Gestational Weight Gain and Adverse Neonatal Outcome Among Term Infants

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OBJECTIVE: To examine the relationship between gestational weight gain and adverse neonatal outcomes among infants born at term (37 weeks or more).

METHODS: This was a retrospective cohort study of 20,465 nondiabetic, term, singleton births. We performed univariable and multivariable analyses of the associations between gestational weight gain and neonatal outcomes. We categorized gestational weight gain by the Institute of Medicine guidelines as well as extremes of gestational weight gain (less than 7 kg and more than 18 kg).

RESULTS: Gestational weight gain above the Institute of Medicine guidelines was more common than gestational weight gain below (43.3% compared with 20.1%). In multivariable analyses, gestational weight gain above guidelines was associated with a low 5-minute Apgar score (adjusted odds ratio [AOR] 1.33, 95% confidence interval [CI] 1.01–1.76), seizure (AOR 6.50, 95% CI 1.43–29.65), hypoglycemia (AOR 1.52, 95% CI 1.06–2.16), polycythemia (AOR 1.44, 95% CI 1.06–1.94), meconium aspiration syndrome (AOR 1.79, 95% CI 1.12–2.86), and large for gestational age (AOR 1.98, 95% CI 1.74–2.25) compared with women within weight gain guidelines. Gestational weight gain below guidelines was associated with decreased odds of neonatal intensive care unit admission (AOR 0.66, 95% CI 0.46–0.96) and increased odds of small for gestational age (SGA; AOR 1.66, 95% CI 1.44–1.92). Gestational weight gain less than 7 kg was associated with increased risk of seizure, hospital stay more than 5 days, and SGA. Gestational weight gain more than 18 kg was associated with assisted ventilation, seizure, hypoglycemia, polycythemia, meconium aspiration syndrome, and large for gestational age.

CONCLUSION: Gestational weight gain above guidelines was common and associated with multiple adverse neonatal outcomes, whereas gestational weight gain below guidelines was only associated with SGA status. Public health efforts among similar populations should emphasize prevention of excessive gestational weight gain. *(Obstet Gynecol 2006;108:635–43)*

LEVEL OF EVIDENCE: II-2

Low gestational weight gain has been associated with an increased risk of delivering small for gestational age (SGA) infants and perinatal mortality.[1–3] SGA status has been associated with various neonatal morbidities and mortality, even among term infants.[4–6] At the other extreme, excessive gestational weight gain is a risk factor for large for gestational age (LGA) and macrosomia,[2,3] which in turn are associated with adverse maternal and neonatal outcomes.[7–10] Proceeding down the causal chain, one might anticipate that both high and low gestational weight gain would, in turn, predict adverse neonatal outcomes, but such an association has not been fully investigated. Because women at risk for low gestational weight gain are also more likely to have other risk factors for SGA, such as smoking, substance abuse, or poor socioeconomic status, could it be that the adverse neonatal outcomes are related to these factors rather than the low weight gain itself? Low maternal weight gain may simply be a marker for adverse perinatal conditions. The same concept may apply to excessive weight gain, macrosomia, and adverse outcomes as well.

Most studies of gestational weight gain have focused on maternal outcomes, and few have evaluated the associated neonatal outcomes other than preterm birth and birth weight. Although a large,

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multi-center, prospective study observed a bimodal relationship between gestational weight gain and perinatal mortality, this study was conducted in the 1960s and may not reflect current obstetric care and neonatal outcomes.[11] A report in 1980 using national, population-based U.S. data found a lower risk of perinatal mortality with increasing weight gain up to 35 lb, the upper limit of weight gain for normal-weight women currently recommended by the Institute of Medicine (IOM).[1] Although the relationship between weight gain and perinatal mortality was consistent across maternal age and body mass index (BMI) subgroups, this report did not include stratification by gestational age nor multivariable analyses to control for confounding. Further, two recent studies report conflicting results regarding gestational weight gain and neonatal outcomes, with one showing similar neonatal outcomes between the weight gain groups[12] and the other reporting increased perinatal mortality in women gaining more than 12 kg compared with those gaining less than 12 kg.[13] However, these studies were small and conducted in Europe and thus may not reflect the heterogeneous population or clinical setting in the United States.

Although perinatal mortality at term is rare in the United States, the association between gestational weight gain and perinatal outcome awaits further elucidation. Therefore, we sought to examine whether gestational weight gain is an independent predictor of adverse neonatal outcome among infants born at term (37 weeks or more) and, in particular, whether infant morbidity was more strongly associated with excessive or inadequate gestational weight gain.

MATERIALS AND METHODS

We conducted a retrospective cohort study of all women delivering term, singleton infants at the University of California, San Francisco Medical Center between 1980 and 2001 with information on prepregnancy weight and weight gain. A research quality database was used to collect information on these women. Demographic, antenatal, intrapartum, and delivery data were entered into a preprinted data sheet by the delivering physician or midwife during admission and immediately after every birth, and additional prenatal, neonatal, and discharge data were collected by trained abstractors. The data are reviewed monthly by a perinatal database committee to insure validity. Pregnancies complicated by multiple gestations, congenital anomalies, chronic hypertension, gestational or pregestational diabetes, birth before 37 weeks of gestation, and maternal transport were excluded. This study was approved by the Committee on Human Research at the University of California, San Francisco.

Prepregnancy weight was determined by patient report, and final pregnancy weight was abstracted from the prenatal record. Gestational weight gain was categorized in multiple ways: first, as above, within, or below the IOM guidelines (Table 1).[14] Because the guidelines do not give an upper limit of weight gain for obese women, we applied the guidelines for overweight women to obese women. Secondly, weight gain was examined as dichotomous variables based on extremes of gain: less than 7 kg (compared with gain within IOM guidelines), which is the lower limit for overweight women, and greater than 18 kg (compared with gain within IOM guidelines), which is the upper limit for underweight women. We also examined the 5th, 10th, 90th, and 95th percentiles of weight gain in this cohort as cutoffs. The association between these weight gain categories and neonatal outcomes was examined.

We examined the following neonatal outcomes: birth trauma, 5-minute Apgar score below 7, need for assisted ventilation, SGA, LGA, umbilical cord arterial pH less than 7.1, umbilical cord arterial base excess under −10, admission to the neonatal intensive care unit (NICU), admission to the special-care nursery (a step-down unit), neonatal infection, seizure, hypoglycemia, polycythemia, meconium aspiration syndrome, jaundice, meconium aspiration syndrome, respiratory distress or tachypnea, anemia, birth asphyxia, and perinatal death. Neonatal infection was defined as neonatal sepsis, pneumonia, or antibiotic treatment. Birth trauma included any of the following diagnoses: clavicular fracture, skull fracture, spinal cord injury, facial nerve injury, brachial plexus injury, cephalohematoma, or "other" birth trauma. Small for gestational age was defined as birth weight less than 10th percentile for gestational age by California norms, and LGA was defined as birth weight more than 90th percentile for gestational age by California

Table 1. Institute of Medicine Recommendations for Weight Gain in Pregnancy

Initial Body Mass Index	Gestational Weight Gain (lb/kg)
Less than19.8 (Low)	28–40/12.5–18
19.8–26.0 (Normal)	25–35/11.5–16
26.1–29.0 (High)	15–25/ 7–11.5
More than 29.0 (Obese)	At least 15/At least 6

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norms. The other maternal and neonatal diagnoses were based on International Classification of Diseases, 9th Revision codes extracted from hospital discharge records.

Results were analyzed using Stata 8 (StataCorp LP, College Station, TX) statistical software. We performed univariable and multivariable analyses to examine the relationship between gestational weight gain, maternal prepregnancy BMI, and the adverse infant outcomes of interest. Univariable analyses were performed using the χ^2 test. Statistical significance was established with a P value less than .05. In the multivariable analyses we controlled for the following maternal characteristics: maternal age, parity, race or ethnicity, cigarette smoking, substance use, gestational hypertension, gestational age at delivery, date of delivery, mode of delivery (spontaneous vaginal delivery, operative vaginal delivery, and cesarean), length of first stage of labor, length of second stage of labor, and birth weight. Models were examined with and without controlling for birth weight, because birth weight may or may not be on the causal pathway between weight gain and different infant outcomes. For the outcome of neonatal infection, models were also examined excluding the length of labor and mode of delivery variables, because these may be on the causal pathway between weight gain and infection. For all regression models, a "cluster" command (Stata 8) was included in logistic regressions, which adjusts the confidence intervals to account for the lack of independence between births to the same mother within the data set.[15]

RESULTS

Of the 36,889 births occurring during the study period, 26,028 women met study inclusion criteria. We excluded women with missing data on any of the variables considered in the multivariable analysis, thus our final study cohort consisted of 20,465 births. Most (94%) of the missing data were related to prepregnancy BMI or gestational weight gain.

More women gained an amount of weight above the IOM guidelines (43.3%) than either within (36.6%) or below (20.1%). Twenty-nine percent of women gained more than 18 kg, and 4.8% gained less than 7 kg. Women aged older than 40 years were less likely to have gestational weight gain above the IOM guideline compared with other age categories. While Caucasian women have higher rates of weight gain above the IOM guideline, Asians were less likely to gain above the guidelines compared with other race or ethnic groups (Table 2). Women with low prepregnancy BMI were more likely to gain within the IOM guidelines, whereas women in the high and obese categories were more likely to gain above the guidelines (Table 2). Women who gain above the IOM guidelines were also more likely to undergo cesarean delivery and have neonates with higher birth weight (Table 2).

We first examined the association between different gestational weight gain categories according to the IOM guidelines and neonatal outcomes. Compared with women who gained within the guidelines, those gaining below guidelines were more likely to have neonates with SGA, but lower rates of birth trauma, cord arterial pH less than 7.1, neonatal infection, and respiratory distress or tachypnea (Table 3). Compared with those gaining within the guidelines, those gaining above the IOM guidelines had higher rates of neonates with 5-minute Apgar score less than 7, assisted ventilation, LGA, special-care nursery admission, neonatal infection, seizure, hypoglycemia, meconium aspiration syndrome, respiratory distress or tachypnea, and prolonged hospital stay (Table 3).

The study cohort was also classified based on the 90th and 95th percentile for excessive weight gain and 10th and 5th percentile for low weight gain to examine the associated neonatal outcomes. We found that the association between excessive weight gain and neonatal outcomes was similar for both the 95th percentile and the 90th percentile subgroups. For low weight gain, we did not see associations between low gain and adverse neonatal outcomes using the 10th percentile but did see differences using the 5th percentile (approximately 7 kg).

Compared with those gaining within IOM guidelines, those gaining less than 7 kg had increased rates of SGA, seizure, meconium aspiration syndrome, and prolonged hospital stay (Table 4). Seven kg corresponds to approximately the 5th percentile of weight gain in this cohort and is also the lower limit of recommended weight gain for overweight women.

Neonates of women who gained more than 18 kg had statistically significantly higher rates of all the adverse neonatal outcomes we examined except hypoglycemia and polycythemia (Table 4) compared with those gaining within IOM guidelines. Eighteen kg corresponds to approximately the 70th percentile for weight gain in this cohort and is also the upper limit of recommended weight gain for underweight women.

Tables 5 and 6 show results of the multivariable logistic regression analyses for weight gain. Weight gain below the IOM guidelines was associated with increased odds of SGA (adjusted odds ratio [AOR] 1.66, 95% confidence interval [CI] 1.44–1.92), and

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Table 2. Maternal Characteristics of Study Cohort (N=20,465) and Rates of Weight Gain Below, Within, and Above Institute of Medicine Guidelines

Characteristic (n)	Gain Below	Gain Within	Gain Above	*P*
Age				
Less than 20 (1,606)	23.4	31.3	45.4	<.001
20–29 (10,335)	19.3	36.6	44.0	
30–39 (8,037)	19.9	37.6	42.5	
More than 40 (487)	25.3	36.3	38.4	
Race or ethnicity				
White (8,841)	16.2	35.8	48.0	<.001
Black (2,616)	25.5	29.4	45.1	
Latina (2,353)	19.2	34.8	46.0	
Asian (4,055)	24.3	43.3	32.4	
Other (2,600)	21.7	37.9	40.4	
Prepregnancy BMI				
Less than 19.8 (4,977)	25.8	49.1	25.0	<.001
19.8–26.0 (12,289)	19.4	34.8	45.8	
26.1–29.0 (1,829)	9.2	23.3	67.5	
More than 29.0 (1,370)	20.6	25.5	53.9	
Parity				
0 (10,716)	17.3	36.2	46.6	<.001
1 (6,287)	22.2	37.8	40.0	
More than 1 (3,462)	25.2	35.6	39.2	
Mode of delivery				
SVD (14,205)	21.9	37.5	40.7	<.001
Operative vaginal (2,864)	18.0	37.5	44.5	
Cesarean (3,396)	14.7	32.1	53.2	
Smoking				
Yes (2,315)	23.5	30.8	45.8	<.001
No (18,150)	19.7	37.3	43.0	
Insurance status				
Private (12,428)	19.7	36.2	44.1	.01
Public (8,037)	20.7	37.2	42.1	
Birth weight				
SGA (1,338)	36.1	39.4	24.5	<.001
AGA (17,291)	20.2	37.5	42.4	
LGA (1,863)	8.5	26.5	65.1	
Year of delivery				
1980–1989 (10,300)	19.8	37.9	42.3	<.001
1990–2001 (10,165)	20.4	35.3	44.3	

BMI, body mass index; SVD, spontaneous vaginal delivery; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.
Data are %.

decreased odds of LGA (AOR 0.58, 95% CI 0.47–0.72) and NICU admission (AOR 0.66, 95% CI 0.46–0.96) (Table 5). Weight gain above the IOM guidelines was associated with 5-minute Apgar score less than 7 (AOR 1.33, 95% CI 1.01–1.76), LGA (AOR 1.98, 95% CI 1.74–2.25), seizure (AOR 6.50, 95% CI 1.43–29.65), hypoglycemia (AOR 1.52, 95% CI 1.06–2.16), polycythemia (AOR 1.44, 95% CI 1.06–1.94), meconium aspiration syndrome (AOR 1.79, 95% CI 1.12–2.86), and decreased odds of SGA (AOR 0.51, 95% CI 0.44–0.59). For most outcomes, results were similar when birth weight was removed from the model, except that weight gain above guidelines was no longer a statistically significant predictor of hypoglycemia and polycythemia, and weight gain below guidelines was no longer statistically significantly associated with decreased odds of NICU admission (data not shown). Because gestational age may be on the causal pathway between weight gain and adverse infant outcomes, we also did a sensitivity analysis not controlling for gestational age, and the results were again very similar (data not shown).

Weight gain less than 7 kg was associated with SGA (AOR 2.26, 95% CI 1.76–2.90), seizure (AOR 10.66, 95% CI 2.17–52.36), and hospital stay longer than 5 days (AOR 1.44, 95% CI 1.02–2.04) (Table 6). Weight gain more than 18 kg was associated with assisted ventilation (AOR 1.52, 95% CI 1.16–2.00),

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Table 3. Unadjusted Rates of Specific Adverse Neonatal Outcomes by Institute of Medicine Weight Gain Status

	Weight Gain by IOM Guidelines*		
Outcome	Within	Below	Above
Birth trauma	3.30	2.54†	3.62
5-min Apgar score less than 7	1.58	1.94	2.14‡
Assisted ventilation	1.86	1.68	2.51‡
SGA	7.05	11.74§	3.70§
LGA	6.62	3.85§	13.76§
Cord arterial pH less than 7.1	2.49	1.88†	2.87
NICU admission	1.88	1.57	2.28
SCN admission	2.04	1.83	2.55†
Neonatal infection	4.44	3.38‡	5.86§
Seizure	0.03	0.09	0.22‡
Hypoglycemia	0.85	0.84	1.24‡
Polycythemia	1.13	1.21	1.41
MAS	0.51	0.68	1.02§
RDS or tachypnea	1.95	1.40†	2.65‡
Hospital stay more than 5 d	5.88	6.17	7.15‡
Hospital stay more than 10 d	0.86	1.05	1.32‡

IOM, Institute of Medicine; SGA, small for gestational age; LGA, small for gestational age; NICU, neonatal intensive care unit; SCN, special-care nursery; MAS, meconium aspiration syndrome; RDS, respiratory distress syndrome.

Data are %. Chi-square tests were used to compare weight gain below guidelines to weight gain within guidelines and weight gain above guidelines to weight gain within guidelines.

* Refers to Institute of Medicine body mass index–specific guidelines (Table 1).

† Denotes $P<.05$.

‡ Denotes $P<.01$.

§ Denotes $P<.001$.

LGA (AOR 2.28, 95% CI 2.00–2.62), seizure (AOR 6.19, 95% CI 1.32–28.96), hypoglycemia (AOR 1.67, 95% CI 1.13–2.46), polycythemia (AOR, 1.59, 95% CI 1.13–2.22), and meconium aspiration syndrome (AOR 1.86, 95% CI 1.13–3.05).

We only had 26 infants with seizure in the data set, so we ran additional models to assess the robustness of the association between gestational weight gain and this outcome. The point estimates for the AOR for seizure were similar whether we included all covariates, just those having a *P* value of .05 or less in the initial model, or just birth weight and gestational age (data not shown).

Cord arterial pH less than 7.1 was not associated with any weight gain variable in the multivariable analyses. Low cord arterial base excess, neonatal anemia, asphyxia, jaundice, and perinatal mortality did not have statistically significant associations with any weight gain variable in univariable or multivariable analyses.

DISCUSSION

In this cohort of term births to nondiabetic women, high weight gain was associated with multiple adverse neonatal outcomes in both the univariable and multivariable analyses. Since this association held even when controlling for birth weight, excessive weight gain is not simply a marker for macrosomia-related adverse outcomes.

In contrast, gestational weight gain below the IOM guidelines was not associated with most adverse infant outcomes, whether or not we controlled for birth weight in the multivariable analysis. In fact, weight gain below the guidelines seemed to be slightly protective against some adverse outcomes. This was despite the finding that low gain was associated with SGA status. It is possible that otherwise normal SGA infants born to healthy women (births uncomplicated by prematurity, hypertension, smoking, congenital anomalies) are not at increased risk for adverse short-term neonatal outcomes. However, extremely low gestational weight gain (below 7 kg) was an independent risk factor for neonatal morbidity. Our findings suggest that with regard to neonates born at term, the lower limit of the IOM guidelines may be slightly high, whereas the upper limit seems appropriate. It is important to note that although 18 kg represents the upper limit for underweight women and 7 kg represents the lower limit for overweight women, nearly 30 % of our cohort gained over 18 kg whereas less than 5% gained less than 7 kg. National data also indicate that the proportion of women gaining more than 40 lb (approximately 18 kg) has increased in recent years.[16] Although both extremes of gain, low and high, are associated with increased neonatal morbidity, from a public health perspective, excessive weight gain is a larger threat.

Current perinatal mortality rates are very low among term infants in developed countries, so our cohort of 20,465 births may be underpowered to examine this outcome. Assuming a neonatal mortality rate of 1.7 per 1,000 live births among term, otherwise normal pregnancies,[17] we would need a sample size of approximately 138,300 births to demonstrate a 50% increase in deaths related to either inadequate or excessive gestational weight gain. This may explain why we did not observe a statistically significant relationship between gestational weight gain and perinatal mortality. However, the increased neonatal morbidity we observed among women with either excessive weight gain or extremely low gain may be a manifestation of the same phenomena that resulted in increased perinatal mortality in the older U.S. studies.

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Table 4. Unadjusted Rates of Specific Adverse Neonatal Outcomes, by Weight Gain Below or Above 18 kg

Outcome	Weight Gain Within IOM Guidelines*	Weight Gain Less Than 7 kg	Weight gain More Than 18 kg
Birth trauma	3.30	2.38	3.98†
5min Apgar score less than 7	1.58	2.39	2.16†
Assisted ventilation	1.86	1.92	2.83‡
SGA	7.05	13.99‡	3.87‡
LGA	6.62	5.26	14.60‡
Cord arterial pH less than 7.1	2.49	1.70	3.06†
NICU admission	1.88	2.00	2.39†
SCN admission	2.04	2.41	2.70†
Neonatal infection	4.44	4.37	5.93‡
Seizure	0.03	0.20†	0.24‡
Hypoglycemia	0.85	1.39	1.14
Polycythemia	1.13	1.49	1.48
MAS	0.51	1.09†	1.08‡
RDS or tachypnea	1.95	1.88	2.49‡
Hospital stay more than 5 d	5.88	8.84	7.33§
Hospital stay more than 10 d	0.86	1.49†	1.29†

IOM, Institute of Medicine; SGA, small for gestational age; LGA, large for gestational age; NICU, neonatal intensive care unit; SCN, special-care nursery; MAS, meconium aspiration syndrome; RDS, respiratory distress syndrome.
Data are %. *P* values are based on χ^2 test comparing to patients gaining within the Institute of Medicine guidelines.
* Refers to Institute of Medicine body mass index–specific guidelines (Table 1).
† Denotes $P<.05$.
§ Denotes $P<.01$.
‡ Denotes $P<.001$.

Table 5. Risk of Adverse Neonatal Outcomes by Gestational Weight Gain by Institute of Medicine Guidelines, Adjusted Odds Ratios and 95% Confidence Intervals

	Gestational Weight Gain	
Outcome (n)	Below IOM guidelines*	Above IOM guidelines*
Birth trauma (673)	0.89 (0.69–1.13)	1.01 (0.84–1.22)
5min Apgar score less than 7 (384)	1.18 (0.84–1.66)	1.33 (1.01–1.76)
Assisted vent (432)	0.69 (0.48–1.00)	1.28 (0.99–1.65)
SGA (1,338)	1.66 (1.44–1.92)†	0.51 (0.44–0.59)†
LGA (1,863)	0.58 (0.47–0.72)†	1.98 (1.74–2.25)†
NICU admission (406)	0.66 (0.46–0.96)	1.03 (0.79–1.35)
SCN admission (452)	0.73 (0.52–1.03)	1.07 (0.84–1.38)
Neonatal infection (994)	0.84 (0.66–1.06)	1.13 (0.95–1.34)
Seizure (26)	1.84 (0.28–11.91)	6.50 (1.43–29.65)
Hypoglycemia (205)	1.02 (0.64–1.62)	1.52 (1.06–2.16)
Polycythemia (260)	1.05 (0.72–1.51)	1.44 (1.06–1.94)
MAS (156)	1.13 (0.61–2.08)	1.79 (1.12–2.86)
RDS or tachypnea (437)	0.73 (0.51–1.04)	1.06 (0.82–1.37)
Hospital stay more than 5 d (1,319)	1.04 (0.85–1.26)	1.05 (0.89–1.23)
Hospital stay more than 10 d (229)	0.99 (0.62–1.57)	1.28 (0.88–1.57)

IOM, Institute of Medicine; SGA, small for gestational age; LGA, large for gestational age; NICU, neonatal intensive care unit; SCN, special-care nursery; MAS, meconium aspiration syndrome; RDS, respiratory distress syndrome.
Data are adjusted odds ratio (95% confidence interval). Models controlled for maternal race or ethnicity, prepregnancy body mass index, parity, maternal age, gestational hypertension, smoking, date of delivery, mode of delivery, length of first stage of labor, length of second stage of labor, gestational age at delivery, and birth weight, except where noted.
* Weight gain above and below Institute of Medicine guidelines were compared with weight gain within Institute of Medicine guidelines (Table 1.)
† Birth weight not included in model.

Of note, although we did find significant associations between high weight gain and several adverse neonatal outcomes, because of the overall low prevalence of some of these outcomes the clinical significance needs to be considered carefully. For example, approximately 134 women with weight gain more

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Table 6. Risk of Adverse Neonatal Outcomes by Extremes of Gestational Weight Gain, Adjusted Odds Ratios and 95% Confidence Intervals

	Gestational Weight Gain	
Outcome (n)	Less Than 7 kg*	More Than 18 kg*
Birth trauma (673)	0.89 (0.56–1.43)	1.09 (0.89–1.37)
5min Apgar score less than 7 (384)	1.29 (0.70–2.39)	1.30 (0.95–1.77)
Assisted ventilation (432)	0.65 (0.33–1.26)	1.52 (1.16–2.00)
SGA (1,338)	2.26 (1.76–2.90)†	0.50 (0.42–0.60)†
LGA (1,863)	0.50 (0.33–0.78)†	2.28 (2.00–2.62)†
NICU admission (406)	0.50 (0.23–1.12)	1.12 (0.84–1.49)
SCN admission (452)	0.60 (0.30–1.21)	1.21 (0.64–1.61)
Neonatal infection (994)	0.96 (0.64–1.44)	1.13 (0.93–1.37)
Seizure (26)	10.66 (2.17–52.36)	6.19 (1.32–28.96)
Hypoglycemia (205)	1.86 (0.91–3.81)	1.67 (1.13–2.46)
Polycythemia (260)	1.32 (0.66–2.62)	1.59(1.13–2.22)
MAS (156)	1.93 (0.82–4.53)	1.86 (1.13–3.05)
RDS or tachypnea (437)	0.56 (0.29–1.06)	1.04 (0.79–1.38)
Hospital stay more than 5 d (1,319)	1.44 (1.02–2.04)	1.07 (0.90–1.28)
Hospital stay more than 10 d (229)	1.13 (0.51–2.53)	1.22 (0.81–1.84)

SGA, small for gestational age; LGA, large for gestational age; NICU, neonatal intensive care unit; SCN, special-care nursery; MAS, meconium aspiration syndrome; RDS, respiratory distress syndrome.

Data are adjusted odds ratio (95% confidence interval). Models controlled for maternal race or ethnicity, prepregnancy body mass index, parity, maternal age, gestational hypertension, smoking, date of delivery, mode of delivery, length of first stage of labor, length of second stage of labor, gestational age at delivery, and birth weight.

* Weight gain less than 7 kg was compared with weight gain 11.5–16 kg, and weight gain more than 18 kg was compared with weight gain 11.5–16.0 kg.

† Birth weight not included in model.

than 18 kg would need to gain within the recommended guidelines to avoid one case of neonatal infection, and 186 women would need to gain within, instead of above, the IOM guidelines to avoid one case of meconium aspiration syndrome. Although our findings are interesting, further work in this arena may help us to identify 1) women at highest risk of these outcomes who may benefit from prevention of excessive weight gain and 2) the specific causal relationship between weight gain and adverse neonatal outcomes. Excessive weight gain has also been associated with more common outcomes, including cesarean birth[18] and postpartum weight retention,[19] and thus may affect a woman's long-term health.

Why might excessive weight gain be associated with adverse neonatal outcomes, even among nondiabetic births, and independent of birth weight and gestational age? One possible explanation could be subclinical insulin resistance in women who screened negative for gestational diabetes mellitus. We did find increased odds of neonatal hypoglycemia associated with excessive gestational gain, which supports this hypothesis. There are likely to be multiple mechanisms, and further research is warranted, especially regarding the observed association between excessive gain and meconium aspiration syndrome (independent of gestational age).

Our study was limited to term infants only. This was done in part for methodologic reasons; women delivering preterm have had less time to gain weight, and the rate of weight gain is not constant throughout pregnancy. We addressed this problem by limiting the cohort to term births and further by controlling for gestational age in the multivariable analysis. However, it must be stressed that a low rate of weight gain, particularly among women with a low prepregnancy BMI, has been associated with preterm birth in multiple studies,[20–22] and preterm birth is a major cause of adverse infant outcome.

Because it is rare to have a clinically-recorded weight before conception, most studies of gestational weight gain have used self-reported prepregnancy weight as we did in this study. Self-reported weight in a nationally representative sample of nonpregnant young women has been found to correlate well with measured weight.[23] However, studies have also shown that overweight women are less accurate at reporting their weights and are more likely to underestimate their weight.[23,24] This could lead to an overestimation of gestational weight gain among overweight women. Although we controlled for prepregnancy BMI in the multivariate analyses, we had inadequate power to stratify by prepregnancy BMI. As a sensitivity analysis we twice reran the models excluding women 1)

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with low or high prepregnancy BMI and 2) obese women, and we saw similar trends in outcomes (data not shown).

Although obesity is associated with adverse neonatal outcome[25]; our results indicate that high gestational weight gain is independently associated with adverse neonatal outcome and is not simply a marker for obesity. Although our findings apply to the cohort as a whole, which includes women of all BMI categories, future studies using larger data sets should examine the relationship between weight gain and infant outcome among subgroups of women with abnormal prepregnancy BMI.

Another limitation of our analysis is that we only had data on short-term infant outcomes. Gestational weight gain, either high or low, could be associated with longer-term adverse outcomes such as late neonatal death, sudden infant death syndrome, or cognitive disabilities that we were unable to assess with these data.

Our findings are based on nonrandomized, retrospective data, thus are prone to confounding. We attempted to control for the major confounders of weight gain either by multivariable analyses or by examining BMI subgroups. However, there may be other confounders that we did not identify. We also had to exclude a large number of births that were missing data on prepregnancy BMI and gestational weight gain. These women had higher rates of adverse neonatal outcomes than women not missing data. It is possible that we underestimated the true association between gestational weight gain and adverse neonatal outcome because of this missing data.

We examined a rather broad range of neonatal outcomes, some of which may be interrelated. We did not include an adjustment for multiple comparisons, because many of these outcomes are rare (less than 1%), and we would then have had inadequate power to discover associations and possible Type II error. We did not limit our analysis to one or two neonatal morbidities because little is known about associations between gestational weight gain and infant outcomes other than birth weight. Thus our analysis should be viewed as exploratory and future research, preferably in large, population-based cohorts, should be performed to validate our findings.

In 1990, the Institute of Medicine issued guidelines for gestational weight gain.[14] These guidelines were somewhat higher than what some health experts had previously advocated, and were based in part on studies showing higher rates of perinatal mortality associated with low weight gain. Unfortunately, these early studies were not able to control for many of the confounders of weight gain and perinatal outcomes. After the release of the IOM guidelines, some investigators and experts expressed concern that higher weight gains among a mostly well- or over-nourished population would not reduce adverse infant outcomes and would put women at risk for delivering macrosomic infants and for postpartum weight retention.[26] The findings of our study suggest that public health efforts in industrialized nations might better be spent on the avoidance of excessive gain rather than the prevention of inadequate gain. As we confront the current obesity epidemic in the United States, the prevention of excessive weight gain in pregnancy is likely to benefit women's health as well as that of their newborns.

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