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Effects of prepregnancy body mass index and gestational weight gain on infant anthropometric outcomes

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Abstract

Objective—To determine whether prepregnancy body mass index (BMI) and gestational weight gain (GWG) influence infant postnatal growth.

Study design—Participants were from the Pregnancy, Infection, and Nutrition Study, a prospective pregnancy cohort. Term infants with weight or length measurements at approximately 6 months were included (n=363). Multivariable regression estimated associations for weight-for-age (WAZ), length-for-age (LAZ), and weight-for-length z-scores (WLZ), and rapid infant weight gain with categorical maternal exposures defined by the 2009 Institute of Medicine recommendations.

Results—Prepregnancy overweight and obesity were associated with higher WAZ (linear regression coefficient (β), 0.32; 95% CI, 0.04-0.61) and WLZ (β, 0.39; 95% CI, 0.02-0.76), respectively. Prepregnancy BMI was not associated with LAZ. Excessive GWG was associated with higher WAZ (β, 0.39; 95% CI, 0.15-0.62) and LAZ (β, 0.34; 95% CI, 0.12-0.56). Excessive GWG≥200% of recommended amount was associated with higher WAZ (β, 0.68; 95% CI, 0.28-1.07), LAZ (β, 0.45; 95% CI, 0.06-0.83), and WLZ (β, 0.43; 95% CI, 0.04-0.82). Risk of rapid weight gain increased across maternal exposure categories; however, none of the estimates were significant.

Conclusions—Prepregnancy BMI and GWG are modifiable intrauterine exposures that influence infant postnatal anthropometric outcomes. Further investigation with infant body composition measurements is warranted.

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Keywords

maternal; obesity; offspring; pregnancy

In the United States, more than one-half of women of reproductive ages are overweight or obese[1] and the majority gain excessive amounts of weight during pregnancy.[2] These trends motivated research on the impact of fetal exposure to increased concentrations of nutrients and metabolic hormones on later health outcomes, including obesity. Results from animal and human studies suggest that increased maternal nutrition via prepregnancy obesity and/or excess nutrient intakes during gestation leads to adiposity, insulin resistance, hyperphagia, hyperleptinemia, and hypertension in the offspring[3]; however, the evidence is not conclusive.

Observational studies of the effects of prepregnancy body mass index (BMI) and gestational weight gain (GWG) on offspring anthropometric outcomes are somewhat limited. Much of the existing literature focused on birthweight or BMI as the main outcome of interest. Birthweight,[4] rapid weight gain during infancy and childhood,5 and early childhood BMI6 are predictors of obesity later in life. Prepregnancy BMI and GWG are positively associated with birthweight7,[8] and offspring BMI[9,10] but there is little information about whether they influence infant anthropometric outcomes, especially linear growth, into the postnatal period.

In the present study, we utilize data from a recent prospective, longitudinal pregnancy cohort study to investigate the effects of maternal prepregnancy BMI and GWG on infant weight-for-age (WAZ), length-for-age (LAZ), and weight-for-length z-scores (WLZ) at 6 months as well as rapid weight gain between birth and 6 months. This time period during infancy has been identified as critical for adverse outcomes later in life.[11],12

Methods

Participants were women from the Pregnancy Infection and Nutrition (PIN) study,13 January 1, 2001- June 30, 2005, who were recruited into and completed the PIN Postpartum study at 12 months postpartum.14 A total of 1,169 women completed the PIN study, delivered a live singleton infant, and were eligible to participate in the PIN Postpartum study (beginning 2003), which included home visits at 3 and 12 months postpartum. Of these women, 480 were excluded from (n=293) or refused (n=187) to participate in the postpartum study. There were 689 and 550 mother-child pairs who completed the study at 3 and 12 months postpartum, respectively. Of the 550 mother-infant pairs, 3 were excluded due to physician diagnosed illnesses related to infant growth, 112 were missing anthropometric measurements, and 27 did not have measurements at ~6 months. Preterm infants (gestational age <37 weeks) were also excluded (n=45). Compared with women who participated in PIN Postpartum (n=689), women who did not participate (n=480) were younger, of higher BMI, less educated, lower income, and more likely to be black, not married, and smokers. For the current analysis, similar differences were observed between included mothers (n=363) and excluded mothers (n=187) with the exception that excluded mothers who had higher glucose tolerance values and there was no difference in the distribution of prenatal smoking behavior. Excluded infants had younger gestational ages and lower birthweights compared with included infants. All other comparisons between those included and excluded for this analysis were not significant. PIN study protocols were approved by the Institutional Review Board of the School of Medicine at the University of North Carolina at Chapel Hill.

Infant birthweights (n=362) and sex (n=363) were abstracted from delivery logs. All other weights and lengths were recorded on study provided doctor's cards during pediatrician visits. Infant measurements at approximately 6 months (median: 6.2; range: 4.8-7.4) were included in analyses. The exact age of the infant was calculated by subtracting the birth date from the visit date. We used the 15th of the month when the day of the visit was missing (n=5) and the pediatrician's recorded age when both the month and day of the visit were missing (n=9).

Gestational age was calculated using an algorithm based on the first ultrasound measurement performed prior to 22 weeks' gestation. If no ultrasound was performed prior to the start of week 22, then the date of last menstrual period was used (n=7). Birthweights were converted to gestational age and sex-specific z-scores (birthweight z-scores) using US reference data.[15] Infant weights (n=354), lengths (n=355), and weight-for-lengths (n=346) at 6 months were converted to sex-and age-specific z-scores using the 2000 CDC/NCHS growth charts.16 Rapid weight gain was defined as a change in WAZ greater than +0.67 between birth and 6 months, which is clinically interpretable as the upward crossing of a centile line on an infant growth chart.5 Maternal prepregnancy BMI (kg/m^2) and total GWG were categorized according to the 2009 IOM recommendations: underweight (BMI<18.5), 28-40 lbs; normal weight (BMI 18.5-24.9), 25-35 lbs; overweight (BMI 25.0-29.9), 15-25 lbs; and obese (BMI ≥ 30), 11-20 lbs.[17] Prepregnancy BMI was calculated using self-reported prepregnancy weight and measured height. Implausible prepregnancy weights (n=6) were imputed based on the measured first trimester weights.13 GWG was defined as the difference between self-reported prepregnancy weight and the last weight measurement prior to delivery. An adequacy of GWG ratio was calculated by dividing the observed total gestational weight gain by the expected weight gain, based on the IOM recommendations specific for a given prepregnancy BMI category and the trimester of gestation, as described previously.13 Inadequate, adequate, and excessive GWG categories were based on ranges of adequacy ratios13 using the IOM recommendations.17 Due to the large distribution of adequacy ratios within the excessive category, excessive GWG was dichotomized at an adequacy ratio of 2.00, or 200%. Excessive I GWG (n=154) was defined as excessive weight gain up to 199% of the recommendations. Excessive II GWG (n=55) was defined as excessive GWG≥200% of the recommended amount.

Data concerning maternal characteristics were collected from prenatal interviews and categorized as shown in Table I. Household income (represented as a percent of the 2001 poverty index) at 3 months postpartum was used when prenatal data was missing (n=13). Glucose tolerance during pregnancy was collected during the late 2nd trimester (mean gestational age ~27 weeks) using previously described methods.[18] Multiple imputation techniques using SAS 9.2 (SAS Institute, Cary, NC) and PROC MI estimated values of missing covariate data for the sample: GWG (n=2), glucose tolerance (n=4), prenatal smoking (n=9), household income (n=1), and birthweight (n=1). All pre- and postnatal variables discussed in the previous section were included in multiple imputation models. We generated ten imputed data sets that were combined into a single set of parameter estimates for the final regression models.19 All presented analyses used the imputed data set and the results did not differ from those obtained by the complete case analyses.

Other statistical analyses were performed using STATA 11 (College Station, TX). Effect measure modifiers and confounders were identified a priori from a literature review and causal diagrams.[20] The interaction of continuous prepregnancy BMI and GWG was tested in crude and full models using interaction terms and Wald tests with an a priori significance p<0.15. Full models were separately adjusted for birthweight z-scores to determine whether any observed associations persisted after controlling for a measure of prenatal growth. T-tests of means and analyses of variance analyzed distributions of baseline characteristics.

Multivariable linear regression models estimated associations of continuous infant outcomes with categorical maternal exposures. Multivariable modified Poisson regression (Poisson regression with a robust error variance) estimated risk ratios of rapid infant weight. This method has been validated for directly estimating relative risks for dichotomous, common outcomes in prospective studies.21 All regression analyses were adjusted for clustering at the individual level22 because there were 13 women with more than one child included in the analyses.

Results

The mean (standard deviation [SD]) prepregnancy BMI was 24.2 (5.6) kg/m^2; approximately 29.2% of the women were overweight or obese. The mean (SD) GWG for the sample was 16.0 (5.4) kg with 57.9% of the women having excessive GWG. The distribution (n) of inadequate, adequate, excessive I, and excessive II GWG across prepregnancy BMI categories were: 4, 7, 9, and 0 among underweight women; 35, 86, 107, and 8 among normal weight women; 2, 6, 29, and 23 among overweight women; and 5, 7, 9, and 24 among obese women. The majority of women were 25-34 years at conception, non-black, married, achieved a high school degree or higher, upper income, and non-smokers during pregnancy. Approximately half of them were nulliparous. The mean (SD) weight and gestational age of the infants at birth were 3433.8 (425.6) g and 39.2 (1.1) weeks, respectively.

Maternal characteristics of prepregnancy BMI, GWG, race, prepregnancy diabetes mellitus, and prenatal smoking were associated with a significant difference in the means of at least one infant anthropometric outcome (Table I). Mean WLZ and WAZ increased across categories of prepregnancy BMI and GWG, respectively. Women with prepregnancy diabetes mellitus had infants with lower mean WAZ and LAZ, and smokers had infants with lower LAZ and black women had infants with higher WLZ. Means for all three infant anthropometric outcomes increased across categories of birthweight.

In full models (Table II), WAZ and WLZ at 6 months increased across categories of prepregnancy BMI. Prepregnancy overweight and obesity were associated with higher WAZ and WLZ, respectively. Risks of rapid infant weight gain between birth and 6 months also increased across maternal prepregnancy BMI categories (Table III), but none of the associations were statistically significant in the full model. Maternal prepregnancy BMI was not associated with LAZ at 6 months (Table II). Adjustment of full models for birthweight z-score (Table II) attenuated the observed associations among overweight and obese women.

Inadequate weight gain was not associated with any of the infant anthropometric outcomes in the full models (Table II). Total excessive GWG (excessive I and excessive II combined, data not shown in Table II) was associated with higher WAZ (β, 0.39; 95% CI, 0.15-0.62) and LAZ (β, 0.34; 95% CI, 0.12-0.56) at 6 months but not WLZ, compared with adequate GWG. Excessive II GWG was associated with higher WAZ, LAZ, and WLZ (Table II). Risks of rapid infant weight gain increased across GWG categories; however, none of the associations were significant (Table III). Adjustment of full models for birthweight z-score (Table II) attenuated the observed associations for GWG and infant size outcomes but significant associations remained for WAZ with excessive II GWG and LAZ with total excessive GWG (data not shown in Tables; β, 0.22; 95% CI, 0.004-0.43). In contrast, risks of rapid weight gain were strengthened after adjustment for birthweight z-score (Table III). There was no evidence for an interaction between GWG and prepregnancy BMI for any of the infant anthropometric outcomes.

Discussion

Few studies have examined the effects of maternal prepregnancy BMI and GWG on infant anthropometric outcomes. Previous systematic reviews identified infant size and growth rate as early predictors of later obesity.[5] Our results suggest that prepregnancy BMI and GWG are modifiable intrauterine exposures that influence infant size and rapid infant weight gain, a measure of infant growth rate, within the first 6 months of life.

We found that infants of overweight and obese mothers have greater weights relative to their lengths, and and infants of mothers with excessive GWG also have greater weights they have proportionally greater lengths (compared with infants of normal weight mothers and infants of mothers with adequate GWG, respectively); the exception being that infants of mothers with excessive II GWG have weights that exceed their lengths. These relationships represent the total effects of prepregnancy BMI and GWG on infant size outcomes (including their effects on birthweight) and suggest that they differ with respect to infant body size. Although risk estimates increased across maternal exposure categories, neither prepregnancy BMI nor GWG was associated with rapid infant weight gain in the full models, which is consistent with other studies.[23,24] Rapid weight gain represents the crossing of a growth chart centile line but does not account for differences in initial or concomitant linear growth. The lack of an association with rapid weight gain suggests that the main effect of the maternal exposures relates to changes in infant size, and previously identified factors, such as early weaning,25 may have greater influence on rate of weight gain.

The addition of birthweight to the full models attenuated the observed associations of prepregnancy BMI and GWG with infant WAZ, LAZ, and WLZ, which suggests that most of the association between the maternal factors and infant size is explained by their effects on prenatal growth. Maternal overweight/obesity is associated with neonatal adiposity,[26] which is a predictor of growth and adiposity in later infancy[27] and childhood.[28] However, it remains unclear whether in utero exposures to maternal overnutrition persist in the postnatal period, independent of prenatal growth; studies that examined the association between GWG and offspring BMI measured later in childhood report significant findings independent of birthweight.[9,29,30] Consistent with these studies, we found significant differences in infant WAZ among excessive II gainers and LAZ among all excessive gainers remained after adjustment for birthweight. These results indicate that, in contrast to prepregnancy BMI, GWG may have an effect on offspring size that is not explained by its influence on prenatal growth and birthweight. Adjustment for birthweight, also resulted in a significant 60% increased risk of rapid infant weight gain among women with excessive II GWG. Although this is consistent with our finding of higher WAZ among this subgroup, the observed strengthening of risk estimates may be a statistical artifact because birthweight is inversely associated with rapid weight gain.

There is little information about an association for prepregnancy BMI and/or GWG with infant size or body composition. Ay et.al.,[27] found no association of GWG during the first 30 weeks of pregnancy with infant percent fat mass (truncal, peripheral, or total fat mass) at 6 months, and prepregnancy BMI was associated with increased peripheral fat mass in these infants. The effects of GWG on infant body composition may also differ by prepregnancy BMI status. In a study by Sewell et.al.,[26] neonatal lean body mass but not percent body fat was correlated with GWG among lean/average women, and only percent body fat was correlated with GWG among overweight/obese women. In the present study, though we did not find an interaction between prepregnancy BMI and GWG and were likely underpowered to do so, there were differences in GWG across BMI categories and differences in how the maternal exposures related to infant weight and length outcomes. Normal and overweight women were most likely to have excessive I GWG, and obese women were most likely to have excessive II GWG; prepregnancy overweight/obesity were associated with weight outcomes, and GWG was associated with both weight and length outcomes. Considering that both child height31 and BMI6 are predictors for later life obesity, more research is needed to examine the effects of maternal diet and GWG in relation to prepregnancy BMI status to determine how they contribute to body composition at birth and throughout childhood.

Our results should be interpreted within the context of several limitations of the study. Infant anthropometrics came from doctor's cards measurements, which are subject to error because they were collected at multiple clinic sites and medical staffs were not trained using standardized methods; however, it is unlikely that this error would be systematic. Infant weight and length are not measurements of infant adiposity so we cannot state whether the observed changes in infant size are due to fat or fat free mass. Attrition between PIN and the PIN Postpartum studies resulted in a disproportionate loss of women among high risk groups. Although the exposure-disease relationship is not expected to differ across many of these factors, losses from high risk groups, such as obese women, may have weakened the observed associations reported here. Lastly, we used self-reported prepregnancy weight in BMI and GWG calculations, which may have led to an underestimation of prepregnancy BMI and an overestimation of GWG.

These findings provide evidence for an influence of maternal nutrition-related factors on offspring anthropometric outcomes in early infancy and can be used to further link results from animal and human studies. Future research with precise measurements of infant body composition is warranted to confirm our results.

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List of Abbreviations

BMI	Body Mass Index
WAZ	Weight-for-age z-score
LAZ	Length-for-age z-score
WLZ	Weight-for-length z-score
PIN	Pregnancy, Infection, and Nutrition
UNC	University of North Carolina

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Table I

Distribution of selected baseline characteristics by mean (SD[1]) infant WAZ (n=354), LAZ (n=355), and WLZ (n=346) at 6 months in the Pregnancy Infection and Nutrition Study.

Variable	N	Mean WAZ (SD)	*P*	N	Mean LAZ (SD)	*P*	N	Mean WLZ (SD)	*P*
Age (years)									
16-24	44	0.14 (0.84)		45	0.28 (0.74)		42	0.07 (1.14)	
25-29	98	0.19 (1.07)	0.67	101	0.44 (0.98)	0.58	97	0.02 (1.08)	0.49
30-34	145	0.10 (0.98)		143	0.49 (0.96)		142	−0.15 (1.10)	
35-47	67	0.28 (0.96)		66	0.50 (0.77)		65	0.04 (1.14)	
Prepregnancy BMI									
Underweight	21	−0.12 (0.76)		20	0.13 (0.84)		20	−0.11 (0.94)	
Normal Weight	231	0.11 (0.98)	0.10	229	0.48 (0.87)	0.31	224	−0.16 (1.13)	0.02
Overweight	58	0.36 (0.89)		61	0.51 (0.90)		58	0.18 (1.10)	
Obese	44	0.35 (1.17)		45	0.35 (1.08)		44	0.32 (0.99)	
Gestational Weight Gain									
Inadequate	46	0.002 (0.95)		46	0.39 (0.82)		46	−0.24 (1.17)	
Adequate	106	−0.04 (0.92)	0.003	104	0.31 (0.84)	0.18	104	−0.17 (1.07)	0.01
Excessive I	148	0.24 (1.03)		149	0.55 (1.00)		143	−0.05 (1.15)	
Excessive II	52	0.52 (0.91)		54	0.50 (0.81)		51	0.41 (0.89)	
Race									
Non-Black	321	0.16 (0.98)	0.67	322	0.48 (0.91)	0.06	313	−0.08 (1.12)	0.03
Black	33	0.23 (0.99)		33	0.17 (0.17)		33	0.35 (0.92)	
Marital Status									
Married	309	0.18 (0.98)	0.43	310	0.49 (0.87)	0.06	304	−0.05 (1.12)	0.54
Other	45	0.06 (1.01)		45	0.21 (1.11)		42	0.06 (1.04)	
Education									
≤ Grade 12	31	0.22 (1.01)		33	0.36 (1.15)		29	0.18 (0.99)	
Grades 13 -16	172	0.20 (1.02)	0.73	171	0.45 (0.90)	0.83	168	0.01 (1.15)	0.27
≥Grade 17	151	0.12 (0.94)		151	0.47 (0.86)		149	−0.14 (1.08)	
Household Income (% Poverty)									
<185%	40	0.17 (1.00)	0.96	41	0.35 (0.86)	0.55	38	0.03 (1.28)	0.49

Variable	N	Mean WAZ (SD)	*P*	N	Mean LAZ (SD)	*P*	N	Mean WLZ (SD)	*P*
185-350%	70	0.19 (0.99)		69	0.39 (1.04)		68	0.09 (0.97)	
>350%	242	0.16 (0.98)		243	0.48 (0.88)		238	−0.08 (1.12)	
Pre-existing Diabetes Mellitus									
No	339	0.18 (0.96)	0.05	341	0.48 (0.87)	0.003	332	−0.04 (1.11)	0.94
Yes	14	−0.34 (1.43)		13	−0.28 (1.51)		13	−0.02 (1.05)	
Glucose Tolerance									
Normal	300	0.17 (0.95)		304	0.49 (0.85)		296	−0.06 (1.12)	
Impaired Glucose Tolerance	29	0.32 (1.05)	0.64	28	0.51 (1.03)	0.51	27	0.12 (1.17)	0.71
Gestational Diabetes	9	0.02 (1.08)		8	0.13 (0.75)		8	−0.15 (1.01)	
Parity									
Nulliparous	176	0.15 (0.96)	0.80	179	0.48 (0.86)	0.52	173	−0.09 (1.12)	0.43
1 or More Births	178	0.18 (1.01)		176	0.42 (0.95)		173	0.007 (1.10)	
Prenatal Smoking									
No	322	0.18 (0.98)	0.58	322	0.47 (0.86)	0.05	315	−0.04 (1.12)	0.20
Yes	24	0.07 (1.04)		24	0.10 (1.36)		23	0.26 (0.73)	
Infant Sex									
Male	183	0.13 (1.00)	0.51	185	0.42 (0.85)	0.56	177	0.03 (1.12)	0.23
Female	171	0.20 (0.96)		170	0.48 (0.97)		169	−0.11 (1.09)	
Birthweight Category (g)									
<3000	44	−0.59 (0.90)		44	−0.08 (1.11)		44	−0.53 (1.10)	
3000-<3500	172	0.04 (0.90)	<0.0001	174	0.33 (0.79)	<0.0001	168	−0.09 (1.11)	0.0001
3500-<4000	102	0.37 (0.90)		101	0.66 (0.86)		100	0.05 (1.05)	
≥4000	35	1.09 (0.83)		35	1.12 (0.75)		33	0.58 (1.02)	

[1] SD, Standard Deviation

Table 2

Differences in infant weight-for-age, length-for-age, and weight-for-length z-scores at 6 months associated with categories of maternal prepregnancy BMI and gestational weight gain according to the 2009 IOM Guidelines

	Anthropometric Outcomes					
	Weight-for-Age z-score (n=354)		Length-For-Age z-score (n=355)		Weight-For-Length z-score (n=346)	
Maternal Prenatal Exposures	**β (95% CI)***	**β (95% CI)†**	**β (95% CI)***	**β (95% CI)†**	**β (95% CI)***	**β (95% CI)†**
Prepregnancy BMI	0.02 (−0.003, 0.04)	0.01 (−0.01, 0.03)	−0.003 (−0.02, 0.02)	−0.01 (−0.03, 0.01)	0.03 (0.01, 0.05)	0.02 (0.003, 0.05)
Per kg/m^2						
Underweight	−0.21 (−0.57, 0.15)	−0.17 (−0.51, 0.16)	−0.35 (−0.75, 0.05)	−0.34 (−0.71, 0.03)	0.07 (−0.36, 0.50)	0.09 (−0.35, 0.53)
Normal Weight	Reference	Reference	Reference	Reference	Reference	Reference
Overweight	0.32 (0.04, 0.61)	0.20 (−0.06, 0.45)	0.14 (−0.14, 0.41)	0.05 (−0.22, 0.32)	0.34 (−0.01, 0.69)	0.24 (−0.08, 0.56)
Obese	0.30 (−0.07, 0.67)	0.24 (−0.14, 0.62)	0.02 (−0.29, 0.32)	−0.02 (−0.34, 0.29)	0.39 (0.02, 0.76)	0.34 (−0.04, 0.71)
Gestational Weight Gain						
Per 10% increase in adequacy	0.03 (0.01, 0.05)	0.02 (0.003, 0.04)	0.02 (0.006, 0.04)	0.02 (0.002, 0.03)	0.02 (−0.0002, 0.04)	0.01 (−0.007, 0.03)
Inadequate	0.08 (−0.24,0.40)	0.08 (−0.22, 0.38)	0.19 (−0.08, 0.47)	0.18 (−0.09, 0.45)	−0.14 (−0.55, 0.26)	−0.13 (−0.52, 0.27)
Adequate	Reference	Reference	Reference	Reference	Reference	Reference
Excessive I	0.32 (0.07, 0.56)	0.18 (−0.05, 0.40)	0.30 (0.07, 0.52)	0.20 (−0.03, 0.42)	0.10 (−0.20, 0.40)	0.03 (−0.24-0.30)
Excessive II	0.68 (0.28, 1.07)	0.46 (0.10, 0.83)	0.45 (0.06, 0.83)	0.31 (−0.05, 0.68)	0.43 (0.04, 0.82)	0.30 (−0.08, 0.67)

*Multivariable linear regression coefficients (β) and 95% confidence intervals (95% CI) for full models adjusted for: gestational age, maternal height, maternal race/ethnicity, marital status, prenatal smoking, household income, and education. Full models for gestational weight gain were also adjusted for prepregnancy BMI and pre-existing diabetes mellitus.

†Full models with additional adjustment for birthweight z-score.

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Table III

Adjusted risk ratios (ARR) of rapid infant weight gain between birth and 6 months associated with categories of maternal prepregnancy BMI status and gestational weight gain according to the 2009 IOM Guidelines (n=354)

	Risk of Rapid Infant Weight Gain			
	ARR (95%CI)*	***P***	**ARR (95%CI)†**	***P***
Prepregnancy BMI				
Per kg/m^2	1.02 (0.99, 1.05)	0.20	1.02 (1.00, 1.05)	0.09
Underweight	0.47 (0.16, 1.41)	0.18	0.47 (0.16, 1.36)	0.16
Normal Weight	1.00 (Reference)		1.00 (Reference)	
Overweight	1.18 (0.74, 1.68)	0.59	1.23 (0.84, 1.80)	0.30
Obese	1.41 (0.90, 2.20)	0.14	1.40 (0.95, 2.07)	0.09
Gestational Weight Gain				
Per 10% adequacy ratio	1.13 (0.91, 1.41)	0.27	1.24 (1.00, 1.54)	0.05
Inadequate	0.94 (0.53, 1.67)	0.82	0.97 (0.56, 1.68)	0.92
Adequate	1.00 (Reference)		1.00 (Reference)	
Excessive I	1.11 (0.74, 1.65)	0.61	1.28 (0.89, 1.84)	0.19
Excessive II	1.29 (0.76, 2.18)	0.34	1.61 (1.00, 2.60)	0.05

*Adjusted risk ratios (ARR) and 95% confidence intervals (95% CI) from multivariable modified Poisson regression for full models adjusted for: gestational age, maternal height, maternal race/ethnicity, marital status, prenatal smoking, household income, and education. Full models for gestational weight gain were also adjusted for prepregnancy BMI and pre-existing diabetes mellitus.

†Full models with additional adjustment for birthweight z-score.