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Gestational Weight Gain and Birth Outcome in Relation to Prepregnancy Body Mass Index and Ethnicity

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Abstract

PURPOSE—The obesity epidemic raises concerns about the impact of excessive and insufficient weight gain during pregnancy.

METHODS—We examined the association between gestational weight gain (GWG) and preterm birth, term small- and large-for-gestational-age (SGA and LGA), term birthweight, and term primary Cesarean delivery, considering prepregnancy body mass index (BMI) and ethnicity in a cohort of 33,872 New York City residents who gave birth between 1995 and 2003 and delivered in hospitals elsewhere in New York State.

RESULTS—Preterm birth (<37 weeks' gestation) showed a modest U-shaped relationship, with projected GWG of <10 kg and 20+ kg associated with odds ratios of 1.4 and 1.3, respectively, relative to 10 to 14 kg. The pattern was stronger for preterm birth <32 weeks' and for underweight women with low GWG and overweight/obese women with high GWG. Term SGA decreased and term LGA and birthweight increased monotonically with increasing GWG. Primary Cesarean delivery followed the same pattern as LGA, but less strongly.

CONCLUSIONS—Although the study is limited by potential selection bias and measurement error, our findings support the contention that GWG may be a modifiable predictor of pregnancy outcome that warrants further investigation, particularly randomized trials, to assess whether the relation is causal.

Keywords

Birth Weight; Cesarean Delivery; Fetal Growth Retardation; Fetal Macrosomia; Infant; Small-for-Gestational Age; Premature Birth; Weight Gain

INTRODUCTION

Evaluating the health consequences of gestational weight gain (GWG) requires careful consideration of both maternal and infant outcomes, as discussed in detail in a recent Institute of Medicine report (1). Past recommendations for optimal GWG have focused largely on the likely benefits of adequate weight gain in the prevention of fetal growth restriction and its consequences (2). Given the current obesity epidemic, the trend of women gaining too much weight in pregnancy, and the growing appreciation of the role of GWG in

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postpartum weight retention (3), the balance of considerations requires reconsideration, with even modest shifts in estimated risks and benefits potentially affecting the best estimate of "optimal" GWG. The immediate infant health consequence of greatest concern is inadequate or excessive fetal growth, with small size at birth associated with increased mortality and morbidity (4, 5) and large size resulting in increased risk for Cesarean delivery and birth injury (1).

The influence of GWG on preterm birth is not as clear as the effect on fetal growth, but a U-shaped relationship is frequently observed (3). We conducted an analysis of GWG for births to New York City residents who delivered at New York State Hospitals (outside New York City) and were able to examine effect modification by pre-pregnancy body mass index (BMI) and ethnicity, analyze subsets of preterm to assess whether associations differed by severity or clinical presentation, and simultaneously consider multiple indicators of infant size at birth, addressing both restricted and excessive growth and the consequences for Cesarean delivery.

MATERIAL AND METHODS

New York City birth data for 1995 to 2003 were linked to hospital discharge data from the Statewide Planning and Research Cooperative System (i.e., SPARCS), as described elsewhere (9, 10). Only births to New York City residents that occurred in hospitals located in New York State but outside of New York City had maternal height available because of coding practices in effect at that time. Height was reported for 33,872 births, making this a large but highly restricted dataset that no longer represents a geographically well-defined population, given the required combination of residence in New York City and delivery in a hospital located elsewhere in New York State. Women in the analysis overrepresented pregnancies from Queens and the Bronx because of proximity to hospitals on Long Island and in Westchester County, respectively, resulting in an increased proportion of non-Hispanic white women, fewer term infants small-for-gestational age (SGA), and more term infants large-for-gestational age (LGA) births than for all New York City residents.

A total of 39,669 births included height data needed to calculate pre-pregnancy BMI and were therefore potentially eligible for the analysis. Gestational age was assigned on the basis of the clinical estimate. We excluded women whose GWG was below 0 (0.5%), given there were too few women in this stratum to analyze separately and reason to be concerned that they differ from women with low weight gain; women whose GWG was greater than 40 kg (0.2%), or missing (0.5%); those with gestational ages outside the range of 26 to 42 completed weeks (0.5%) because extremely preterm births are unlikely to be influenced by GWG; implausible combinations of birth weight and gestational age (0.1%; birth weight >2.5 SD deviant from the mean for a given gestational age) (6); birth defects (11.3%); missing pregnancy outcome (1.0%); missing covariate data (maternal age, parity, education, smoking; 0.7%); and self-reported race/ethnicity other than non-Hispanic white, non-Hispanic black, Hispanic, or Asian (1.6%), for a final sample size of 33,872 (85.4% of potentially eligible births).

Dependent Variables

We considered preterm birth in the aggregate (<37 completed weeks' gestation), and two subsets of preterm birth (medically indicated vs. spontaneous; 26–33 vs. 34–36 weeks' gestation), SGA among term births, LGA among term births, a continuous measure of birthweight among term births, and term primary Cesarean delivery. To differentiate between medically indicated and spontaneous preterm births (arising from either premature rupture of the membranes or spontaneous preterm labor), we used International Classification of Diseases, Ninth Revision hospital discharge diagnosis and procedure codes, as described in more detail elsewhere (7). Term SGA infants were those whose birth weight was less than the 10th percentile and term LGA greater than the 90th percentile by week of gestation, using norms defined by the combination of infant gender, maternal race (black/non-black), and parity (nulliparous/multiparous) (8). We examined mean birth weight (in g) among term births as a continuous measure. Term primary Cesarean delivery excluded women with repeat Cesarean deliveries and vaginal births after Cesarean delivery, indicated on the birth certificate.

Independent Variables

GWG was calculated as delivery weight minus prepregnancy weight (as reported on the birth certificate) and then converted from pounds to kilograms. For analyses restricted to term births (SGA, LGA, continuous birth-weight, and Cesarean delivery), calculated GWG (with no normalization of gestational age in the term range) was used as a categorical measure (0–9 kg, 10–14 kg [referent], 15–19 kg, 20–40 kg). For preterm birth and its subtypes, we calculated the weekly rate of GWG (weeks of gestation at delivery divided by total weight gain), multiplied by 40 to estimate the amount of weight gain projected had the pregnancy lasted 40 weeks, and used the same category cutpoints as for GWG among term births.

BMI was computed as pre-pregnancy weight (kg) divided by height (cm) squared and categorized as underweight (BMI <18.5), normal weight (BMI 18.5 – <25), overweight (BMI 25 – <30), and obese (BMI ≥30 kg/m^2) (9).Maternal race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, Asian) was self-reported on the birth certificate. Additional maternal demographic characteristics that were modeled as a priori covariates included maternal age, number of previous live births (0, ≥ 1), education (<12 years, 12 years, >12 years), and tobacco use during pregnancy (smoker, non-smoker).

Statistical Analysis

Analyses were restricted to singleton births with complete information on all measures and were performed with SAS, Version 9.1 (SAS Institute, Cary, NC). We used unconditional logistic regression to estimate odds ratios and 95% confidence intervals (CIs) for the relation between GWG and categorical birth outcome and linear regression for the analyses of mean birthweight. The analyses of birth-weight were adjusted for gestational age within the term range because it still has a substantial influence on size at birth. For each birth outcome, we first calculated the unadjusted association and then adjusted for maternal age, parity, education, and tobacco use.

We included two-way interactions between GWG and BMI and between GWG and race/ethnicity to assess effect modification. We also fit separate models for each race/ethnicity and evaluated the product interaction between GWG and BMI to evaluate joint effects of BMI and race/ethnicity. The use of generalized additive models (10), as implemented in SAS by Gregory (11) to examine the functional relationship between GWG and birth outcomes, did not suggest considering alternative category cutpoints for GWG. As a secondary analysis, we calculated risk and risk difference measures for dichotomous outcomes.

RESULTS

Preterm birth in the aggregate (Table 1) showed a modest U-shaped relationship overall, with projected weight gain of <10 kg and 20+ kg associated with odds ratios of 1.4 and 1.3, respectively, relative to 10 to 14 kg. Stratification by BMI suggested that lower weight gain among underweight women and greater weight gain among overweight and obese women was somewhat more strongly associated with increased risk, with odds ratios in the range of 1.4 to 1.7. Stratification by ethnicity provided little indication of effect modification. Given the elevated baseline risk of preterm birth among obese women and non-Hispanic black women, the risk differences for these groups with low and high GWG are more pronounced than suggested by the risk ratios, for instance, obese women gaining 20+ kg had an increase of 5.0 per 100 in preterm births relative to those gaining 10 to 14 kg (data not shown).

The patterns found for preterm birth in the aggregate were stronger for earlier preterm birth (Table 2). The U-shaped relationship was more pronounced overall and within BMI groups. The association between *low* GWG and preterm birth was most notably enhanced for early preterm birth. Division by clinical presentation (spontaneous vs. medically indicated; Table 2) showed a distinctive pattern of interaction with prepregnancy BMI. Underweight women with low weight gain and overweight women with high weight gain were at notably increased risk for medically indicated preterm birth relative to the pattern found for spontaneous preterm birth. For underweight women, there was essentially no relationship between GWG and spontaneous preterm birth. The patterns for spontaneous and medically indicated preterm birth did not differ by ethnicity.

Term SGA (Table 3) showed a strong, monotonic decrease in risk with increasing GWG. Although relative risks were similar across BMI categories, the baseline risks of SGA vary markedly by BMI so that the risk difference between lowest and greatest GWG levels ranged from 15.4 cases per 100 among underweight women to 3.9 cases per 100 among obese women (data not shown). Relative risks were similar for SGA across ethnic groups (Appendix table), with risk differences varying in relation to the baseline risk (higher baseline risk yielding larger risk differences; data not shown). Underweight African-American women who gained <10 kg were at increased risk compared with their non-Hispanic white counterparts, with adjusted odds ratios of 2.2 (95% CI, 0.9–5.8) and 1.0 (95% CI, 0.5–1.9) for African-American women and non-Hispanic white women, respectively comparing 0- to 9-kg weight gain versus 10- to 14-kg weight gain among underweight women (data not shown). The opposite pattern of increasing risk with increasing GWG was found for term LGA (Table 3). Although there were some fluctuations by BMI and ethnicity in relative risks, risk differences suggested similar absolute effects across these strata (data not shown). Mean birthweight at term (Table 4) showed a gradient of more than 200 g from lowest to highest GWG categories, even more extreme for underweight women (353 g), but clear and consistent across all BMI and ethnic groups.

Cesarean delivery showed a monotonic gradient in the same direction found for LGA but with a much reduced magnitude of effect, with little indication for reduced risk among those with low GWG (Table 5). Among women with greater GWG, there remained clear increased risk relative to those with lower GWG, possibly more pronounced among women with lower prepregnancy BMI.

DISCUSSION

The results of this study extend previous work on the consequences of GWG on infant health outcomes as summarized recently (1, 3). The U-shaped relationship of GWG to preterm birth identified by others was found in the present study, although it was modest in magnitude relative to most other studies (12–15). The pattern was enhanced for more severe preterm birth, as noted by others (16, 17), adding to its potential clinical significance. Our finding that the association of low GWG with preterm birth was strongest among women with lower prepregnancy BMI is consistent with some previous literature (12–14, 16) but counter to a recent study among African-American women in which the authors found GWG below recommendations was associated with increased risk of preterm birth only among obese women (15).

We found stronger evidence for an enhanced risk of preterm birth with high GWG among overweight and obese women, which also was found by investigators (14–16), but not observed by Rudra et al. (18) in a study focused on pregnancy weight gain before 22 weeks' gestation. Given that the number of women with both elevated BMI and excessive GWG is substantial and appears to be increasing over time (19), the high end of the U-shaped association warrants at least as much concern as the lower part. The marked enhancement of the increased risk of preterm birth among high GWG women for medically indicated preterm births is consistent with the reduction in association for high GWG found by Dietz et al. (16) when births with hypertension or diabetes were excluded. Although this finding points towards specific complications of pregnancy as potentially important, it does not resolve the complex question of causal sequence: do the evolving pregnancy complications that give rise to medically indicated preterm birth manifest themselves through increases in GWG (e.g., edema related to increased blood pressure), or does high GWG in overweight/obese women cause the complications that lead to medically indicated preterm birth? The authors of two studies considered preterm birth subtypes in detail (12, 18) and found that only high early pregnancy GWG among normal weight women was associated with increased risk of medically indicated preterm birth. Low GWG was associated with a reduced risk of spontaneous preterm birth, suggesting that the left side of the U-shaped curve may be due to spontaneous preterm birth and the right side due to medically indicated preterm birth, but the research remains limited.

The pattern of association between GWG and preterm birth stratified by ethnicity generally showed similar patterns across groups. The few studies that have considered ethnic variation in the impact of GWG have generally corroborated this absence of substantial differences (15, 20–22). A more detailed consideration of ethnicity would require a larger population to support joint stratification by ethnicity and BMI, and the opportunity to examine more homogeneous ethnic subsets, for instance, Dominicans, East Asians.

Our results for fetal growth, measured as SGA/LGA and mean birthweight, build upon a much larger, more robust set of findings (1, 3). We corroborated the finding of a shift in the distribution corresponding with variation in GWG: more weight gain is associated with larger infants. The association with SGA is similar to that for preterm birth, whereas the association with LGA is much greater in magnitude. The association between low GWG and SGA was stronger among underweight women and the association between high GWG and LGA was greater among overweight/obese women (3, 23). Our study adds to the increasingly clear evidence that the impact of GWG is on the continuum of fetal growth, not just on the low end (as implied by the traditional focus on SGA) or high end (as suggested by a focus on LGA and its sequelae, including Cesarean section). Demonstrating that there are some direct clinical consequences of increased GWG, Cesarean delivery was monotonically related to GWG, though with a less pronounced gradient than was found for risk of LGA. This relationship is similar to that reported in a number of studies compiled by Viswanathan et al. (3). In contrast to the studies that suggested a weaker relationship among overweight and obese women (24, 25), we found similar relative risks across the range of BMI except perhaps an enhanced association among underweight women but limited by imprecision.

The population that was included in this analysis is large but limited by the restriction to New York City residents who delivered in hospitals located in New York State, but outside New York City. This is a small fraction of all births to New York City residents, and overrepresents women who live nearer to hospitals in Westchester and on Long Island, with resulting shifts in the distribution of demographic characteristics and health outcomes. The unusually high proportion with birth defects (11.3%; excluded from this analysis) likely reflects the tendency for women whose infants are known to have health problems to deliver at more distant hospitals. However, in order for this selection to distort associations between GWG and pregnancy outcome, there would need to be joint effects on both, i.e., overrepresentation of women with both higher (or lower) GWG and more favorable (or less favorable) pregnancy outcomes (26, 27). A shift in either the distribution of GWG alone, a shift in the pregnancy outcome alone, or even an independent shift in both GWG and pregnancy outcome would not distort measures of association. Although this is possible, for subtle reasons or even by chance, and tempers confidence in our findings, there is no obvious reason to believe that it is likely to have occurred.

Although our study was based on a large population, more than 30,000 births, the interest in studying effect modification by BMI and ethnicity, individually and jointly, results in imprecision, particularly for some of the key combinations of prepregnancy BMI and GWG of interest. Although we were able to consider ethnicity, more work is needed to determine whether the implications of GWG for infant health outcomes are universal. The information we had to estimate GWG was self-reported prepregnancy weight, known to be a fallible measure (28). Given that measured weight before conception is extremely difficult to obtain, a preferred approach might be to have measured weight early in prenatal care, but that depends on early entry into care. The impact of underreporting prepregnancy weight on both BMI (understated) and GWG (overstated) does not lead to a clear prediction regarding the potential bias in associations with adverse pregnancy outcomes. Also, because we did not have longitudinal information on weight during pregnancy, we could only consider the total amount of gain and make adjustments for varying duration of pregnancy. We assumed a linear increase in weight in extrapolating to a 40-week pregnancy even though growth is concentrated in the later part of pregnancy, introducing error into the comparisons of interest. In addition, there are well-known limitations in the quality of birth certificate data in measuring gestational age based on last menstrual period, but we relied on clinical gestational age estimates which appear to be superior (29). In addition, we attempted to classify preterm births as medically indicated or spontaneous, recognizing that any such algorithm based on incomplete information is subject to erroneous assignment, limiting the certainty of these results.

The primary inherent limitation in our study and essentially all those that precede it is uncertainty about whether observed associations are causal. Although GWG is modifiable through altered energy balance, it is also a consequence or marker of underlying health of the pregnancy. For example, edema is a common symptom of pregnancy associated with pregnancy-induced hypertension, and of course related to greater weight gain. Plasma volume expansion is a marker of the course of pregnancy and affects weight gain. Beyond underlying pathophysiology, appetite and activity levels during pregnancy are influenced by psychosocial well-being, tobacco use, economic conditions, cultural attitudes about pregnancy, and related considerations. For all these reasons, the causal effect of GWG on outcome may well be confounded by correlated medical conditions, psychosocial factors, and lifestyle factors. Although we and others have adjusted for known, available potential confounders, there is a compelling need for randomized trials that can experimentally seek to optimize weight gain and observe the impact on pregnancy outcome. The results of small randomized trials (30, 31) suggest that excessive weight gain can be reduced through intervention and that doing so has the predicted consequences on maternal physiology and infant size at birth, encouraging continued focus on the potential causal significance of the data linking GWG to pregnancy outcome. Even small trials can address the impact on fetal growth, given how strong the observed associations are, although much larger trials would be needed to determine the impact on preterm birth.

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Selected Abbreviations and Acronyms

GWG	gestational weight gain
BMI	body mass index
LGA	large-for-gestational-age
SGA	small-for-gestational-age
CI	confidence interval

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TABLE 1

Odds ratios and 95% confidence intervals for the association of 40-week projected gestational weight gain* with preterm birth (<37 weeks' gestation) among singleton births to New York City residents delivering in New York State, 1995 to 2003, n = 33,872

	40-Week projected gestational weight gain							
	Cases, n	**0–9 kg**	**Cases, n**	**10–14 kg**	**Cases, n**	**15–19 kg**	**Cases, n**	**20+ kg**
Overall, unadjusted	516	1.4 (1.2–1.5)	764	1.0	630	1.1 (1.0–1.2)	461	1.3 (1.2–1.5)
By BMI† (GWG* BMI *p* = .05)								
Underweight	20	1.5 (0.9–2.6)	51	1.0	51	1.4 (0.9–2.1)	22	1.0 (0.6–1.7)
Normal weight	204	1.5 (1.2–1.7)	409	1.0	362	1.1 (1.0–1.3)	238	1.3 (1.1–1.5)
Overweight	134	1.1 (0.9–1.4)	186	1.0	141	1.1 (0.9–1.4)	121	1.4 (1.1–1.8)
Obese	158	1.1 (0.9–1.4)	118	1.0	76	1.2 (0.9–1.6)	80	1.7 (1.3–2.3)
By race/ethnicity† (GWG * race *p* = .53)								
Non-Hispanic white	161	1.2 (1.0–1.5)	277	1.0	239	1.1 (0.9–1.3)	197	1.5 (1.2–1.8)
Non-Hispanic black	233	1.3 (1.1–1.6)	275	1.0	232	1.3 (1.0–1.5)	169	1.3 (1.1–1.7)
Hispanic	86	1.2 (0.9–1.6)	125	1.0	95	1.0 (0.8–1.3)	74	1.1 (0.8–1.4)
Asian	36	1.0 (0.7–1.5)	87	1.0	64	1.1 (0.7–1.5)	21	1.0 (0.6–1.6)

BMI = body mass index; GWG = gestational weight gain.

* 40-week projected gestational weight gain is the average weekly gestational weight gain multiplied by 40 to approximate the amount of weight that would have been gained had all women delivered at 40 weeks

† Adjusted for BMI, race/ethnicity, maternal age, parity, education, tobacco.

TABLE 2

Odds ratios and 95% confidence intervals for the association of 40-week projected gestational weight gain* with preterm birth subsets among singleton births to New York City residents delivering in New York State, 1995 to 2003, n = 33,872

	40-Week projected gestational weight gain							
	Cases, n	0–9 kg	Cases n	10–14 kg	Cases, n	15–19 kg	Cases, n	20+ kg
Preterm birth 26–33 weeks and 34–36 weeks vs. term birth ≥37 weeks								
Overall, unadjusted								
26–33 weeks	162	1.8 (1.4–2.2)	184	1.0	151	1.1 (0.9–1.4)	115	1.4 (1.1–1.7)
34–36 weeks	354	1.2 (1.1–1.4)	580	1.0	479	1.1 (1.0–1.3)	346	1.3 (1.1–1.5)
By BMI† (GWG * BMI p = .06)								
26–33 weeks								
Underweight	6	2.2 (0.8–6.1)	10	1.0	12	1.6 (0.7–3.8)	6	1.3 (0.5–3.7)
Normal weight	61	2.0 (1.5–2.9)	85	1.0	81	1.2 (0.9–1.7)	49	1.2 (0.9–1.7)
Overweight	39	1.0 (0.7–1.5)	58	1.0	44	1.1 (0.7–1.6)	43	1.6 (1.1–2.4)
Obese	56	1.5 (1.0–2.4)	31	1.0	14	0.8 (0.4–1.5)	17	1.4 (0.8–2.5)
34–36 weeks								
Underweight	14	1.3 (0.7–2.5)	41	1.0	39	1.3 (0.8–2.1)	16	0.9 (0.5–1.7)
Normal weight	143	1.3 (1.1–1.6)	324	1.0	281	1.1 (0.9–1.3)	189	1.3 (1.0–1.5)
Overweight	95	1.1 (0.9–1.5)	128	1.0	97	1.1 (0.8–1.4)	78	1.3 (1.0–1.7)
Obese	102	1.0 (0.7–1.3)	87	1.0	62	1.3 (0.9–1.8)	63	1.9 (1.3–2.6)
Spontaneous preterm birth and medically indicated preterm birth vs. term birth ≥37								
Overall, unadjusted								
Spontaneous preterm birth	383	1.4 (1.2–1.6)	545	1.0	447	1.1 (1.0–1.3)	318	1.3 (1.1–1.5)
Medically indicated preterm birth	133	1.2 (1.0–1.5)	219	1.0	183	1.1 (0.9–1.4)	143	1.4 (1.2–1.8)
By BMI† (GWG * BMI p = .05)								
Spontaneous preterm birth								
Underweight	11	1.0 (0.5–2.0)	42	1.0	39	1.3 (0.8–2.0)	17	0.9 (0.5–1.7)
Normal weight	157	1.6 (1.3–2.0)	286	1.0	252	1.1 (0.9–1.3)	163	1.2 (1.0–1.5)
Overweight	106	1.2 (0.9–1.6)	130	1.0	104	1.1 (0.9–1.5)	84	1.4 (1.0–1.8)
Obese	109	1.1 (0.8–1.4)	87	1.0	52	1.1 (0.7–1.5)	54	1.6 (1.1–2.3)
Medically indicated preterm birth								

	40-Week projected gestational weight gain							
	Cases, n	0–9 kg	Cases n	10–14 kg	Cases, n	15–19 kg	Cases, n	20+ kg
Underweight	9	3.7 (1.4–9.5)	9	1.0	12	1.8 (0.8–4.4)	5	1.3 (0.4–4.0)
Normal weight	47	1.1 (0.8–1.6)	123	1.0	110	1.1 (0.9–1.5)	75	1.3 (1.0–1.8)
Overweight	28	0.8 (0.5–1.2)	56	1.0	37	0.9 (0.6–1.5)	37	1.4 (0.9–2.2)
Obese	49	1.3 (0.8–2.1)	31	1.0	24	1.4 (0.8–2.4)	26	2.1 (1.3–3.7)

BMI = body mass index; GWG = gestational weight gain; PROM = premature rupture of membranes.

* 40-week projected gestational weight gain is the average weekly gestational weight gain multiplied by 40, to approximate the amount of weight that would have been gained had all women delivered at 40 weeks.

† Adjusted for BMI, race/ethnicity, maternal age, parity, education, tobacco.

TABLE 3

Odds ratios and 95% confidence intervals for the association of gestational weight gain with term small and large for gestational age among singleton births to New York City Residents delivering in New York State, 1995 to 2003, n = 31,501

	Gestational weight gain							
	Cases (n)	**0–9 kg**	**Cases (n)**	**10–14 kg**	**Cases (n)**	**15–19 kg**	**Cases (n)**	**20+ kg**
Term small-for-gestational age								
Overall, unadjusted	742	1.3 (1.1–1.4)	1,123	1.0	584	0.7 (0.7–0.8)	238	0.5 (0.4–0.6)
By BMI* (GWG * BMI *p* = .37)								
Underweight	41	1.5 (1.0–2.3)	112	1.0	60	0.7 (0.5–1.0)	15	0.3 (0.2–0.6)
Normal weight	388	1.5 (1.3–1.7)	762	1.0	407	0.7 (0.6–0.8)	151	0.5 (0.4–0.6)
Overweight	171	1.3 (1.1–1.7)	184	1.0	84	0.6 (0.5–0.8)	51	0.6 (0.4–0.8)
Obese	142	1.8 (1.3–2.4)	65	1.0	33	0.9 (0.6–1.4)	21	0.9 (0.5–1.4)
Term large-for-gestational age								
Overall, unadjusted	458	0.9 (0.8–1.0)	979	1.0	925	1.4 (1.3–1.5)	859	2.5 (2.3–2.7)
By BMI* (GWG * BMI *p* = .01)								
Underweight	2	0.4 (0.1–1.8)	16	1.0	17	1.6 (0.8–3.2)	25	5.1 (2.7–9.7)
Normal weight	113	0.7 (0.6–0.9)	451	1.0	489	1.5 (1.3–1.7)	458	2.9 (2.5–3.3)
Overweight	125	0.6 (0.5–0.7)	293	1.0	251	1.3 (1.1–1.6)	243	2.2 (1.8–2.7)
Obese	218	0.7 (0.6–0.9)	219	1.0	168	1.5 (1.2–1.9)	133	1.9 (1.5–2.5)

BMI = body mass index; GWG = gestational weight gain.

*Adjusted for BMI, race/ethnicity, maternal age, parity, education, tobacco use.

TABLE 4

Change in mean adjusted birth weight (g) and 95% confidence interval by gestational weight gain among singleton births to New York City residents delivering in New York State, 1995 to 2003, n = 31,501

	Gestational weight gain			
	0–9 kg	**10–14 kg***	**15–19 kg**	**20+ kg**
Overall, adjusted for gestational age only	−45.9 (−59.2, −32.6)	3039.4 (3022.9–3055.9)	72.4 (60.2–84.5)	173.5 (158.8–188.2)
By BMI† (GWG * BMI *p* = .34)				
Underweight	−111.5 (−182.3, −40.8)	2861.0 (2823.2–2898.7)	91.2 (39.7–142.7)	241.6 (176.3–306.9)
Normal weight	−84.6 (−103.4, −65.9)	2974.5 (2953.5–2995.6)	79.1 (64.4–93.9)	181.5 (163.3–199.7)
Overweight	−79.0 (−104.5, −53.4)	3055.2 (3030.0–3080.4)	86.3 (60.6–111.9)	198.8 (169.1–228.5)
Obese	−85.4 (−115.4, −55.4)	3156.4 (3126.7–3186.0)	71.5 (33.7–109.3)	139.4 (95.9–183.0)
By race/ethnicity* (GWG * race *p* = .83)				
Non-Hispanic white	−72.8 (−92.1, −53.6)	2968.8 (2947.3–2990.3)	85.1 (68.5–101.8)	192.1 (172.0–212.1)
Non-Hispanic black	−84.8 (−108.8, −60.7)	2856.0 (2832.1–2879.9)	76.0 (52.1–99.9)	176.5 (148.5–204.5)
Hispanic	−97.9 (−131.9, −64.0)	2926.1 (2898.9–2953.3)	79.9 (48.3–111.5)	166.1 (130.2–202.0)
Asian	−103.5 (−143.0, −64.0)	2865.1 (2836.7–2893.6)	70.7 (36.2–105.3)	198.4 (145.3–251.5)

BMI = body mass index.

*Mean birthweight and 95% confidence interval for GWG of 10–14 kg.

†Adjusted for BMI, race/ethnicity, maternal age, parity, education, tobacco, and gestational age.

TABLE 5

Odds ratios and 95% confidence intervals for the association of gestational weight gain with term primary cesarean section* (versus vaginal delivery) among singleton births to New York City residents delivering in New York State, 1995 to 2003, n = 27,406

	Gestational weight gain							
	No. cases	0–9 kg	No. cases	10–14 kg	No. cases	15–19 kg	No. cases	20+ kg
Overall, unadjusted	936	0.9 (0.9–1.0)	1,875	1.0	1,567	1.2 (1.1–1.3)	1,124	1.7 (1.6–1.9)
By BMI† (GWG * BMI *p* = .34)								
Underweight	13	0.7 (0.4–1.3)	63	1.0	72	1.6 (1.1–2.3)	41	2.0 (1.3–3.2)
Normal weight	336	0.9 (0.8–1.1)	1,068	1.0	940	1.2 (1.1–1.3)	640	1.6 (1.4–1.8)
Overweight	259	0.8 (0.7–1.0)	440	1.0	346	1.1 (0.9–1.3)	280	1.4 (1.2–1.7)
Obese	328	0.8 (0.7–1.0)	304	1.0	209	1.3 (1.1–1.7)	163	1.5 (1.1–1.9)
By race/ethnicity † (GWG * race *p* = .52)								
Non-Hispanic white	358	0.8 (0.7–1.0)	824	1.0	760	1.2 (1.1–1.4)	559	1.6 (1.4–1.8)
Non-Hispanic black	336	0.9 (0.8–1.1)	525	1.0	396	1.2 (1.0–1.4)	297	1.6 (1.3–1.9)
Hispanic	157	0.9 (0.7–1.2)	283	1.0	234	1.1 (0.9–1.4)	188	1.3 (1.1–1.7)
Asian	85	0.8 (0.6–1.1)	243	1.0	177	1.1 (0.8–1.3)	80	1.8 (1.3–2.4)

*Primary Cesarean excludes 940 term vaginal births after Cesarean delivery and 3,315 term repeat cesarean deliveries.

†Adjusted for BMI, race/ethnicity, maternal age, parity, education, tobacco.