal and early life anthropometric parameters with child adiponectin and leptin levels at age 9

			9 Year Child			
			Adiponectin (μg/ml)		Leptin (logged)	
Characteristic	**N**	**Mean[1] ±SD%CI)**	**Beta[2] (95% CI)**	**P**	**Beta (95% CI)**	**P**
Birth Weight (kg)						
Crude[3]	146	3.5 ±0.5 (3.4, 3.6)	−4.7 (−12.0, 2.6)	0.2	0.12 (−0.08, 0.31)	0.26
Adjusted[3,4]	146		−1.6 (−8.6, 5.3)	0.64	−0.06 (−0.19, 0.08)	0.4
Birth Length (cm)						
Crude[3]	146	50.5 ±2.6 (50.0, 50.9)	−0.2 (−1.5,1.2)	0.83	0.02 (−0.01, 0.06)	0.23
Adjusted[3,4]	146		−0.1 (−1.4,1.2)	0.88	0.02 (−0.01, 0.05)	0.12
Weight Gain in First 6 Months of Life (lOOg/month)						
Crude	133	7.4 ±1.6 (7.1, 7.7)	−2.8 (−4.8, −0.8)	0.007	0.04 (−0.01, 0.1)	0.15
Adjusted[4]	133		−2.0 (−1.79, −0.5)	0.04	0.01 (−0.05, 0.03)	0.61
Length Gain in First 6 Months of Life (cm/month)						
Crude	133	2.6 ±0.5 (2.5, 2.7)	−9.7 (−16.7,−2.8)	0.007	−0.001 (−0.19, 0.19)	0.99
Adjusted[4]	133		−8.2 (−15.0,−1.5)	0.02	−0.1 (−0.23, 0.03)	0.14
Child 9Y Adiponectin (μg/ml)						
Crude	146	44.2 ±18.8 (41.1,47.2)	-----		−0.007 (−0.01,−0.002)	0.003
Adjusted[4]	146		-----		0.001 (−0.002, 0.004)	0.56
Child 9Y Leptin						
Crude	146	7.6 ±3.2 (6.3, 9.2)	−8.9 (−14.7,−3.0)	0.003	-----	
Adjusted[4]	146		2.5 (−5.9,10.8)	0.56	-----	
Pre-Pregnancy BMI						
Crude	146	27.4 ±5.4 (26.5, 28.2)	−0.8 (−1.4, −0.2)	0.006	0.03 (0.01, 0.04)	<0.001
Adjusted[4]	146		−0.3 (−0.9, .3)	0.28	0.001 (−0.01, 0.01)	0.84
Weight Gain During Pregnancy (kg)						
Crude	146	13.2 ±5.1 (12.4,14.0)	−0.1 (−0.8, 0.5)	0.65	0.01 (−0.01, 0.02)	0.43

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Characteristic	N	Mean[1] ±SD%CI)	9 Year Child Adiponectin (µg/ml) Beta[2] (95% CI)	P	9 Year Child Leptin (logged) Beta (95% CI)	P
Adjusted[4]	146		0.03 (−0.5, 0.6)	0.91	−0.003 (−0.01, 0.01)	0.61
Maternal Adiponectin At 9 Year Visit (µg/ml)						
Crude	146	29.2 ±13.7 (26.9, 31.4)	0.4(0.2, 0.6)	<0.001	−0.0002 (−0.01, 0.01)	0.95
Adjusted[4]	146		0.3(0.1, 0.6)	0.001	0.003 (−0.002, 0.01)	0.23
Maternal Leptin At 9 Year Visit						
Crude	146	22.3 ±2.4 (19.3, 25.7)	−9.3 (−17.4,−1.2)	0.02	0.42(0.21, 0.63)	<0.001
Adjusted[4]	146		−5.9 (−13.7,1.8)	0.13	0.23 (0.08, 0.38)	0.002

[1]Geometric mean for leptin.

[2]Linear regression estimate.

[3]Model adjusted for gestational age.

[4]Model adjusted for 9-year child BMI.

Table 3

Associations between child adiponectin, leptin and metabolic parameters, including lipid profile (N = 56) and blood pressure (N = 122)

	Child Metabolic Parameters							
	Glucose (mg/dL)	**Cholesterol (mg/dL)**	**TG (mg/dL)**	**VLDL (mg/dL)**	**LDL (mg/dL)**	**HDL(mg/dL)**	**SBP(mmHg)**	**DBP(mmHg)**
Mean ±SD, Range	89±6, 73-101	151±30,94-228	83±42, 30-195	17±8, 6-39	82±26,35-156	52±12, 27-98	97.4±11.1, 74.5 -133	53.4±5.9, 37.5-70
Child Adiponectin								
Crude Beta (P)	−0.0004(0.99)	−0.04(0.81)	−0.8 (<0.001)	−0.2 (<0.001)	−0.1(0.44)	0.2 (<0.001)	−0.2(0.004)	−0.1(0.04)
Adjusting for 9Yr BMI (P)	0.01(0.81)	−0.1(0.63)	−0.5(0.03)	−0.1(0.03)	−0.1(0.44)	0.1(0.02)	−0.01(0.86)	−0.02(0.58)
Child Leptin (logged)								
Crude Beta (P)	1.5(0.38)	−6.3 (0.47)	31.9 (0.007)	6.4 (0.007)	1.1(0.88)	−13.8 (<0.001)	15.1 (<0.001)	5.3 (<0.001)
Adjusting for 9Yr BMI (P)	1.8(0.53)	−7.3(0.59)	−13.8(0.38)	−2.9 (0.4)	−0.5(0.97)	−4.9 (0.23)	7.6 (<0.001)	3.6(0.02)

Abbreviations: BMI, Body mass index; TG, Triglycerides; VLDL, Very low-density lipoprotein; LDL, Low-density lipoprotein; HDL, High-density lipoprotein; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.