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Gestational Weight Gain and Obesity: Is 20 Pounds Too Much?

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Abstract

Objective—To compare maternal and neonatal outcomes in obese women according to weight change and obesity class.

Study design—Cohort study from the Consortium on Safe Labor of 20,950 obese women with a singleton, term, livebirth from 2002–2008. Risk for adverse outcomes was calculated by multiple logistic regression analysis for weight change categories [weight loss (<0kg), low (0–4.9kg), normal (5.0–9.0kg), high weight gain (>9.0 kg)] in each obesity class (I 30.0–34.9kg/m², II 35.0–39.9kg/m², and III ≥40 kg/m²) and by predicted probabilities with weight change as a continuous variable.

Results—Weight loss was associated with decreased cesareans for class I women (nulliparas OR 0.21, 95%CI 0.11–0.42; multiparas OR 0.61, 95%CI 0.45–.83) and increased small for gestational age (SGA) infants (class I OR 1.8, 95%CI 1.3–2.5; class II OR 2.2, 95%CI 1.5–3.2; class III OR 1.7, 95%CI 1.1–2.6). High weight gain was associated with increased large for gestational age (LGA) infants (class I OR 2.4, 95%CI 1.9–2.9; class II OR 1.7, 95%CI 1.3–2.1; class III OR 1.6, 95%CI 1.3–2.1). As weight change increased, the predicted probability for cesareans and LGA infants increased. The predicted probability of low birth weight never exceeded 4% for all obesity classes, but SGA increased with decreased weight change. The lowest average predicted

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probability of adverse outcomes (cesarean, postpartum hemorrhage, SGA, LGA, NICU admission) occurred when women (class I,II,III) lost weight.

Conclusion—Optimal maternal and neonatal outcomes appear to occur when weight gain is less than current IOM recommendations for obese women. Further study of long-term outcomes is needed with respect to gestational weight changes.

Keywords

obesity; pregnancy; gestational weight gain; maternal and neonatal outcomes

Introduction

Obesity has reached epidemic proportions, estimated at 35.7% for adults in the United States.¹ The prevalence of obese reproductive age women (20–39 years) increased by 64% between 1988–1994 and 2007–2008, accounting for the greatest increase in obesity for women of any age category.² The obesity epidemic and its associated obstetrical and neonatal complications has highlighted the issue of gestational weight gain (GWG). Regardless of maternal weight status, high GWG has been associated with both maternal (e.g., cesarean deliveries, long-term weight retention) and offspring risks (e.g., larger infants, childhood obesity).^{3–8} Although the evidence is less consistent, an association between higher GWG and gestational diabetes and preeclampsia has also been reported.^{9–12} On the other hand, low GWG and weight loss have also been associated with maternal ketonemia and fetal growth restriction.¹³

According to conventional wisdom, pregnancy is a time for weight gain, not for dieting or weight loss. Typically, an additional 300 calories per day is recommended for appropriate fetal growth and this was reflected in the 1990 Institute of Medicine report on Nutrition During Pregnancy.¹⁴ More recently, in 2009, the Institute of Medicine published revised guidelines for GWG. Important updates included a range of 5–9kg (or 11–20lbs) for GWG in obese women, defined by a prepregnancy body mass index (BMI) $\geq 30\text{kg/m}^2$. This differed from the prior recommendation of “at least 15 pounds.”¹³ Notably, all obese women, were grouped into one category as a result of insufficient data from women in individual obesity classes (i.e. obesity classes I–III) and the inability to draw statistically sound conclusions for GWG for the separate obesity classes. Behavioral interventions for women who are obese at conception have shown some success at meeting GWG recommendations,¹⁵ but limited evidence suggests that lower GWG or weight loss (i.e. gestational weight change) in this population may improve maternal and neonatal outcomes.^{12,16,17} Given the nationwide rise in obesity as well as the influence of GWG on maternal and neonatal outcomes, we hypothesized that the current recommendations (up to a 20 pound weight gain) were too high for obese women and required closer scrutiny into each of the obesity classes. The objective of our investigation was to evaluate maternal and neonatal outcomes at birth in obese women by weight change and BMI class.

Materials and Methods

The Consortium on Safe Labor is a retrospective, observational, electronic database acquired from 12 institutions (19 hospitals) across 9 American College of Obstetricians and Gynecologists (ACOG) districts in the United States. The complete database contains 233,730 births resulting from 228,562 deliveries. Although the data were collected from 2002 to 2008, 87% of the births in the database occurred between 2005 and 2007. Extensive data were collected on each delivery including demographics, prenatal complications, labor and delivery information, and maternal and neonatal outcomes. Validation studies on four

outcomes (shoulder dystocia, cesarean delivery for non-reassuring fetal heart rate, neonatal intensive care unit [NICU] admission for respiratory conditions, and neonatal asphyxia) were performed by hand-abstraction of eligible charts. Most variables reviewed were highly accurate when comparing data from the electronic database and the hand-abstraction. Further detail regarding the database is available.^{18,19}

Inclusion criteria for the current study were a prepregnancy BMI $\geq 30\text{kg/m}^2$ and known gestational weight change in a singleton, term (≥ 37.0 weeks), live-born gestation. If a woman contributed more than one pregnancy to the database, only the first pregnancy was analyzed to maintain the independence of the observations. Class I-III obesity was defined according to the World Health Organization (WHO) criteria as class I $30.0\text{--}34.9\text{kg/m}^2$, class II $35.0\text{--}39.9\text{kg/m}^2$, and class III $\geq 40\text{kg/m}^2$.²⁰ Weight change was defined as the difference between the self-reported prepregnancy weight and delivery weight. The weight change categories were defined as weight loss, low ($0\text{--}4.9\text{kg}$), normal ($5.0\text{--}9.0\text{kg}$), and high ($>9.0\text{kg}$). The weight change categories were chosen for their simplicity, ease of clinical use, and were also modeled after those of another investigation.²¹ Although the range of gestational weight change was -55kg to 77kg in the current cohort, this range was restricted to -20kg to 50kg to reflect a more clinically plausible value, also similar to the range chosen in another study.²² In doing so, only 70 women or 0.3% of the cohort was excluded.

Maternal demographics and characteristics included age, race/ethnicity, marital status, insurance, parity, smoking status, prior cesarean delivery, pregestational diabetes, chronic hypertension, and gestational age at delivery. The primary maternal outcomes were operative vaginal delivery, cesarean delivery, and postpartum hemorrhage. The primary neonatal outcomes were birth weight, shoulder dystocia, 5 minute Apgar score <7 , and NICU admission. Small and large for gestational age infants (SGA, LGA) were defined by birth weights $<10^{\text{th}}$ or $>90^{\text{th}}$ %, respectively, for the gestational age at birth.²³ Low birth weight (LBW) and macrosomia were defined by birth weights $<2500\text{g}$ or $>4500\text{g}$, respectively.

All analyses were stratified by obesity class (I, II, III). For the maternal demographics and characteristics, Pearson Chi-square and analysis of variance tests were used to statistically compare the association between categorical and continuous variables, respectively, and weight change category. A P-value <0.05 was considered statistically significant. Through multiple logistic regression analysis, adjusted odds ratios (aOR) with 95% confidence intervals (CI) were generated for each maternal and neonatal outcome in each of the weight change categories, using $5.0\text{--}9.0\text{kg}$ as the referent, for each obesity class and adjusting for age, race/ethnicity, marital status, insurance, parity, smoking, and gestational age. To clarify the potential maternal and neonatal risks and benefits of weight change, logistic regression models were created with weight change as a continuous variable (kg) for each BMI class. The estimated logistic regression coefficients then determined the predicted probabilities for each of the maternal and neonatal outcomes, similar to the analysis approach of another study.²⁴ The average predicted probability of five outcomes (cesarean, postpartum hemorrhage, SGA, LGA, and NICU) was then calculated over a weight change of -20kg to $+50\text{kg}$. These outcomes were chosen for their clinical relevance or the apparent association between gestational weight change in the logistic regression models and the individual predicted probabilities. Given that each of these five outcomes increased with increased weight change except for SGA, we performed a sensitivity analysis weighting SGA (2–5 times) to determine how varying the importance of this outcome would influence the average predicted probability.

To further determine the potential immediate neonatal risk associated with either weight loss or low GWG, we analyzed neonatal outcomes for SGA infants born to women with weight

loss or low (0–4.9kg) weight gain and compared them to SGA infants born to women with normal (5.0–9.0kg) weight gain using Chi-square or Fisher's exact tests. The following neonatal outcomes were reported for this analysis: respiratory distress syndrome (RDS), transient tachypnea of the newborn (TTN), use of ventilators, oxygen or CPAP (continuous positive airway pressure), pneumonia, meconium aspiration, anemia, sepsis, asphyxia, congenital anomalies, NICU admission, and death. All statistical analyses were performed with SAS software (version 9.2, Cary, N.C.) using primarily LOGSTIC and GLM procedures. Appropriate Institutional Review Board approval was obtained from all the participating institutions.

Results

From the 228,562 deliveries in the entire database, 20,950 obese women (11,984 class I, 5,307 class II, and 3,659 class III) were studied (Figure 1). Of the 57 stillbirths, which were excluded from the remainder of the analysis, 70% occurred in those with high weight gain and none occurred in those who lost weight. There were differences among the weight change categories with respect to age, race/ethnicity, marital status, insurance, parity, smoking, and prior cesarean, $P = 0.001$ (Table 1). This analysis was stratified by obesity class and the differences in the comparisons persisted for each obesity class, $P < 0.02$ (data not shown). The mean ($\pm$ SD) GWG was 12.5 ± 7.6 kg class I, 10.6 ± 8.1 kg class II, and 8.9 ± 8.9 kg class III, $P < 0.001$. Weight loss was most common in class III (12%) and high weight gain was most common in class I women (69%). For women who lost weight, the mean ($\pm$ SD) weight loss was -4.8 ± 4.5 kg, -4.6 ± 4.3 kg, and -5.6 ± 4.2 kg for class I, II, and III, respectively. The proportion of women gaining within the 2009 Institute of Medicine recommended guidelines (5–9kg) was 17% for all obesity classes.

The adjusted ORs for the maternal and neonatal outcomes from the multiple logistic regression analysis are presented in Tables 2 and 3, respectively. Cesareans decreased for class I women who lost weight, but increased in women with high weight gain in most BMI classes, compared to normal weight gain. Operative vaginal delivery and postpartum hemorrhage did not differ from normal weight gain in all obesity classes. SGA infants increased for women in all obesity classes who lost weight whereas LGA and macrosomia increased with high weight gain in most obesity classes, compared to normal weight gain. Shoulder dystocia and 5 minute Apgar < 7 did not differ from normal weight gain in all obesity classes.

The predicted probability of cesarean increased linearly as weight change increased for all obesity classes whereas operative vaginal delivery and postpartum hemorrhage did not vary significantly with weight change (Figures 2a–c). The predicted probabilities of SGA decreased as weight change increased whereas LGA and macrosomia increased exponentially with increased weight change. Shoulder dystocia, 5 minute Apgar < 7 , and NICU admissions showed a less pronounced increase as weight change increased for all obesity classes (Figures 3a–c). The predicted probability of LBW was always $< 4\%$ for all the obesity classes. The average predicted probability of five maternal and neonatal outcomes (Figure 4) shows that the lowest probability of these outcomes occurred at weight loss in all obesity classes. In the sensitivity analysis of varying weights for SGA, weight gain was associated with the lowest average predicted probability only when SGA was weighted four times for class I (lowest predicted probability of 10.6% at 5.0kg), three times for class II (lowest predicted probability of 12.4% at 4.5kg), and five times for class III (lowest predicted probability of 13.1% at 2.9kg) obese women (Figure 5). There were no differences in neonatal outcomes for SGA infants born to women with either low weight gain or weight loss for each BMI class compared to those with normal weight gain, $P = 0.05$ (Table 4). The occurrence of these outcomes was rare and the numbers were too small to

perform statistical analysis within each obesity class, so comparisons were reported for all obesity classes combined.

Comment

In our investigation of 20,950 obese women, several maternal and neonatal outcomes improved for obese women who lost weight during pregnancy, with up to 77% reduction in cesarean deliveries and up to 52% reduction in LGA infants compared to women who gained 5–9kg. However, a prepregnancy BMI ≥ 30 kg/m² does not appear to protect these women from having a SGA infant given that the odds for a SGA infant nearly doubled in all women who lost weight. It is noteworthy that low weight gain was not associated with SGA in obese women. Our data also confirm the risks of high GWG in obese women (e.g., increased cesareans, LGA infants, macrosomia).^{12,21,24–26} Based on the average predicted probabilities, immediate adverse outcomes are lowest when weight loss occurs for all obesity classes, with the effect most pronounced for class III women. According to the sensitivity analysis which weighted SGA differently, SGA would need to be weighted 3–5 times in the predicted probability models to make any weight gain better than weight loss when evaluating the outcomes of cesarean delivery, postpartum hemorrhage, SGA, LGA, and NICU admission in obese women. The analysis of weight change as a categorical and continuous variable in a large heterogeneous population from the United States is unique in deriving these findings.

This information is timely with the Institute of Medicine's shift in focus from preventing LBW (1990 Nutrition During Pregnancy) to addressing contemporary issues related to perinatal outcomes in the United States such as increased maternal age, complications during pregnancy, racial diversity, the global increase in BMI, and very importantly, increased GWG (2009 Reexamining the Guidelines).^{13,14} However, our data suggest that the existing guidelines should be further refined for obese women. Since the publication of the 2009 IOM guidelines, several studies have also suggested that obese women and their neonates may benefit from limiting weight gain^{21,24–27} or even losing weight^{21,23,24,26} during pregnancy. In one study, a weight loss of 0.19kg/week was associated with the lowest predicted occurrence of adverse maternal and neonatal outcomes (preterm delivery, SGA, LGA, childhood obesity, maternal long-term weight retention) for obese women which translates to a weight loss of 7.6kg at term for obese women.²⁷ Beyerlein et al noted that optimal neonatal outcomes (e.g., SGA, LGA) occurred with a weight loss of up to 15kg in obese women.²² Similar to our study, Blomberg showed a 23–44% decrease in cesareans for obese women who lost weight during pregnancy.²¹ Given that the cesarean delivery rate reached an all-time high of 32.9% in 2009²⁸ and obese women are at very high risk for cesarean delivery,²⁹ the public health implications of reducing GWG may include curbing the cesarean delivery rate in obese women.

Because lower GWG may result in lower birth weights (e.g., LBW or SGA), it is important to balance the maternal benefits with neonatal risks especially if the etiology for the lower birth weight could be attributed to nutritional deprivation or metabolic changes in-utero. One investigation reported only 4% SGA infants in women with a BMI >35 kg/m² who either lost weight or did not gain weight during pregnancy.³⁰ Furthermore, Lapolla et al reported no differences in the number of SGA infants when comparing pregnancies after bariatric surgery to either obese women without bariatric surgery or normal weight women. This was also true in a group of women who lost weight during the pregnancy after bariatric surgery – 0% SGA in the weight loss group compared to 2.9% in the group gaining 0–10kg.³¹ In a randomized clinical trial of a balanced nutritional regimen (e.g., nutritional counseling, food diaries) for 232 obese women, 57 women in the intervention arm who gained <10 pounds during pregnancy had fewer occurrences of gestational diabetes (5.3% vs. 15.4% , $P<0.05$)

and similar mean birth weights (3437 ± 475 vs. 3594 ± 612 g, $P=0.06$) compared to the control group.¹⁷ Maternal and neonatal outcomes were not reported separately for the 23 women who lost weight during the pregnancy. Our data, as well as others, suggest that immediate neonatal outcomes are not adversely affected with lower weight gains or a small amount of weight loss.

We recognize several limitations to the study. Our database did not contain information about the circumstances of the weight loss (e.g. intentional, a result of a pregnancy complication, or severe maternal illness) or data about the long-term physical or neurocognitive development of infants after discharge from the hospital. We have documented that stillbirths were absent in obese women who lost weight and that other neonatal morbidities and mortality were rare in SGA infants of women with low weight gain or weight loss (Table 4). If low GWG or weight loss were to increase the risk for future complications (e.g., adult chronic diseases such as hypertension or diabetes in the offspring), these consequences would impact GWG guidelines as well; however, data on these types of long-term outcomes are not currently available. Further study of long-term outcomes including childhood and adolescent obesity in offspring of obese women with low GWG or weight loss (and its quantity) during pregnancy, is needed.

This database uses self-reported weight, which is more likely to be inaccurate in women with higher BMI's who might underestimate prepregnancy weight resulting in information bias including underrepresentation of women who lost weight and over reporting of women with high weight gains.³⁴ Given the number of women missing either prepregnancy weight or height data (Figure 1), we performed a sensitivity analysis that compared maternal demographics and characteristics between those with a missing and non-missing BMI. There were no significant differences between age, parity, smoking, prior cesarean, pregestational diabetes, chronic hypertension, or weight change between these two groups. However, non-Hispanic blacks had the most missing BMIs (39%) compared to non-Hispanic whites (30%) and Hispanics (27%), $p<0.001$. Since the prevalence of obesity is highest in non-Hispanic black women,¹² we may have introduced bias in excluding women with a missing BMI. However, there was no systematic explanation for the missing data (e.g., not specific to a single site). The pregnancies in this retrospective observational database also occurred prior to the publication of 2009 Institute of Medicine guidelines. As such, obese women may have been counseled to gain weight according to the previous guidelines (i.e., "at least 15 pounds"). Furthermore, we were not able to ascertain prenatal care content including nutritional counseling and whether or not women were advised on weight gain goals. We also restricted the analysis to full-term, singleton live births, so the results may not be applicable to all pregnancies. Because of reverse causality, preeclampsia and gestational diabetes were not studied as outcomes as only a total GWG instead of a weight gain at the time of the diagnosis of the outcome was available in our database. 14 Finally, the study may have been underpowered to detect differences in several of the maternal and neonatal outcomes such as postpartum hemorrhage, should dystocia, and 5 minute Apgar <7.

Obesity in pregnancy is an important public health issue. We recognize the difficulty in recommending a lower weight gain or even weight loss in a culture where weight gain is expected and considered to be "healthy" in pregnancy. Furthermore, there may be risks to weight loss in pregnancy. Based on the 2009 IOM guidelines, 63% of obese women would have exceeded the current weight gain recommendations (>9kg), consistent with other reports (59–64%),^{26,35} highlighting the urgency of interventions that are not only effective, but feasible in modifying weight change. Based on this observational data, future research should develop interventions that assist obese women in reaching weight goals through a combination of behavioral changes, diet monitoring with proper nutritional counseling, and

physical activity and then ultimately determine if the interventions improve maternal and neonatal outcomes in a randomized controlled trial.

This type of research could address many unresolved issues including the lower limit of gestational weight change for each of the obesity classes, the influence of weight change on outcomes specific to pregnancy such as gestational diabetes and preeclampsia, and the long-term implications for the offspring of obese women who lose weight during pregnancy. Future research should also evaluate weight change and perinatal outcomes among women in the highest obesity class ($> 40\text{kg/m}^2$).

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Figure 1.
Flow diagram for participant selection. BMI body mass index

Figure 2. Predicted probabilities of maternal outcomes for (a) Class I Obese Women (BMI 30.0–34.9 kg/m²), (b) Class II Obese Women (BMI 35.0–39.9 kg/m²), and (c) Class III Obese Women (BMI 40.0 kg/m²)

Figure 3. Predicted probabilities of neonatal outcomes for (a) Class I Obese Women (BMI 30.0–34.9 kg/m²), (b) Class II Obese Women (BMI 35.0–39.9 kg/m²), and (c) Class III Obese Women (BMI 40.0 kg/m²). SGA small for gestational age; LBW low birth weight; LGA large for gestational age; NICU neonatal intensive care unit

Figure 4.

Average predicted probabilities of maternal and neonatal outcomes (cesarean delivery, postpartum hemorrhage, SGA, LGA, and NICU admission) for Class I Obese Women (BMI 30.0–34.9 kg/m²), Class II Obese Women (BMI 35.0–39.9 kg/m²), and Class III Obese Women (BMI 40.0 kg/m²). SGA small for gestational age; LGA large for gestational age; NICU neonatal intensive care unit

Figure 5.

Average predicted probabilities of maternal and neonatal outcomes (cesarean delivery, postpartum hemorrhage, SGA, LGA, and NICU admission) for (a) Class I Obese Women (BMI 30.0–34.9 kg/m²), (b) Class II Obese Women (BMI 35.0–39.9 kg/m²), and (c) Class III Obese Women (BMI 40.0 kg/m²) with weighting of SGA. SGA small for gestational age; LGA large for gestational age; NICU neonatal intensive care unit

Table 1

Maternal demographics and characteristics by weight change categories

Variable n(%) or mean (SD)	Weight Change Categories ^a				P-Value
	Loss n=1182	Low n=3028	Normal n=3613	High n=13127	
Age (years)	28.1±5.7	28.8±5.7	28.7±5.8	27.7±5.9	<0.001 ^b
Race/Ethnicity					<0.001 ^c
Non-Hispanic white	555(48.3)	1419(48.38)	1582(44.9)	5710(44.8)	
Non-Hispanic black	405(35.2)	848(28.9)	988(28.0)	3943(30.9)	
Hispanic	161(14.0)	556(18.9)	826(23.4)	2555(20.0)	
Other	28(2.4)	114(3.9)	128(3.6)	544(4.3)	
Insurance					<0.001 ^c
Private	576 (48.7)	1597 (52.7)	1798 (49.8)	6412 (48.8)	
Public	540 (45.7)	1167 (38.5)	1416 (39.2)	5288 (40.3)	
Other	66 (5.6)	264 (8.7)	399 (11.0)	1427 (10.9)	
Married	637 (53.9)	1808 (59.7)	2124 (58.9)	7011 (53.4)	<0.001 ^c
Parity					<0.001 ^c
0	305(25.8)	743(24.5)	983(27.2)	4908(37.4)	
1	877(74.2)	2285(75.5)	2630(72.8)	8219(62.6)	
Smoker	138(11.7)	248(8.2)	259(7.2)	1025(7.8)	<0.001 ^c
Prior cesarean	232(21.0)	641(22.6)	826(24.2)	2552(20.4)	<0.001 ^c
Pregestational diabetes	59(5.4)	143(5.0)	153(4.6)	505(4.1)	0.05 ^c
Chronic hypertension	69(6.7)	173(6.6)	210(6.6)	872(7.6)	0.11 ^c
Weight change (kg)	-5.0±4.4	2.8±1.6	7.1±1.1	16.0±5.8	<0.001 ^b

Variable n(%) or mean (SD)	Weight Change Categories ^a				P-Value
	Loss n=1182	Low n=3028	Normal n=3613	High n=13127	
Gestational age at delivery (weeks)	39.1±1.1	39.1±1.1	39.1±1.1	39.2±1.1	<0.001 ^b

^aWeight loss (<0kg), low (0–4.9kg weight gain), normal (5.0–9.0kg weight gain), and high (>9.0kg weight gain)

^bANOVA

^cChi Square; SD standard deviation

Table 2

Maternal outcomes for each obesity class by weight change categories

Variable		Weight Change Categories ^a			
		Loss	Low	Normal	High
Operative vaginal delivery	Class I	n(%)	24(6.2)	80(4.1)	460(5.5)
		aOR (95% CI)	1.5(0.93–2.5)	1	1.3(0.98–1.6)
	Class II	n(%)	16(4.6)	41(4.0)	133(4.4)
		aOR (95% CI)	1.2(0.64–2.2)	1	1.0(0.70–1.4)
	Class III	n(%)	18(4.0)	27(4.1)	82(4.6)
Nulliparas Cesarean Delivery		aOR (95% CI)	0.97(0.52–1.8)	1	1.1(0.73–1.8)
	Class I	n(%)	15(14.7)	111(34.6)	1279(41.8)
		aOR (95% CI)	0.21(0.11–0.42)	1	1.2(1.0–1.5)
	Class II	n(%)	30(34.9)	90(41.7)	565(48.2)
		aOR (95% CI)	0.81(0.48–1.4)	1	1.5(1.1–2.0)
Class III	n(%)	58(43.9)	105(51.0)	79(45.4)	401(58.6)
		aOR (95% CI)	0.79(0.49–1.3)	1	1.7(1.2–2.4)
Multiparas Cesarean Delivery	Class I	n(%)	64(21.6)	292(28.1)	425(30.1)
		aOR (95% CI)	0.61(0.44–0.83)	1	1.3(1.1–1.4)
	Class II	n(%)	86(32.0)	237(33.8)	277(38.1)
		aOR (95% CI)	0.82(0.60–1.1)	1	1.1(0.93–1.3)
	Class III	n(%)	144(41.0)	222(40.7)	233(47.5)
Postpartum hemorrhage		aOR (95% CI)	0.76(0.56–1.0)	1	1.1(0.94–1.5)
	Class I	n(%)	4(1.5)	25(2.7)	38(2.7)
		aOR (95% CI)	0.55(0.19–1.6)	1	1.1(0.75–1.5)
	Class II	n(%)	6(2.6)	20(3.2)	33(4.5)
		aOR (95% CI)	0.54(0.22–1.3)	1	0.74(0.49–1.1)
Class III	n(%)	15(4.5)	20(3.8)	19(3.8)	90(6.6)
		aOR (95% CI)	1.1(0.55–2.2)	1	1.6(0.97–2.7)

^aWeight loss (<0kg), low (0–4.9kg weight gain), normal (5.0–9.0kg weight gain, referent), and high (>9.0kg weight gain) aOR adjusted odds ratio after controlling for age, race/ethnicity, marital status, insurance, parity, smoking, and gestational age

Table 3

Neonatal outcomes for each obesity class by weight change categories

Variable		Weight Change Categories ^a			
		Loss	Low	Normal	High
SGA infants	Class I	n(%)	135(10.0)	187(9.7)	549(6.6)
		aOR (95% CI)	1.8(1.3–2.5)	1	0.60(0.50–0.72)
	Class II	n(%)	100(10.9)	85(8.4)	193(6.4)
		aOR (95% CI)	2.2(1.5–3.2)	1	0.66(0.51–0.87)
	Class III	n(%)	57(12.8)	51(7.7)	119(6.7)
		aOR (95% CI)	1.7(1.1–2.6)	1	0.73(0.51–1.0)
LGA infants	Class I	n(%)	13(3.4)	76(5.6)	1029(12.5)
		aOR (95% CI)	0.59(0.33–1.1)	1	2.4(1.9–2.9)
	Class II	n(%)	17(5.0)	67(7.3)	435(14.5)
		aOR (95% CI)	0.51(0.30–0.86)	1	1.7(1.3–2.1)
	Class III	n(%)	31(6.9)	77(10.3)	315(17.7)
		aOR (95% CI)	0.48(0.31–0.75)	1	1.6(1.3–2.1)
LBW	Class I	n(%)	17(4.4)	28(2.1)	133(1.6)
		aOR (95% CI)	1.6(0.85–3.0)	1	0.65(0.46–0.94)
	Class II	n(%)	15(4.4)	22(2.4)	61(2.1)
		aOR (95% CI)	2.4(1.1–4.9)	1	1.0(0.59–1.7)
	Class III	n(%)	9(2.0)	16(2.1)	33(1.9)
		aOR (95% CI)	1.1(0.45–2.8)	1	0.91(0.45–1.9)
Macrosomia	Class I	n(%)	2(0.52)	7(0.52)	191(2.3)
		aOR (95% CI)	0.83(0.19–3.6)	1	3.1(1.9–5.4)
	Class II	n(%)	1(0.29)	8(0.88)	87(2.9)
		aOR (95% CI)	0.24(0.03–1.9)	1	2.4(1.3–4.4)
	Class III	n(%)	7(1.6)	11(1.5)	66(3.7)
		aOR (95% CI)	0.58(0.24–1.4)	1	1.5(0.86–2.5)
Shoulder dystocia	Class I	n(%)	1(0.28)	13(1.0)	156(2.0)
		aOR (95% CI)	0.16(0.02–1.2)	1	1.1(0.76–1.7)

Variable			Weight Change Categories ^a			
			Loss	Low	Normal	High
	Class II	n(%)	3(0.93)	17(2.0)	15(1.6)	43(1.5)
		aOR (95% CI)	0.58(0.17–2.0)	1.3(0.64–2.6)	1	0.91(0.50–1.7)
	Class III	n(%)	6(1.5)	6(0.9)	8(1.3)	30(1.8)
		aOR (95% CI)	1.1(0.37–3.2)	0.69(0.24–2.0)	1	1.4(0.63–3.1)
5 minute Apgar <7	Class I	n(%)	2(0.52)	5(0.37)	16(0.83)	78(0.94)
		aOR (95% CI)	0.56(0.13–2.4)	0.43(0.16–1.2)	1	0.98(0.57–1.7)
	Class II	n(%)	3(0.87)	8(0.87)	9(0.89)	28(0.93)
		aOR (95% CI)	1.0(0.28–3.9)	1.0(0.40–2.7)	1	0.96(0.45–2.1)
	Class III	n(%)	4(0.89)	3(0.40)	6(0.90)	23(1.3)
		aOR (95% CI)	0.91(0.26–3.3)	0.15(0.02–1.2)	1	1.3(0.52–3.2)
	Class I	n(%)	33(8.5)	79(5.8)	146(7.6)	715(8.6)
		aOR (95% CI)	1.1(0.72–1.6)	0.75(0.56–1.0)	1	1.1(0.92–1.3)
NICU admission	Class II	n(%)	28(8.1)	92(10.0)	81(8.0)	307(10.1)
		aOR (95% CI)	1.0(0.64–1.6)	1.3(0.92–1.7)	1	1.3(0.99–1.7)
	Class III	n(%)	51(10.8)	57(7.7)	83(12.8)	196(11.0)
		aOR (95% CI)	0.83(0.57–1.2)	0.56(0.39–0.80)	1	0.85(0.64–1.1)

^aWeight loss (<0kg), low (0–4.9kg weight gain), normal (5.0–9.0kg weight gain, referent), and high (>9.0kg weight gain) aOR adjusted odds ratio after controlling for age, race/ethnicity, marital status, insurance, parity, smoking, and gestational age; SGA small for gestational age, LGA large for gestational age, LBW low birth weight, NICU neonatal intensive care unit

Table 4
Neonatal Outcomes in Small for Gestational Age Infants with <5.0 kg Gestational Weight Gain

Variable n(%)	< 5.0 kg Weight Gain				5.0–9.0 kg Weight Gain	P-value ^d
	30–34.9 kg/m ² Class I n=201	35.0–39.9 kg/m ² Class II n=157	40.0 kg/m ² Class III n=129	All Obesity Classes n=487	All Obesity Classes n=323	
RDS	2(1.0)	3(1.9)	0	5(1.0)	4(1.2)	0.74
TTN	4(2.0)	6(3.1)	2(1.5)	12(2.5)	14(4.3)	0.14
Ventilator use	2(1.0)	4(2.7)	1(0.77)	7(1.4)	2(0.62)	0.33
Oxygen use	11(5.5)	9(5.8)	1(0.78)	21(4.3)	12(3.8)	0.72
CPAP use	4(2.0)	2(1.3)	1(0.78)	7(1.5)	3(0.95)	0.75
Pneumonia	2(1.0)	2(1.3)	0	4(0.82)	0	0.16
Meconium aspiration	4(2.0)	2(1.3)	2(1.6)	8(1.6)	3(0.93)	0.54
Composite respiratory morbidity ^b	13(6.5)	14(8.9)	5(3.9)	32(6.6)	24(7.4)	0.64
Anemia	3(1.5)	2(1.3)	1(0.78)	6(1.2)	4(1.2)	0.99
Sepsis	2(1.0)	4(2.6)	3(2.3)	9(1.8)	6(1.9)	0.99
Asphyxia	1(0.5)	2(1.3)	0	3(0.62)	2(0.62)	0.99
Congenital anomaly	16(8.0)	6(3.8)	7(5.4)	29(6.0)	22(6.8)	0.62
NICU admission	19(9.4)	21(13.4)	7(5.4)	47(9.6)	37(11.5)	0.41
Death prior to discharge	1(0.57)	0	0	1(0.24)	2(0.77)	0.56

^a Comparisons (either Chi-Square or Fisher's exact test) are between <5.0 kg (n=487) gestational weight gain vs. 5.0–9.0 kg (n=323) gestational weight change for all obesity classes combined.

^b Composite respiratory morbidity was calculated as an occurrence of any respiratory morbidity (respiratory distress syndrome, transient tachypnea of the newborn, ventilator use, oxygen use, CPAP use, pneumonia, and/or meconium aspiration) per neonate. RDS respiratory distress syndrome, TTN transient tachypnea of the newborn, CPAP continuous positive airway pressure, NICU neonatal intensive care unit