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Excessive gestational weight gain is associated with severe maternal morbidity

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Abstract

Purpose—We determined the association between gestational weight gain and severe maternal morbidity.

Methods—We used data on 84,241 delivery hospitalizations at Magee-Womens Hospital, Pittsburgh, Pennsylvania (2003–2012). Total gestational weight gain (kg) was converted to gestational age-standardized z-scores. We defined severe maternal morbidity as having 1 of the 21 Centers for Disease Control diagnosis or procedure codes for severe maternal morbidity identification, intensive care unit admission, or extended postpartum stay. We used multivariable logistic regression to determine the association between weight gain and severe maternal morbidity after confounder adjustment.

Results—High gestational weight gain z-scores were associated with an increased risk of severe maternal morbidity. Compared with z-score 0 SD (equivalent to 16 kg at 40 weeks in a normal weight woman), risk differences (95% confidence intervals) for z-scores –2 SD (7 kg), –1 SD (11 kg) +1 SD (23 kg), and +2 SD (31 kg) were 1.5 (–0.71, 3.7), 0.056 (–0.81, 0.93), 3.4 (1.7, 5.0),

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KEF, KPH, LMB designed research; KEF, KPH, SMP, LMB conducted research; KEF, SMP analyzed data or performed statistical analysis; KEF, KPH, LMB wrote the paper; JAH, SMP, KMM, MMB critically reviewed and edited the paper; LMB had primary responsibility for final content. All authors approved the final version of the paper.

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and 8.6 (4.0, 13) per 1000 deliveries. Results did not vary by gestational age at delivery or prepregnancy body mass index.

Conclusions—The increased risk of severe maternal morbidity with high pregnancy weight gain may allow scientists to understand and prevent this serious condition.

Introduction

The U.S. maternal mortality rate has doubled in the last 30 years, sparking urgent calls to understand factors underlying this public health tragedy (1, 2). Severe maternal morbidity is considered a surrogate for maternal mortality because without intervention, some cases could lead to death. Furthermore, severe maternal morbidity, which includes serious complications like eclampsia, myocardial infarction, pulmonary embolism, renal failure requiring dialysis, or hemorrhage requiring an unplanned hysterectomy, leads to extended hospital stays, long-term rehabilitation, and decreased quality of life (3, 4).

The obesity epidemic is thought to be a major contributor to the rise in severe maternal morbidity (4, 5). Modifying weight before conception, however, is challenging because most women do not seek preconception care (6) and half of pregnancies are unplanned (7). In contrast, weight gain during pregnancy can be managed using lifestyle interventions (8). A recent study found that excessive pregnancy weight gain was positively associated with severe maternal morbidity in term pregnancies (9). It is unknown whether this relation is generalizable to preterm deliveries, which make up 40% of severe maternal morbidity cases and have an underlying disease profile distinct from term deliveries (10). Another recent study reported that high and low pregnancy weight gain were related to severe maternal morbidity (11), but the authors used a measure of weight gain that is known to misspecify associations between weight gain and gestational age-dependent outcomes (12). We sought to determine the dose-response association between total gestational weight gain z-scores and the risk of severe maternal morbidity.

Material and Methods

Data came from an electronic database of delivery hospitalizations 2003–2012 at Magee-Womens Hospital of the University of Pittsburgh Medical Center in Pittsburgh, Pennsylvania (13). From the cohort of 84,536 singleton deliveries, we excluded 3 that were missing data on infant sex, parity, and dates of admission and discharge, as well as 43 records with a missing gestational age at delivery and 249 records with a gestational age <20 or >42 weeks. The final analytic sample was 84,241 contributed by 72,467 women. This analysis was approved by the University of Pittsburgh Institutional Review Board.

Prepregnancy body mass index (BMI) was calculated by dividing self-reported prepregnancy weight (kg) by measured height (m) squared, and categorized as underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), or obese (≥30.0 kg/m²) (14). Weight at delivery was either measured at the last antenatal visit or self-reported at delivery. Total gestational weight gain (kg) was calculated by subtracting prepregnancy weight from delivery weight. We converted total weight gain to gestational age-standardized z-scores based on prepregnancy BMI category-specific charts. These charts were created

using serial weight gain measurements from a sample of women with healthy, term pregnancies at Magee-Womens Hospital (15, 16).

We defined severe maternal morbidity as having any of the following criteria: one or more of the 21 Centers for Disease Control and Prevention International Classification of Diseases (9th revision) diagnosis or procedure codes used for the identification of severe maternal morbidity up to and including delivery, (3) maternal admission to the intensive care unit, or extended postpartum length of stay (>3 standard deviations beyond the mean length of stay according to mode of delivery) (17). In an internal validation study of 349 cases and 349 noncases (18), the performance of this definition against medical record review did not meaningfully vary according to gestational weight gain category (45%–51% positive predictive values, 97%–100% negative predictive values), and these predictive values were consistent with prior research (17).

Gestational age was determined using the best obstetric estimate based on a comparison of menstrual dating and ultrasound dating (19). Preterm birth was defined as delivery of a live-born infant at <37 weeks' gestation. Data on maternal race/ethnicity, education, smoking, marital status, and maternal age were based on self-report. Parity, insurance type, and preexisting conditions came from the medical record.

Statistical analysis

Records were missing data on prepregnancy weight or height (24%), delivery weight (8.6%), length of hospital stay (3.6%), maternal education (0.5%), or race/ethnicity (0.05%). We addressed the missing data using multiple imputation by chained equations (20, 21). We jointly imputed maternal height, prepregnancy weight, delivery weight, length of stay, education, and race/ethnicity using data on preexisting conditions, year, route of delivery, maternal age, smoking, parity, gestational diabetes, insurance, marital status, fetal death, gestational age at delivery, maternal ID, and census tract of residence. We created 25 imputed datasets to stabilize our variance estimates (22).

We estimated the association between gestational weight gain z-score and severe maternal morbidity using multivariable logistic regression with generalized estimating equations and an exchangeable correlation structure to account for 11,774 repeated pregnancies in the cohort. We specified total gestational weight gain z-score as a categorical variable as well as in a smoothed, nonlinear form using a restricted cubic spline with 3 knots determined by Akaike information criterion and placed at 10%, 50%, and 90% on the distribution (23). We used theory-based causal graphs (24) to identify potential confounders (age, prepregnancy BMI, race, parity, education, preexisting diabetes or hypertension, smoking, marital status, and payment method), all of which were included in the final models. We calculated adjusted predicted probabilities, risk differences (RD) and corresponding 95% confidence intervals (CI) via marginal standardization. Based on literature reporting different associations by gestational age and BMI (9, 11), we evaluated additive effect modification by gestational age and prepregnancy BMI by calculating synergy indexes (25) and visually inspecting stratified risk curves. We reran our models after excluding eclampsia from the definition of severe maternal morbidity because it is possible that the underlying disease process that led to the morbid event altered total pregnancy weight gain at delivery (26).

Results

Women tended to be non-Hispanic White, multiparous, married, college-educated, normal weight, and had private health insurance. The mean (standard deviation) maternal age was 29 (6.1) years and the median (interquartile range) of gestational age at delivery was 39 (2.0) weeks. The incidence of preterm birth was 11%. The mean total gestational weight gain was 14.7 (7.0) kg and the mean weight gain z-score was -0.10 (1.1) standard deviations (SD). Weight gain was higher in term (15.1 (6.9) kg) compared with preterm deliveries (12.2 (7.3) kg), but z-scores were similar (-0.09 (1.0) vs. -0.12 (1.3) SD, respectively).

Severe maternal morbidity occurred in 1.9% ($n=1598$) of delivery hospitalizations, and ICU admission, blood transfusion, and heart failure during procedure or surgery were the most common indicators for severe maternal morbidity (Appendix Table 1). The outcome was 5 times as common in preterm (6.4%) versus term (1.3%) deliveries (Table 1). Women with obesity or women who were non-Hispanic Black, unmarried, lacking private health insurance, with less than a college degree or with preexisting hypertension or diabetes were more likely than their counterparts to have severe maternal morbidity. Risk factors for severe maternal morbidity did not meaningfully differ by gestational age at delivery.

In the overall population and among term and preterm deliveries, women with high gestational weight gain z-scores were more likely than those with moderate z-scores to have severe maternal morbidity (Table 1). Women with very low z-scores also had a higher incidence, though sample sizes in these groups were relatively small.

After adjusting for confounders, the risk of severe maternal morbidity was approximately level from gestational weight gain z-scores of -2 SD to 0 SD, after which risk increased (Figure Panel A). Compared with a gestational weight gain of 0 SD (equivalent to 16 kg at 40 weeks in a normal weight woman), weight gain z-scores of $+1$ (23 kg) and $+2$ SD (31 kg) were associated with 3.4 (95% CI 1.7, 5.0) and 8.6 (4.0, 13) excess cases per 1000 deliveries, respectively (Table 2). These results did not differ when eclampsia were removed from the definition of the outcome (data not shown).

Gestational age did not modify the association between pregnancy weight gain and severe maternal morbidity. There were no meaningful differences in the adjusted risk curves (Figure Panel B) or risk differences (Table 2) between term and preterm deliveries. The lack of effect measure modification on the additive scale was confirmed by synergy indexes (Appendix Table). Similarly, there was no evidence of effect measure modification on the additive scale by prepregnancy BMI category (Appendix Figure, Appendix Table 2).

Discussion

We observed a positive association between high gestational weight gain and risk of severe maternal morbidity that did not meaningfully vary according to gestational age at delivery or prepregnancy BMI. The absolute risk differences associated with higher weight gain were of notable magnitude given the rarity of severe maternal morbidity as well as the gestational weight gains with elevated risk (equivalent to >23 kg at term in normal weight women) occur in 13% of pregnancies.

Platner et al. studied 515,148 term deliveries in New York City and found that compared with women who gained within the 2009 Institute of Medicine weight gain recommendations, women who gained 9 kg more than recommended (25 kg total in a normal weight woman) had a 20% increased risk of severe maternal morbidity, but women who gained below the guidelines had no difference in risk (9). Ukah et al. observed a similar effect estimate associated with gain above or below the IOM guidelines in some BMI groups (11). These effects are substantially smaller than ours. However, in these studies, the authors broadly categorized weight gain, which may have limited their ability to detect the stronger associations that we observed in the upper tail of the distribution. Additionally, Ukah et al. used rate of pregnancy weight gain, which is known to produce spurious results when studied relative to a gestational age-dependent outcome like severe maternal morbidity (26). Our use of gestational age-standardized weight gain z-scores, which are independent of pregnancy duration overcomes this bias.

We cannot determine which deliveries in our database transferred from an outlying hospital to our tertiary-care center. If gestational weight gain also differs in transfers compared with deliveries in the underlying population, selection bias will occur. A detailed medical record reviews that would be necessary to define severe maternal morbidity using obstetric professional societies' proposed list of diagnoses was beyond the scope of this project (27). Our definition, which is used widely in surveillance and etiologic research, overestimates the number of true cases, but our internal validation study (18) found this was not systematically different by pregnancy weight gain. Most individual indicators of severe maternal morbidity were too rare to evaluate separately, and medical record review would be needed to detail this further. However, such work would be necessary to explore underlying disease mechanisms potentially related to pregnancy weight gain.

Pregnancy weight gain equivalent to >23 kg at term in a normal weight woman, which occurred in 13% of the pregnancies in our cohort, is associated with an increased risk of severe maternal morbidity. This association may help scientists and care providers better understand and prevent severe maternal morbidity.

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Appendix

Appendix Figure.

Adjusted predicted risk of severe maternal morbidity by gestational weight gain z-score stratified by prepregnancy body mass index category. Magee-Womens Hospital, Pittsburgh, Pennsylvania, 2003–2012, n=84,241.

The solid lines represent the point estimate and dashed lines represent its 95% confidence bands. Normal weight women are represented with red lines, overweight women are represented with green lines, and women with obesity are represented with blue lines. Gestational weight gain z-scores of -2 , -1 , 0 , $+1$, and $+2$ standard deviations are equivalent to total weight gain of 7, 11, 16, 23, and 31 kg at 40 weeks, respectively, in a normal weight woman. Predicted risks were marginally standardized after adjustment for maternal age, race/ethnicity, parity, education, preexisting hypertension or diabetes, smoking during pregnancy, marital status, and primary method of payment.

Appendix Table 1.

Indicators of severe maternal morbidity. Magee-Womens Hospital. Pittsburgh, Pennsylvania, n=1598.

Severe maternal morbidity indicator	Cases (n)	%
Intensive care unit admission	475	30
Prolonged postpartum length of stay	405	25
Acute myocardial infarction	1	0.10
Acute renal failure	81	5.1
Adult respiratory distress syndrome	89	5.6

Severe maternal morbidity indicator	Cases (n)	%
Amniotic fluid embolism	7	0.44
Aneurysm	2	0.13
Cardiac arrest/ ventricular fibrillation	9	0.56
Disseminated intravascular coagulation	100	6.3
Eclampsia	67	4.2
Heart failure during procedure or surgery	431	27
Puerperal cerebrovascular disorders	28	1.8
Pulmonary edema	39	2.4
Severe anesthesia complications	25	1.6
Sepsis	41	2.6
Shock	57	3.6
Sickle cell anemia with crisis	10	0.63
Thrombotic embolism	17	1.1
Blood transfusion	469	29
Conversion of cardiac rhythm	1	0.10
Hysterectomy	93	5.8
Temporary tracheostomy	2	0.13
Ventilation	42	2.6

Percentages do not total 100 because some women with severe maternal morbidity have more than one indicator.

Appendix Table 2.

Synergy Index values calculated as a test of departure from additivity by gestational age at delivery or prepregnancy body mass index in the association between pregnancy weight gain z-score and severe maternal morbidity. Magee-Womens Hospital, Pittsburgh, Pennsylvania, 2003–2012, n=84,241.

Pregnancy weight gain z-score**, SD	Potential effect measure modifier		
	Preterm birth	Prepregnancy overweight	Prepregnancy obesity
	Synergy index (95% CI)	Synergy index (95% CI)	Synergy index (95% CI)
–1 vs 0	1.0 (0.90, 1.1)	1.2 (0.11, 2.2)	0.87 (0.37, 1.4)
+1 vs. 0	1.1 (0.92, 1.3)	1.1 (0.37, 1.8)	0.88 (0.43, 1.3)

A synergy index of 1.0 implies no interaction (perfect additivity), <1 indicates antagonism, and >1 indicates synergy.

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Figure.

Adjusted predicted risk of severe maternal morbidity by gestational weight gain z-score overall (Panel A) and among term and preterm births (Panel B; note the different axes).

Magee-Womens Hospital, Pittsburgh, Pennsylvania, 2003–2012, n=84,241.

The solid lines represent the point estimate and dashed lines represent its 95% confidence bands. Gestational weight gain z-scores of -2, -1, 0, +1, and +2 standard deviations are equivalent to total weight gain of 7, 11, 16, 23, and 31 kg at 40 weeks, respectively, in a normal weight woman. Predicted risks were marginally standardized after adjustment for maternal age, prepregnancy body mass index, race/ethnicity, parity, education, preexisting hypertension or diabetes, smoking during pregnancy, marital status, and primary method of payment.

Table 1.
Incidence of severe maternal morbidity by maternal characteristics. Magee-Womens Hospital, Pittsburgh, Pennsylvania, 2003–2012. n=84,241.

	Overall			Term deliveries (≥ 37 weeks)			Preterm deliveries (<37 weeks)		
	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)
Overall	84,241	1,598		74,879	998	1.3	9,362	600	6.4
Prepregnancy BMI									
Underweight	4063	70	1.7	3488	45	1.3	575	25	4.3
Normal weight	43,741	700	1.6	39,401	469	1.2	4,340	231	5.3
Overweight	20,084	400	2.0	17,869	245	1.4	2,215	155	7.0
Obese	16,353	428	2.6	14,121	239	1.7	2,232	189	8.5
Age (years)									
<20	5930	146	2.5	5080	93	1.8	850	53	6.2
20–30	38,086	670	1.8	33,622	428	1.3	4,464	242	5.4
>30	40,225	782	1.9	36,177	477	1.3	4,048	305	7.5
Race/ethnicity									
Non-Hispanic White	63,061	1035	1.6	56,408	630	1.1	6,653	405	6.1
Non-Hispanic Black	16,540	468	2.8	14,218	292	2.1	2,322	176	7.6
Other	4640	95	2.0	4,253	76	1.8	387	19	4.9
Parity									
0	38,598	794	2.1	34,213	539	1.6	4,385	255	5.8
1 or more	45,643	804	1.8	40,666	459	1.1	4,977	345	6.9
Marital status									
Unmarried	33,450	801	2.4	28,579	475	1.7	4,871	326	6.7
Married	50,791	797	1.6	46,300	523	1.1	4,491	274	6.1
Education									
High school or less	25,702	638	2.5	21,815	372	1.7	3,887	266	6.8
Some college	19,476	391	2.0	17,075	224	1.3	2,401	167	7.0
College graduate	39,063	569	1.5	35,989	402	1.1	3,074	167	5.4
Preexisting hypertension or diabetes									

	Overall			Term deliveries (≥ 37 weeks)			Preterm deliveries (<37 weeks)		
	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)	Population at risk (n)	Severe maternal morbidity cases (n)	Incidence (%)
Yes	3743	221	5.9	2581	74	2.9	1162	147	13.0
No	80,498	1377	1.7	72,298	924	1.3	8200	453	5.5
Smoking									
Yes	12,323	259	2.1	10,272	147	1.4	2051	112	5.5
No	71,918	1339	1.9	64,607	851	1.3	7311	488	6.7
Insurance									
Private	57,772	927	1.6	52,460	605	1.2	5312	322	6.1
Public or other	2,6469	671	2.5	22,419	393	1.8	4050	278	6.9
Gestational weight gain z-score									
<-2	3362	83	2.5	2755	40	1.5	607	43	7.1
-2 to <-1	10152	182	1.8	8900	116	1.3	1252	66	5.3
-1 to <0	30,232	501	1.7	27,315	329	1.2	2917	172	5.9
0 to <+1	29,800	555	1.9	26,744	356	1.3	3056	199	6.5
+1 to <+2	9408	226	2.4	8124	129	1.6	1284	97	7.6
+2	1287	51	4.0	1041	28	2.7	246	23	9.3

BMI, body mass index

Underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), obese (≥ 30 kg/m²)

Gestational weight gain z-scores of -2, -1, 0, +1, and +2 are equivalent to total maternal weight gain at 36 weeks gestation of 6.3, 10, 15, 21, and 28 kg, respectively and total maternal weight gain at 40 weeks gestation of 7.0, 11, 16, 23, and 31 kg, respectively.

Table 2.

Association between gestational weight gain z-score and severe maternal morbidity overall and by gestational age at delivery. Magee-Womens Hospital. Pittsburgh, Pennsylvania. 2003–2012, n=84,241.

Pregnancy weight gain z-score **, SD	Unadjusted number of excess cases per 1000 deliveries (95% CI)	Adjusted* number of excess cases per 1000 deliveries (95% CI)
<i>Overall</i>		
–2	2.2 (0, 4.3)	1.5 (–0.71, 3.7)
–1	0.14 (–0.70, 0.98)	0.056 (–0.81, 0.93)
0	Reference	Reference
+1	4.6 (3.0, 6.3)	3.4 (1.7, 5.0)
+2	12 (7.4, 17)	8.6 (4.0, 13)
<i>Term deliveries</i>		
–2	0.32 (–1.9, 2.6)	–0.21 (–2.4, 2.0)
–1	–0.26 (–1.2, 0.63)	–0.39 (–1.3, 0.53)
0	Reference	Reference
+1	2.5 (1.0, 4.0)	1.9 (0.43, 3.4)
+2	6.4 (2.2, 11)	4.7 (0.65, 8.7)
<i>Preterm deliveries</i>		
–2	1.6 (–9.4, 13)	2.1 (–9.0, 13)
–1	–0.93 (–5.4, 3.5)	–0.33 (–4.9, 4.2)
0	Reference	Reference
+1	10 (2.4, 18)	7.2 (–0.49, 15)
+2	25 (4.3, 45)	18 (–2.2, – 37)

CI, confidence interval; SD, standard deviation

* Adjustment for maternal age, prepregnancy body mass index, race/ethnicity, parity, education, preexisting hypertension or diabetes, smoking during pregnancy, marital status, and primary method of payment.

** Gestational weight gain z-scores of –2, –1, 0, +1, and +2 are equivalent to total maternal weight gain at 36 weeks gestation of 6.3, 10, 15, 21, and 28 kg, respectively and total maternal weight gain at 40 weeks gestation of 7.0, 11, 16, 23, and 31 kg, respectively.