JAMA Network Open

Original Investigation | Obstetrics and Gynecology

Weight Gain During Pregnancy and Severe Maternal Morbidity

Sahar Khademioore, MSc; Elizabeth K. Darling, PhD; Rohan D'Souza, PhD; Giulia M. Muraca, PhD; Yanfang Guo, PhD; Laura N. Anderson, PhD

Abstract

IMPORTANCE Severe maternal morbidity (SMM) carries serious consequences for pregnant individuals, yet the association between gestational weight gain (GWG) and SMM remains poorly understood.

OBJECTIVE To examine the association between GWG and SMM across prepregnancy body mass index (BMI) categories.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study used linked birth registry data from Better Outcomes Registry & Network Ontario and hospitalization data from the Canadian Institute for Health Information for singleton pregnancies with a hospital delivery at a gestational age of 20 weeks or greater in Ontario, Canada, from April 1, 2012, to March 31, 2022. Data were analyzed from May 1 to November 1, 2025.

EXPOSURES Continuous GWG as mean weekly gain in the second and third trimesters and categorical GWG (inadequate, adequate, or excessive) according to the 2009 Institute of Medicine recommendations based on prepregnancy BMI.

MAIN OUTCOMES AND MEASURES SMM, defined as a composite of 13 indicators per the Canadian Perinatal Surveillance System, occurring during delivery hospitalization.

RESULTS Among 1 035 927 pregnancies, 192 731 (18.6%) had inadequate, 296 448 (28.6%) had adequate, and 546 748 (52.8%) had excessive GWG; 15 119 (14.59 per 1000 births) experienced SMM. Compared with adequate GWG, excessive GWG was associated with increased SMM across all BMI categories: underweight (adjusted rate ratio [ARR], 1.33 [95% CI, 1.15-1.53]), normal weight (ARR, 1.24 [95% CI, 1.17-1.31]), overweight (ARR, 1.16 [95% CI, 1.06-1.27]), obesity class I (ARR, 1.21 [95% CI, 1.08-1.35]), obesity class II (ARR, 1.28 [95% CI, 1.07-1.54]), and obesity class III (ARR, 1.24 [95% CI, 1.03-1.48]). Inadequate GWG was associated with increased SMM predominantly among individuals with normal weight (ARR, 1.13 [95% CI, 1.06-1.21]) and overweight (ARR, 1.19 [95% CI, 1.05-1.35]). GWG showed nonlinear associations with SMM across all BMI categories, with risk elevated at both low and high GWG in individuals with underweight, normal weight, and overweight, while in those with obesity classes I to III, risk was concentrated at high GWG values. Estimated SMM rates were lowest at 0.4 kg/wk GWG for underweight through overweight BMI categories and declined across obesity classes to 0.1 kg/wk GWG for the obesity class III category.

CONCLUSIONS AND RELEVANCE In this cohort study of 1 035 927 pregnancies, GWG outside Institute of Medicine–recommended ranges was associated with increased SMM risk, with patterns varying by BMI category. These findings may complement existing evidence informing GWG guidance.

Key Points

Question Is gestational weight gain (GWG) associated with severe maternal morbidity across prepregnancy body mass index (BMI) categories, and what weekly GWG is associated with lowest risk?

Findings In this cohort study of 1 035 927 singleton pregnancies, excessive GWG was associated with increased severe maternal morbidity across all prepregnancy BMI categories, as was inadequate GWG among individuals with normal weight and overweight. The weekly GWG associated with lowest estimated risk decreased with increasing prepregnancy BMI.

Meaning These findings suggest that recommended GWG ranges may not correspond to the lowest severe maternal morbidity risk and warrant consideration when these recommendations are evaluated.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

JAMA Network Open. 2026;9(10):e2640027. doi:10.1001/jamanetworkopen.2026.40027

Open Access. This is an open access article distributed under the terms of the CC-BY-NC-ND License, which does not permit alteration or commercial use, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by guest on 11/24/2026

Introduction

Severe maternal morbidity (SMM) encompasses unexpected complications arising during the perinatal period that carry meaningful health consequences for the pregnant individuals and may represent a near miss for death.[1-3] The rising incidence of SMM in high-income countries represents a major public health challenge, necessitating identification of modifiable risk factors and opportunities for prevention.[4-8]

Gestational weight gain (GWG) and prepregnancy body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) are established risk factors for several pregnancy outcomes.[9,10] For SMM specifically, prepregnancy BMI is consistently linked to SMM risk,[11-15] and the contribution of GWG is less understood.

Current Institute of Medicine (IOM) guidelines specify target GWG ranges based on prepregnancy BMI, applying a single recommendation to all obesity classes.[16] SMM was not among the outcomes used to derive these ranges, and adequacy of these guidelines has been questioned, particularly for individuals with overweight or obesity.[17-19] Gain outside these ranges remains common in the general pregnant population in Ontario, alongside rising prepregnancy BMI.[20,21] Assessing the adequacy of these ranges is further complicated by recent recognition that BMI alone does not best define obesity and capture metabolic risk, and individuals with preexisting medical conditions may face compounding vulnerability when GWG falls outside recommended ranges.[22,23]

Therefore, we conducted a population-based retrospective cohort study in Ontario, Canada (2012-2022), to evaluate associations between GWG and SMM across prepregnancy BMI groups. We examined categorical and continuous dose-response relationships to identify the GWG associated with lowest SMM risk and assessed additive interaction between inadequate or excessive GWG and preexisting medical conditions.

Methods

Study Design and Data Sources

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines. We conducted a population-based retrospective cohort study using data from Better Outcomes Registry & Network (BORN) Ontario, a prescribed registry capturing all births in Ontario[24] and linked with the Canadian Institute for Health Information Discharge Abstract Database, which captures all hospital admissions in Canada.[25] This study was approved by the Hamilton Integrated Research Ethics Board. BORN Ontario is authorized under the Personal Health Information Protection Act to disclose personal health information without individual consent.[24]

Inclusion Criteria

This study included pregnant individuals with hospital-delivered singleton birth (live or stillbirth) at a gestational age of 20 weeks or more or birth weight greater than 500 g in Ontario, Canada, between April 1, 2012, and March 31, 2022. We considered prepregnancy BMI values less than 15.0 or more than 70.0, gestational weight loss greater than 30 kg, or GWG greater than 50 kg to be biologically implausible and excluded them from our analysis (<1% of observations).[26-28]

Measurements

Total GWG constituted the exposure. Total GWG was recorded at BORN Ontario by subtracting prepregnancy weight from maternal weight at delivery and is a widely used variable with strong criterion validity.[26,29-31] Prepregnancy weight and weight at delivery were obtained from measured or self-reported values at the time of delivery; when unavailable, weight recorded at the last prenatal visit was used.

Downloaded from jamanetwork.com by guest on 11/24/2026

We classified GWG into 3 categories (inadequate, adequate, and excessive) using the IOM weight gain ranges specific to prepregnancy BMI classification.[16] To account for gestational age, we calculated the ratio of observed to expected GWG and derived BMI-specific ratio ranges by dividing IOM limits by expected GWG at 40 weeks (detailed calculation in eTable 1 in Supplement 1).[26,28,29,32] When analyzing GWG as a continuous variable, we used mean weekly weight gain during the second and third trimesters.[29]

Prepregnancy BMI was considered as an effect modifier and was calculated from self-reported height and prepregnancy weight. We classified BMI using World Health Organization criteria as underweight (BMI <18.5), normal weight (BMI, 18.5-24.9), overweight (BMI, 25.0-29.9), obesity class I (BMI, 30.0-34.9), obesity class II (BMI, 35.0-39.9), and obesity class III (BMI ≥40.0).[33] The primary outcome was composite SMM occurring during delivery hospitalization, defined per the Canadian Perinatal Surveillance System as 13 heterogeneous conditions grouped by prolonged hospitalization, high case fatality, or clinical significance rather than by shared etiology (eTable 2 in Supplement 1).[7]

We identified potential confounders using a directed acyclic graph based on a review of relevant literature (eFigure 1 in Supplement 1). These included maternal age, parity, race (self-reported or recorded by clinicians as part of prenatal screening requisitions as Asian, Black, White, or other [including Indigenous, Latin American, Middle Eastern, and multiracial groups]), area-level income, educational attainment, material deprivation quintiles derived from census data linked to maternal residential postal code,[34] prepregnancy smoking status, fetal sex, and a composite of preexisting medical conditions (prepregnancy diabetes, chronic hypertension, cardiovascular disease, asthma, and pulmonary diseases). We included maternal race in our models as a proxy for the effects of racism and structural inequities, given evidence of racial disparities in GWG and SMM.[26,35]

Statistical Analysis

To examine the association between GWG and SMM, we used modified Poisson regression with robust error variance and generalized estimating equations, with an exchangeable correlation structure to account for correlation among pregnancies from the same individual, to estimate risk ratios (RRs) and 95% CIs. All analyses were stratified by prepregnancy BMI and used adequate GWG as a reference category. The models were adjusted for potential confounders as described above.

We used multiple imputations with the fully conditional specification method to address missing covariate data. Five complete datasets were generated, and results were pooled across all imputed datasets according to Rubin's rules.[36] We treated missing race due to no prenatal screening (29.4%) as a distinct category, as we considered this missingness to be informative. We performed a sensitivity analysis restricted to individuals with observed race to evaluate the impact of the missing race category.

Assessment of Nonlinear Associations

To assess nonlinear associations between GWG and SMM, we modeled mean weekly GWG using restricted cubic splines, stratified by prepregnancy BMI group. The exposure was restricted to −0.3 to 1.5 kg/wk for model stability, and knots were placed at the 5th, 35th, 65th, and 95th percentiles per Harrell's recommendations.[37] Spline models used modified Poisson regression with generalized estimating equations, adjusted for the same covariates as the primary analysis. RRs were calculated relative to the IOM-recommended mean weekly GWG for each BMI category: 0.51 kg/wk for individuals with underweight, 0.42 kg/wk for individuals with normal weight, 0.28 kg/wk for individuals with overweight, and 0.22 kg/wk for individuals with obesity.[16]

To evaluate whether preexisting medical conditions (prepregnancy diabetes, chronic hypertension, cardiovascular disease, asthma, and pulmonary diseases) modify the GWG-SMM association within BMI strata, we examined additive interaction by creating joint GWG category and preexisting condition (present or absent) exposure variables and calculating the relative excess risk due to interaction (RERI) with SEs estimated via the delta method with robust covariance matrices.[38,39]

Downloaded from jamanetwork.com by guest on 11/24/2026

Sensitivity Analyses

To evaluate potential selection bias from missing data, we compared characteristics of individuals excluded due to missing BMI or GWG with the study cohort using standardized mean differences (SMDs). We repeated the main analysis restricted to term pregnancies (gestational age ≥37 weeks) to assess consistency of our results after excluding preterm births. We assessed whether prepregnancy BMI is associated with SMM beyond its role as an effect modifier by examining the BMI-SMM association. To account for potential overestimation of GWG due to fluid retention from severe hypertensive disorders, we repeated the analyses with severe pre-eclampsia, eclampsia, and HELLP (hemolysis, elevated liver enzyme levels, and low platelet count) syndrome removed from the definition of SMM. We estimated associations between GWG and SMM within racial groups in each BMI category, combining obesity classes owing to small event counts in some cells. Analyses were performed in SAS, version 9.4 (SAS Institute Inc), or R, version 4.3.1 (R Program for Statistical Computing), with statistical significance set at a 2-sided $\alpha = .05$. Data were analyzed from May 1 to November 1, 2025.

Results

The study included 1 035 927 singleton pregnancies after applying the inclusion and exclusion criteria (eFigure 2 in Supplement 1). Most individuals were aged 30 to 34 years (388 133 [37.5%]) and with normal prepregnancy BMI (501 675 [48.4%]). Maternal race included 197 137 individuals (19.0%) identified as Asian; 47 725 (4.6%) as Black; 433 730 (41.9%) as White; and 42 771 (4.1%) as other race. Overall, 546 748 individuals (52.8%) had excessive, 296 448 (28.6%) had adequate, and 192 731 (18.6%) had inadequate GWG based on IOM criteria (**Table 1**).

The overall rate of any SMM was 14.59 per 1000 births (15 119 cases) (eTable 3 in Supplement 1). Rates of SMM per 1000 births were highest among those with excessive GWG (16.09 per 1000 births), followed by inadequate GWG (14.08 per 1000 births) and adequate GWG (12.18 per 1000 births) (eTable 3 in Supplement 1). The rate of SMM per 1000 births increased with increasing prepregnancy BMI category across all GWG categories and within each BMI stratum (**Figure 1**; eTable 4 in Supplement 1). The most common SMM types were severe hemorrhage (4.93 per 1000 births); severe preeclampsia, eclampsia, and HELLP syndrome (4.48 per 1000 births); intensive care unit admission (1.83 per 1000 births); and hysterectomy (1.81 per 1000 births) (eTable 3 in Supplement 1). Rates of severe preeclampsia, eclampsia, and HELLP syndrome increased progressively from adequate to excessive GWG, particularly in higher BMI categories (eTable 4 in Supplement 1). In contrast, severe hemorrhage rates remained relatively stable (range, 3.99 to 5.94 per 1000 births) across all BMI and GWG groups.

Excessive GWG, compared with adequate GWG, was associated with increased SMM in all prepregnancy BMI categories including underweight (ARR, 1.33 [95% CI, 1.15-1.53]), normal weight (ARR, 1.24 [95% CI, 1.17-1.31]), overweight (ARR, 1.16 [95% CI, 1.06-1.27]), class I obesity (ARR, 1.21 [95% CI, 1.08-1.35]), class II obesity (ARR, 1.28 [95% CI, 1.07-1.54]), and class III obesity (ARR, 1.24 [95% CI, 1.03-1.48]) (**Table 2**). Compared with adequate GWG, ARRs for inadequate GWG were 1.00 (95% CI, 0.85-1.18) for underweight, 1.13 (95% CI, 1.06-1.21) for normal weight, 1.19 (95% CI, 1.05-1.35) for overweight, 1.11 (95% CI, 0.96-1.29) for obesity class I, 1.10 (95% CI, 0.88-1.37) for obesity class II, and 1.07 (95% CI, 0.88-1.31) for obesity class III (Table 2).

SMM rates were higher among individuals with preexisting medical conditions in each BMI and GWG category (eFigure 3 in Supplement 1). Among those with adequate GWG, preexisting conditions were associated with approximately 2-fold increased SMM risk across all BMI categories (ARR range, 1.78 [95% CI, 1.19-2.68] for obesity class II to 2.53 [95% CI, 1.79-3.57] for obesity class III) (**Table 3**). Among those with inadequate or excessive GWG, joint exposure with preexisting conditions produced the highest SMM risks observed in the analysis.

For excessive GWG, significant positive interactions were observed in individuals with normal weight (RERI, 0.59 [95% CI, 0.22-0.97]), overweight (RERI, 0.41 [95% CI, 0.09-0.76]), obesity class

Downloaded from jamanetwork.com by guest on 11/24/2026

Table 1. Maternal, Socioeconomic, and Pregnancy Characteristics by Gestational Weight Gain Category According to the Institute of Medicine Guidelines[a]

Characteristic	Singleton births, No. (%)			
	GWG category according to the IOM guideline			
	Inadequate (n = 192 731)	Adequate (n = 296 448)	Excessive (n = 546 748)	Total (N = 1 035 927)
Maternal age, y				
<18	1006 (0.5)	1110 (0.4)	2787 (0.5)	4903 (0.5)
18-24	23 318 (12.1)	29 449 (9.9)	63 880 (11.7)	116 647 (11.3)
25-29	49 890 (25.9)	76 717 (25.9)	151 157 (27.6)	277 764 (26.8)
30-34	69 188 (35.9)	114 623 (38.7)	204 322 (37.4)	388 133 (37.5)
35-39	39 625 (20.6)	61 363 (20.7)	103 287 (18.9)	204 275 (19.7)
≥40	9601 (5.0)	13 037 (4.4)	21 099 (3.9)	43 737 (4.2)
Missing	103 (0.1)	149 (0.1)	216 (0.04)	468 (0.05)
Median household income quintile				
1 (Lowest)	45 385 (23.5)	58 321 (19.7)	113 126 (20.7)	216 832 (20.9)
2	36 996 (19.2)	54 528 (18.4)	102 573 (18.8)	194 097 (18.7)
3	33 811 (17.5)	53 778 (18.1)	101 544 (18.6)	189 133 (18.3)
4	38 269 (19.9)	64 162 (21.6)	116 514 (21.3)	218 945 (21.1)
5 (Highest)	35 177 (18.3)	61 362 (20.7)	104 707 (19.2)	201 246 (19.4)
Missing	3093 (1.6)	4297 (1.4)	8284 (1.5)	15 674 (1.5)
Neighborhood educational attainment quintile				
1 (Lowest)	40 852 (21.2)	52 709 (17.8)	106 942 (19.6)	200 503 (19.4)
2	40 923 (21.2)	59 041 (19.9)	117 398 (21.5)	217 362 (21.0)
3	33 723 (17.5)	52 815 (17.8)	101 570 (18.6)	188 108 (18.2)
4	42 229 (21.9)	70 364 (23.7)	124 692 (22.8)	237 285 (22.9)
5 (Highest)	33 121 (17.2)	58 911 (19.9)	90 957 (16.6)	182 989 (17.7)
Missing	1883 (1.0)	2608 (0.9)	5189 (0.9)	9680 (0.9)
Material deprivation quantile				
1 (Lowest)	29 549 (15.3)	54 459 (18.4)	95 626 (17.5)	179 634 (17.3)
2	37 307 (19.4)	63 416 (21.4)	115 515 (21.1)	216 238 (20.9)
3	37 644 (19.5)	60 408 (20.4)	111 364 (20.4)	209 416 (20.2)
4	36 633 (19.0)	53 236 (18.0)	100 785 (18.4)	190 654 (18.4)
5 (Highest)	48 612 (25.2)	61 233 (20.7)	115 473 (21.1)	225 318 (21.8)
Missing	2986 (1.5)	3696 (1.2)	7985 (1.5)	14 667 (1.4)
Maternal race				
Asian	44 051 (22.9)	68 847 (23.2)	84 239 (15.4)	197 137 (19.0)
Black	10 459 (5.4)	12 538 (4.2)	24 728 (4.5)	47 725 (4.6)
White	61 905 (32.1)	116 102 (39.2)	255 723 (46.8)	433 730 (41.9)
Other[b]	7662 (4.0)	11 926 (4.0)	23 183 (4.2)	42 771 (4.1)
Missing due to no PSO screening	66 750 (34.6)	84 074 (28.4)	153 564 (28.1)	304 388 (29.4)
Missing information for race in PSO screening	1904 (1.0)	2961 (1.0)	5311 (1.0)	10 176 (1.0)
Prepregnancy BMI				
Underweight (<18.5)	20 508 (10.6)	36 920 (12.5)	25 770 (4.7)	83 198 (8.0)
Normal (18.5-24.9)	108 091 (56.1)	169 897 (57.3)	223 687 (40.9)	501 675 (48.4)
Overweight (25.0-29.9)	24 425 (12.7)	46 256 (15.6)	147 752 (27.0)	218 433 (21.1)
Obesity class I (30.0-34.9)	19 551 (10.1)	26 791 (9.0)	106 004 (19.4)	152 346 (14.7)
Obesity class II (35.0-39.9)	9105 (4.7)	9027 (3.0)	24 959 (4.6)	43 091 (4.2)
Obesity class III (≥40.0)	11 051 (5.7)	7557 (2.5)	18 576 (3.4)	37 184 (3.6)
Parity				
1	70 891 (36.8)	124 330 (41.9)	257 239 (47.0)	452 460 (43.7)
2	70 762 (36.7)	108 563 (36.6)	183 570 (33.6)	362 895 (35.0)
≥3	49 992 (25.9)	61 667 (20.8)	102 998 (18.8)	214 657 (20.7)
Missing	1086 (0.6)	1888 (0.6)	2941 (0.5)	5915 (0.6)

(continued)

Downloaded from jamanetwork.com by guest on 11/24/2026

Table 1. Maternal, Socioeconomic, and Pregnancy Characteristics by Gestational Weight Gain Category According to the Institute of Medicine Guidelines[a] (continued)

Characteristic	Singleton births, No. (%)			
	GWG category according to the IOM guideline			
	Inadequate (n = 192 731)	Adequate (n = 296 448)	Excessive (n = 546 748)	Total (N = 1 035 927)
Smoking status				
No	169 129 (87.8)	268 732 (90.7)	487 562 (89.2)	925 423 (89.3)
Yes	20 218 (10.5)	21 846 (7.4)	50 015 (9.1)	92 079 (8.9)
Missing	3384 (1.8)	5870 (2.0)	9171 (1.7)	18 425 (1.8)
Preexisting medical condition[c]				
No	174 304 (90.4)	269 435 (90.9)	490 095 (89.6)	933 834 (90.1)
Yes	11 373 (5.9)	14 873 (5.0)	36 095 (6.6)	62 341 (6.0)
Missing	7054 (3.7)	12 140 (4.1)	20 558 (3.8)	39 752 (3.8)
Infant sex				
Male	94 976 (49.3)	149 629 (50.5)	286 816 (52.5)	531 421 (51.3)
Female	97 686 (50.7)	146 727 (49.5)	259 745 (47.5)	504 158 (48.7)
Missing	69 (0.04)	92 (0.03)	187 (0.03)	348 (0.03)
Gestational age, wk				
Mean (SD)	38.7 (1.9)	38.9 (1.6)	38.9 (1.7)	38.9 (1.7)
Preterm (<37)	14 342 (7.4)	15 448 (5.2)	31 096 (5.7)	60 886 (5.9)
Term (37-41)	177 652 (92.2)	279 838 (94.4)	513 639 (93.9)	971 129 (93.7)
Postterm (≥42)	737 (0.4)	1162 (0.4)	2013 (0.4)	3912 (0.4)
Birth weight, g				
Mean (SD)	3198.2 (536.3)	3306.7 (496.5)	3450.8 (537.1)	3362.6 (535.1)
Low (<2500)	15 058 (7.8)	14 090 (4.8)	20 897 (3.8)	50 045 (4.8)
Average (2500-4000)	176 509 (91.6)	280 150 (94.5)	514 243 (94.1)	970 902 (93.7)
High (>4000)	1164 (0.6)	2208 (0.7)	11 608 (2.1)	14 980 (1.4)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); GWG, gestational weight gain; IOM, Institute of Medicine; PSO, Prenatal Screening Ontario.

[a] Participants include individuals with singleton birth, Ontario, Canada, 2012 to 2022.

[b] Includes Indigenous, Latin American, Middle Eastern, and multiracial or multiethnic.

[c] Includes prepregnancy diabetes, hypertension, cardiovascular, asthma, and pulmonary diseases.

I (RERI, 0.40 [95% CI, 0.05-0.78]), obesity class II (RERI, 0.65 [95% CI, 0.08-1.21]), and obesity class III (RERI, 0.58 [95% CI, 0.06-1.14]) (Table 3). For inadequate GWG, significant positive interactions emerged in individuals with normal weight (RERI, 0.28 [95% CI, 0.01-0.55]), overweight (RERI, 0.39 [95% CI, 0.07-0.74]), and obesity class II (RERI, 0.60 [95% CI, 0.02-1.19]). No significant interactions were observed among individuals with underweight for either GWG category (Table 3).

In spline models, risk at high weekly gain was elevated in every BMI category, whereas risk at low weekly gain declined as BMI increased, with smaller estimates in obesity classes I to III (**Figure 2**). For example, among individuals with normal weight, the ARR was 1.48 (95% CI, 1.31-1.68) at GWG of 0.0 kg/wk and 1.85 (95% CI, 1.72-1.99) at GWG of 1.0 kg/wk, relative to the IOM-recommended mean weekly gain within each BMI category. In individuals with obesity class II, the corresponding estimates were 1.01 (95% CI, 0.84-1.21) and 1.80 (95% CI, 1.45-2.22), respectively (eTable 5 in Supplement 1). Estimated SMM rates were lowest at GWG of 0.4 kg/wk for the underweight, normal weight, and overweight BMI categories but at progressively lower values with increasing obesity class (eTable 6 in Supplement 1). These values fell below the IOM-recommended weekly gain for underweight and obesity class III BMI categories, above it in overweight and obesity class I categories, and close to it in normal weight and obesity class II categories (eFigure 4 in Supplement 1). However, estimated rates in obesity classes I to III categories differed little across the range from −0.3 to 0.2 kg/wk (eTable 6 in Supplement 1). Compared with normal weight BMI, the ARR of SMM in underweight BMI was 0.94 (95% CI, 0.88-1.00), whereas risk increased in a dose-response manner with higher BMI categories (eTable 7 in Supplement 1).

In sensitivity analyses, associations between excessive GWG and SMM in term pregnancies were attenuated but remained present in the underweight, normal weight, and obesity class I categories. Inadequate GWG showed no associations in this restricted analysis (eTable 8 in Supplement 1).

Downloaded from jamanetwork.com by guest on 11/24/2026

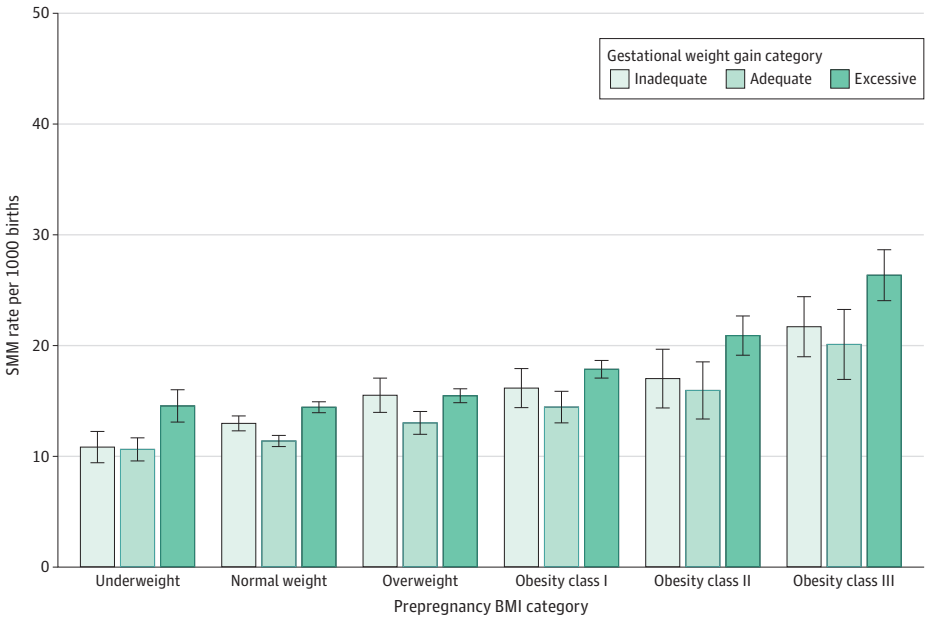
Excluding hypertensive disorders from the SMM definition attenuated associations with excessive GWG in all BMI categories, reaching the null among individuals with overweight (ARR, 0.99 [95% CI, 0.89-1.09]), while estimates remained elevated in individuals with underweight (ARR, 1.18 [95% CI, 1.00-1.39]), normal weight (ARR, 1.12 [95% CI, 1.04-1.19]), and obesity class I (ARR, 1.20 [95% CI, 1.05-1.37]) and absent in those with obesity class II (ARR, 1.18 [95% CI, 0.94-1.48]) and obesity class III (ARR, 1.10 [95% CI, 0.88-1.37]) (eTable 9 in Supplement 1). For excessive GWG, estimates for hypertensive SMM alone were higher than those for the full composite in every BMI category.

Comparison of the analytic cohort and excluded participants showed statistically significant differences in race (42.3% vs 35.0% White and 29.7% vs 37.0% missing race [SMD, 0.178]), educational attainment (17.8% vs 22.4% in the highest quintile [SMD, 0.117]), and preterm birth (5.9% vs 8.3% [SMD, 0.095]) (eTable 10 in Supplement 1). In analyses stratified by race, associations between excessive GWG and SMM were in the same direction across all racial groups within each BMI category, and there was no evidence that the association differed by race (eTable 11 in Supplement 1). In a sensitivity analysis restricted to individuals with recorded race, estimates were consistent with the primary analysis (eTable 12 in Supplement 1).

Discussion

In this population-based cohort study of 1 035 927 pregnancies in Ontario, Canada, excessive GWG was associated with elevated risk of SMM across all BMI groups. Inadequate weight gain was associated with increased SMM risk among individuals with normal weight and overweight, with adjusted risk differences of similar magnitude to those of individuals with normal weight across the obesity classes but wider 95% CIs; no association was observed among individuals with underweight. Nonlinear analyses showed elevated risk at both extremes among lower BMI categories and risk concentrated at high GWG values among obesity classes, with the weekly gain associated with lowest estimated SMM lower in the higher obesity classes.

Figure 1. Bar Graph of Severe Maternal Morbidity (SMM) Rates by Gestational Weight Gain and Prepregnancy Body Mass Index (BMI)



Gestational weight gain categories are relative to the 2009 Institute of Medicine recommendations. Error bars indicate 95% CIs.

Downloaded from jamanetwork.com by guest on 11/24/2026

Table 2. Association Between GWG and SMM Stratified by Prepregnancy BMI Category[a]

BMI and GWG categories	SMM (No./total No.)	SMM rate per 1000	RR (95% CI)		Adjusted RD per 1000 (95% CI)
			Unadjusted	Adjusted	
Underweight					
Inadequate	222/20 508	10.83	1.02 (0.87 to 1.20)	1.00 (0.85 to 1.18)	0.0 (−1.7 to 1.8)
Adequate	392/36 920	10.62	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	375/25 770	14.55	1.37 (1.19 to 1.58)	1.33 (1.15 to 1.53)	3.5 (1.7 to 5.3)
Normal weight					
Inadequate	1402/108 091	12.97	1.14 (1.06 to 1.22)	1.13 (1.06 to 1.21)	1.5 (0.7 to 2.4)
Adequate	1933/169 897	11.38	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	3228/223 687	14.43	1.26 (1.20 to 1.34)	1.24 (1.17 to 1.31)	2.8 (2.1 to 3.5)
Overweight					
Inadequate	379/24 425	15.52	1.19 (1.05 to 1.35)	1.19 (1.05 to 1.35)	2.5 (0.7 to 4.4)
Adequate	602/46 256	13.01	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	2286/147 752	15.47	1.19 (1.09 to 1.30)	1.16 (1.06 to 1.27)	2.1 (0.8 to 3.3)
Obesity class I					
Inadequate	316/19 551	16.16	1.12 (0.97 to 1.30)	1.11 (0.96 to 1.29)	1.6 (−0.7 to 3.9)
Adequate	387/26 791	14.45	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	1894/106 004	17.87	1.24 (1.11 to 1.38)	1.21 (1.08 to 1.35)	2.9 (1.3 to 4.6)
Obesity class II					
Inadequate	155/9105	17.02	1.06 (0.85 to 1.33)	1.10 (0.88 to 1.37)	1.6 (−2.1 to 5.3)
Adequate	144/9027	15.95	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	522/24 959	20.91	1.31 (1.09 to 1.57)	1.28 (1.07 to 1.54)	4.3 (1.2 to 7.5)
Obesity class III					
Inadequate	240/11 051	21.72	1.07 (0.88 to 1.31)	1.07 (0.88 to 1.31)	1.5 (−2.7 to 5.7)
Adequate	152/7557	20.11	1 [Reference]	1 [Reference]	0 [Reference]
Excessive	490/18 576	26.38	1.30 (1.09 to 1.56)	1.24 (1.03 to 1.48)	4.9 (1.0 to 8.8)

Abbreviations: BMI, body mass index; GWG, gestational weight gain; RD, risk difference; RR, risk ratio; SMM, severe maternal morbidity.

[a] Participants include individuals with singleton birth, Ontario, Canada, 2012 to 2022. Models were adjusted for maternal age, parity, race, median neighborhood household income quintile, neighborhood educational attainment quintile, material deprivation quintile, prepregnancy smoking status, fetal sex, and a composite of preexisting medical conditions (prepregnancy diabetes, chronic hypertension, cardiovascular disease, asthma, and pulmonary disease).

Table 3. Joint Association of GWG and Preexisting Medical Condition With Severe Maternal Morbidity by Prepregnancy BMI Category[a]

BMI and GWG categories	Adjusted RR (95% CI)		RERI (95% CI)[b]
	No preexisting medical condition	With preexisting medical condition	
Underweight			
Inadequate	1.05 (0.89 to 1.24)	1.29 (0.70 to 2.37)	0.12 (−0.72 to 0.96)
Adequate	1 [Reference]	2.46 (1.71 to 3.54)	NA
Excessive	1.35 (1.16 to 1.56)	2.71 (1.90 to 3.86)	0.36 (−0.48 to 1.08)
Normal weight			
Inadequate	1.14 (1.06 to 1.23)	2.52 (2.11 to 3.01)	0.28 (0.01 to 0.55)
Adequate	1 [Reference]	2.34 (2.01 to 2.72)	NA
Excessive	1.24 (1.17 to 1.31)	2.97 (2.64 to 3.35)	0.59 (0.22 to 0.97)
Overweight			
Inadequate	1.16 (1.01 to 1.34)	2.99 (2.24 to 3.99)	0.39 (0.07 to 0.74)
Adequate	1 [Reference]	2.16 (1.70 to 2.75)	NA
Excessive	1.16 (1.05 to 1.28)	2.58 (2.24 to 2.97)	0.41 (0.09 to 0.76)
Obesity class I			
Inadequate	1.13 (0.96 to 1.33)	2.18 (1.63 to 2.92)	0.34 (−0.06 to 0.76)
Adequate	1 [Reference]	2.12 (1.61 to 2.79)	NA
Excessive	1.22 (1.08 to 1.37)	2.49 (2.13 to 2.91)	0.40 (0.05 to 0.78)
Obesity class II			
Inadequate	1.00 (0.77 to 1.29)	2.64 (1.85 to 3.77)	0.60 (0.02 to 1.19)
Adequate	1 [Reference]	1.78 (1.19 to 2.68)	NA
Excessive	1.20 (0.97 to 1.48)	2.85 (2.22 to 3.65)	0.65 (0.08 to 1.21)
Obesity class III			
Inadequate	1.09 (0.85 to 1.40)	2.63 (1.96 to 3.52)	0.44 (−0.06 to 0.98)
Adequate	1 [Reference]	2.53 (1.79 to 3.57)	NA
Excessive	1.29 (1.03 to 1.60)	2.87 (2.24 to 3.68)	0.58 (0.06 to 1.14)

Abbreviations: BMI, body mass index; GWG, gestational weight gain; NA, not applicable; RERI, relative excess risk due to interaction; RR, risk ratio.

[a] Participants include individuals with singleton birth, Ontario, Canada, 2012 to 2022. Estimates are from modified Poisson regression models adjusted for maternal age, parity, race, median household income, education quantile, material deprivation quintile, prepregnancy smoking status, fetus sex, and prepregnancy medical condition composite (prepregnancy diabetes, hypertension, cardiovascular, asthma, and pulmonary diseases). Reference category consists of individuals with adequate GWG and no preexisting medical condition within each BMI stratum.

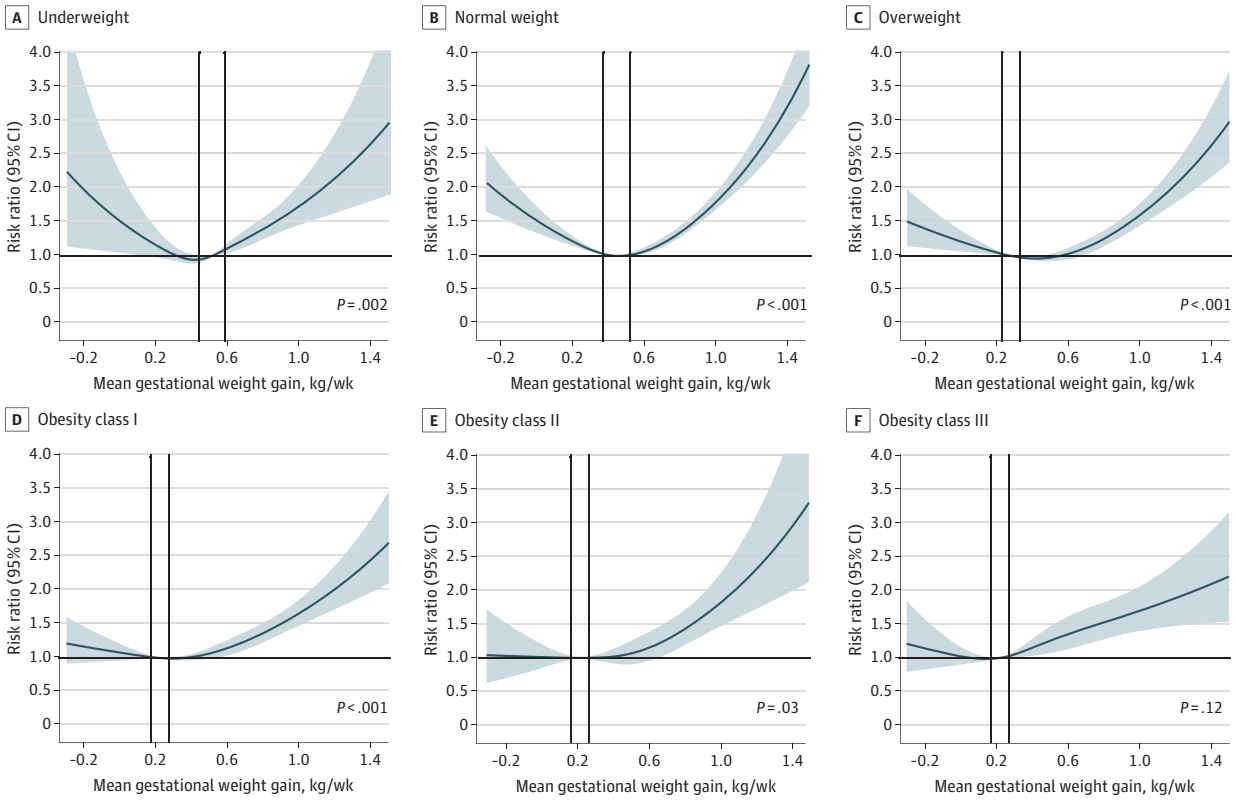
[b] $RERI = RR_{11} - RR_{10} - RR_{01} + 1$. RERI > 0 indicates positive additive interaction between GWG and preexisting medical condition for severe maternal morbidity risk. RR_{11} indicates both GWG outside the recommended range and a preexisting condition; RR_{10}, GWG outside the recommended range only; and RR_{01}, preexisting condition only, each relative to adequate GWG without a preexisting condition.

Downloaded from jamanetwork.com by guest on 11/24/2026

Our findings align with those of a study from Washington State that found inadequate GWG increased SMM and mortality risk among individuals with normal weight and overweight BMI, while excessive GWG was associated with increased risk in women with underweight, normal weight, and obesity.[40] A California study reported the same pattern for inadequate GWG but found no association between excessive GWG and SMM in a cohort that excluded women with gestational hypertensive disorders or heart failure; risk was higher across BMI groups when these women were included.[41] In our sensitivity analysis that removed hypertensive disorders from the SMM definition, we similarly observed attenuated associations for excessive GWG across BMI categories, suggesting that hypertensive disorders contribute substantially to this association. However, weight measured at delivery may itself be inflated by fluid retention from hypertensive disorders, raising the possibility of reverse causation, and these sensitivity analyses cannot fully disentangle this; studies with weight measured prior to hypertension onset would be necessary.

It is now widely recommended that BMI be considered in combination with other conditions,[22] and in our data the co-occurrence of preexisting medical conditions with inadequate or excessive weight gain was associated with SMM risk beyond that conferred by either exposure alone. Our findings support risk-stratified GWG counseling that considers individual BMI subclass alongside medical comorbidities rather than categorical targets treating all individuals within a BMI class as equivalent.

Figure 2. Adjusted Spline Models of Weekly Gestational Weight Gain and Severe Maternal Morbidity (SMM), by Body Mass Index (BMI) Category



Restricted cubic spline models show adjusted risk ratios (solid lines) and 95% CIs (shaded areas) for SMM across the continuous distribution of mean weekly gestational weight gain during the second and third trimesters. Vertical lines indicate the recommended weekly gain for each BMI category according to the 2009 Institute of Medicine guideline. Models were adjusted for maternal age, parity, race, median household income, educational attainment quintile, material deprivation quintile, prepregnancy smoking status, fetal sex, and a prepregnancy medical condition composite (diabetes of any type, hypertension, cardiovascular disease, asthma, and pulmonary disease).

Downloaded from jamanetwork.com by guest on 11/24/2026

Our spline models showed that low weight gain or weight maintenance may carry less SMM risk among individuals with obesity than among those with lower prepregnancy BMI, whereas risk increased steeply at high GWG across all BMI categories. The weekly gain associated with lowest SMM risk fell outside IOM-recommended ranges in several groups, a pattern also observed in another study,[41] where lowest-risk weight gain was above IOM recommendations for individuals with normal weight, overweight, and obesity class I and lowest at minimal gain or weight loss for those with class III obesity. Current guidelines apply a single recommendation to all obesity classes, yet the weekly gain associated with lowest risk differed across these classes. Estimated risk changed little across weight gain values near each minimum, so these weekly values are best interpreted as approximate rather than as clinical targets. Further, the gains associated with lowest SMM risk may not optimize other maternal and neonatal outcomes,[17-19] which are more frequent and formed the basis of current recommendations.

Some studies suggest that higher prepregnancy BMI is more strongly associated with pregnancy complications than GWG itself.[42-44] However, higher prepregnancy BMI may appear more strongly associated with these complications partly because IOM thresholds narrow with increasing BMI, making excessive GWG more common despite lower absolute weight gain.[20] The apparent primacy of prepregnancy BMI may therefore partly reflect how excessive GWG is defined rather than independent effects. In our study, the associations between excessive GWG and SMM were observed within each prepregnancy BMI category, and prepregnancy BMI was associated with SMM in a dose-response manner.

Limitations

This study has some limitations. Our data captured SMM only during delivery hospitalization, potentially underestimating morbidity identified at pregnancy or postpartum readmission; however, most cases of SMM occur during delivery admission.[8] Most individual SMM components were too rare to model separately, and the composite outcome reflects 13 conditions that may have different biological mechanisms. Although we used mean weekly GWG to account for length of gestation, this approach assumes linear weight gain throughout the second and third trimesters, which may not capture individual trajectory patterns such as accelerated early gain followed by plateau or vice versa.[45] For some participants, prepregnancy weight was ascertained from a health care encounter at delivery admission; however, the source of these data is unknown. If a substantial proportion were self-reported, BMI may be underestimated, particularly among individuals with higher BMI.[46,47] Race was collected only on prenatal genetic screening requisitions, accessed by 65% to 70% of the population, and was recorded in broad categories in which the Asian group spans South, East, Southeast, and West Asian populations.[48] Because this missingness reflects whether screening occurred rather than nonresponse, we retained these observations as a distinct category, although their inclusion limits interpretation of racial differences. The broad categories also meant ethnicity-specific BMI thresholds could not be applied.[26] Last, fewer SMM events in obesity classes II and III limited precision, leaving inadequate GWG estimates in these strata inconclusive.

Conclusions

In this cohort study of 1 035 927 pregnancies, GWG outside IOM-recommended ranges was associated with increased SMM risk, with the pattern of association varying by prepregnancy BMI category. The weekly GWG associated with lowest estimated SMM risk was above IOM recommendations for overweight and obesity class I and below the recommendations for underweight and obesity class III. Risk was further elevated when weight gain outside recommended ranges co-occurred with preexisting medical conditions, identifying a subgroup that may warrant enhanced clinical surveillance. These findings may complement the evidence used to inform GWG guidance.

Downloaded from jamanetwork.com by guest on 11/24/2026

ARTICLE INFORMATION

Accepted for Publication: August 26, 2026.

Published: October 22, 2026. doi:10.1001/jamanetworkopen.2026.40027

Open Access: This is an open access article distributed under the terms of the CC-BY-NC-ND License, which does not permit alteration or commercial use, including those for text and data mining, AI training, and similar technologies. © 2026 Khademioore S et al. *JAMA Network Open*.

Corresponding Author: Sahar Khademioore, MSc, McMaster University Medical Centre, 2C Area, 1280 Main St W, Hamilton, ON L8S 4K1, Canada (khades1@mcmaster.ca).

Author Affiliations: Department of Health Research Methods, Evidence and Impact, McMaster University, Hamilton, Ontario, Canada (Khademioore, D'Souza, Muraca, Anderson); McMaster Midwifery Research Centre, McMaster University, Hamilton, Ontario, Canada (Darling); Department of Obstetrics & Gynecology, McMaster University, Hamilton, Ontario, Canada (Darling, D'Souza, Muraca); School of Epidemiology and Public Health, University of Ottawa, Ottawa, Ontario, Canada (Guo); Better Outcomes Registry and Network (BORN) Ontario, Children's Hospital of Eastern Ontario, Ottawa, Ontario, Canada (Guo).

Author Contributions: Ms Khademioore had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Khademioore, D'Souza, Muraca, Guo, Anderson.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Khademioore.

Critical review of the manuscript for important intellectual content: All authors.

Statistical analysis: Khademioore, Muraca, Guo, Anderson.

Administrative, technical, or material support: Khademioore, Muraca.

Supervision: D'Souza, Muraca, Anderson.

Conflict of Interest Disclosures: Dr D'Souza reported receiving personal fees from Sanofi SA, Pfizer Inc, Pharmacosmos, and Biohaven and grants from Pfizer Inc outside the submitted work. Dr Anderson reported receiving grant support from the Canadian Institutes of Health Research during the conduct of the study. No other disclosures were reported.

Funding/Support: This study was supported by the Juravinski Research Institute, in partnership with Hamilton Health Sciences, McMaster University, and St. Joseph's Healthcare Hamilton, as part of the SERENE Project.

Role of the Funder/Sponsor: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The opinions, results, analyses, conclusions, and statements expressed herein are those of the authors and not necessarily those of BORN Ontario, the Ontario Ministry of Health, or Canadian Institute for Health Information. No endorsement by any of these organizations is intended or should be inferred.

Data Sharing Statement: See Supplement 2.

REFERENCES

1. Kilpatrick SK, Ecker JL; American College of Obstetricians and Gynecologists and the Society for Maternal–Fetal Medicine. Severe maternal morbidity: screening and review. *Am J Obstet Gynecol*. 2016;215(3):B17-B22. doi:10.1016/j.ajog.2016.07.050

2. Ray JG, Urquia ML, Berger H, Vermeulen MJ. Maternal and neonatal separation and mortality associated with concurrent admissions to intensive care units. *CMAJ*. 2012;184(18):E956-E962. doi:10.1503/cmaj.121283

3. Obstetric care consensus No. 5: severe maternal morbidity: screening and review. *Obstet Gynecol*. 2016;128(3):e54-e60. doi:10.1097/AOG.0000000000001642

4. Aoyama K, Pinto R, Ray JG, et al. Association of maternal age with severe maternal morbidity and mortality in Canada. *JAMA Netw Open*. 2019;2(8):e199875. doi:10.1001/jamanetworkopen.2019.9875

5. Fink DA, Kilday D, Cao Z, et al. Trends in maternal mortality and severe maternal morbidity during delivery-related hospitalizations in the United States, 2008 to 2021. *JAMA Netw Open*. 2023;6(6):e2317641. doi:10.1001/jamanetworkopen.2023.17641

6. Mokashi M, Yee L, Feinglass J. Trends in severe maternal morbidity, obstetric comorbidities, and birth complications in Illinois. *O G Open*. 2024;1(4):46. doi:10.1097/og9.0000000000000046

7. Dzakpasu S, Deb-Rinker P, Arbour L, et al. Severe maternal morbidity surveillance: monitoring pregnant women at high risk for prolonged hospitalisation and death. *Paediatr Perinat Epidemiol*. 2020;34(4):427-439. doi:10.1111/ppe.12574

Downloaded from jamanetwork.com by guest on 11/24/2026

8. Rajasingham M, Premranjith P, Brown HK, et al; SERENE Study Investigators. Severe maternal morbidity from conception to 6 weeks postpartum in Ontario: a population-based, longitudinal cohort study. *CMAJ*. 2026;198 (10):E344-E357. doi:10.1503/cmaj.251425

9. Goldstein RF, Abell SK, Ranasinha S, et al. Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. *JAMA*. 2017;317(21):2207-2225. doi:10.1001/jama.2017.3635

10. Vats H, Saxena R, Sachdeva MP, Walia GK, Gupta V. Impact of maternal pre-pregnancy body mass index on maternal, fetal and neonatal adverse outcomes in the worldwide populations: a systematic review and meta-analysis. *Obes Res Clin Pract*. 2021;15(6):536-545. doi:10.1016/j.orcp.2021.10.005

11. Lisonkova S, Muraca GM, Potts J, et al. Association between prepregnancy body mass index and severe maternal morbidity. *JAMA*. 2017;318(18):1777-1786. doi:10.1001/jama.2017.16191

12. Siddiqui A, Azria E, Howell EA, Deneux-Tharaux C; EPIMOMS Study Group. Associations between maternal obesity and severe maternal morbidity: findings from the French EPIMOMS population-based study. *Paediatr Perinat Epidemiol*. 2019;33(1):7-16. doi:10.1111/ppe.12522

13. Schummers L, Hutcheon JA, Bodnar LM, Lieberman E, Himes KP. Risk of adverse pregnancy outcomes by prepregnancy body mass index: a population-based study to inform prepregnancy weight loss counseling. *Obstet Gynecol*. 2015;125(1):133-143. doi:10.1097/AOG.0000000000000591

14. Leonard SA, Carmichael SL, Main EK, Lyell DJ, Abrams B. Risk of severe maternal morbidity in relation to prepregnancy body mass index: roles of maternal co-morbidities and caesarean birth. *Paediatr Perinat Epidemiol*. 2020;34(4):460-468. doi:10.1111/ppe.12555

15. Frey HA, Ashmead R, Farmer A, et al. Association of prepregnancy body mass index with risk of severe maternal morbidity and mortality among Medicaid beneficiaries. *JAMA Netw Open*. 2022;5(6):e2218986. doi:10.1001/jamanetworkopen.2022.18986

16. Rasmussen KM, Yaktine AL, eds. *Weight Gain During Pregnancy: Reexamining the Guidelines*. National Academies Press; 2009.

17. Bodnar LM, Johansson K, Himes KP, et al. Do current pregnancy weight gain guidelines balance risks of adverse maternal and child health in a United States cohort? *Am J Clin Nutr*. 2024;119(2):527-536. doi:10.1016/j.ajcnut.2023.10.015

18. Bodnar LM, Johansson K, Himes KP, et al. Gestational weight gain below recommendations and adverse maternal and child health outcomes for pregnancies with overweight or obesity: a United States cohort study. *Am J Clin Nutr*. 2024;120(3):638-647. doi:10.1016/j.ajcnut.2024.06.011

19. Johansson K, Bodnar LM, Stephansson O, Abrams B, Hutcheon JA. Safety of low weight gain or weight loss in pregnancies with class 1, 2, and 3 obesity: a population-based cohort study. *Lancet*. 2024;403(10435):1472-1481. doi:10.1016/S0140-6736(24)00255-1

20. Khademioore S, Darling EK, D'Souza R, Muraca GM, Guo Y, Anderson LN. Trends in gestational weight gain in Ontario, Canada from 2012 to 2022: a population-based descriptive study. *J Obstet Gynaecol Can*. 2026;48(8): 103406. doi:10.1016/j.jogc.2026.103406

21. Khademioore S, Darling EK, D'Souza R, Muraca GM, Guo Y, Anderson LN. Prepregnancy body mass index in Ontario from 2012 to 2022: a population-based descriptive study. *Can J Public Health*. Published online June 5, 2026. doi:10.17269/s41997-026-01214-w

22. Rubino F, Cummings DE, Eckel RH, et al. Definition and diagnostic criteria of clinical obesity. *Lancet Diabetes Endocrinol*. 2025;13(3):221-262. doi:10.1016/S2213-8587(24)00316-4

23. AMA adopts new policy clarifying role of BMI as a measure in medicine. American Medical Association. June 4, 2023. Accessed January 27, 2026. https://www.ama-assn.org/press-center/ama-press-releases/ama-adopts-new-policy-clarifying-role-bmi-measure-medicine

24. Murphy MSQ, Fell DB, Sprague AE, et al. Data resource profile: Better Outcomes Registry & Network (BORN) Ontario. *Int J Epidemiol*. 2021;50(5):1416-1417h. doi:10.1093/ije/dyab033

25. Discharge Abstract Database (DAD) metadata. Canadian Institute for Health Information. Accessed September 14, 2026. https://www.cihi.ca/en/discharge-abstract-database-dad-metadata

26. Guo Y, Miao Q, Huang T, et al. Racial/ethnic variations in gestational weight gain: a population-based study in Ontario. *Can J Public Health*. 2019;110(5):657-667. doi:10.17269/s41997-019-00250-z

27. Lebel A, Subramanian SV, Hamel D, Gagnon P, Razak F. Population-level trends in the distribution of body mass index in Canada, 2000-2014. *Can J Public Health*. 2018;109(4):539-548. doi:10.17269/s41997-018-0060-7

28. Palumbo AM, Muraca GM, Fuller A, et al; TARGet Kids! collaboration. The association between self-reported total gestational weight gain by pre-pregnancy body mass index and moderate to late preterm birth. *BMC Pregnancy Childbirth*. 2025;25(1):27. doi:10.1186/s12884-024-07106-6

29. Guo Y, Souza SCS, Bruce L, et al. Risk related to gestational weight loss among individuals with obesity: a population-based cohort study. *Obesity (Silver Spring)*. 2024;32(12):2376-2387. doi:10.1002/oby.24143

30. Dayan N, Fell DB, Guo Y, et al. Severe maternal morbidity in women with high BMI in IVF and unassisted singleton pregnancies. *Hum Reprod*. 2018;33(8):1548-1556. doi:10.1093/humrep/dey224

Downloaded from jamanetwork.com by guest on 11/24/2026

31. Srugo SA, Gaudet L, Corsi D, Fakhraei R, Guo Y, Fell DB. Examining the effects of pre-pregnancy weight and gestational weight gain on allergic disease development in offspring: a protocol for a population-based study using health administrative databases in Ontario, Canada. *BMJ Paediatr Open*. 2021;5(1):e000893. doi:10.1136/bmjpo-2020-000893

32. Bodnar LM, Siega-Riz AM, Simhan HN, Himes KP, Abrams B. Severe obesity, gestational weight gain, and adverse birth outcomes. *Am J Clin Nutr*. 2010;91(6):1642-1648. doi:10.3945/ajcn.2009.29008

33. Nutrition for a healthy life—WHO recommendations. World Health Organization. July 18, 2025. Accessed December 24, 2025. https://www.who.int/europe/news-room/fact-sheets/item/nutrition---maintaining-a-healthy-lifestyle

34. Matheson FI, Moloney G, van Ingen T. 2021 Ontario Marginalization Index: user guide. St. Michael's Hospital–Public Health Ontario. July 2023. Accessed September 14, 2026. https://www.publichealthontario.ca/-/media/Documents/O/2017/on-marg-userguide.pdf

35. Leonard SA, Main EK, Scott KA, Profit J, Carmichael SL. Racial and ethnic disparities in severe maternal morbidity prevalence and trends. *Ann Epidemiol*. 2019;33:30-36. doi:10.1016/j.annepidem.2019.02.007

36. *SAS/STAT 14.1 User's Guide: The MIANALYZE Procedure*. SAS Institute Inc; 2015. Accessed September 14, 2026. https://support.sas.com/documentation/onlinedoc/stat/141/mianalyze.pdf

37. Harrell FE. *Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression, and Survival Analysis*. Vol 608. Springer; 2001. doi:10.1007/978-1-4757-3462-1

38. Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. *Int J Epidemiol*. 2012;41(2):514-520. doi:10.1093/ije/dyr218

39. VanderWeele TJ, Knol MJ. A tutorial on interaction. *Epidemiol Methods*. 2014;3(1):33-72. doi:10.1515/em-2013-0005

40. Ukah UV, Bayrampour H, Sabr Y, et al. Association between gestational weight gain and severe adverse birth outcomes in Washington State, US: a population-based retrospective cohort study, 2004-2013. *PLoS Med*. 2019;16(12):e1003009. doi:10.1371/journal.pmed.1003009

41. Leonard SA, Abrams B, Main EK, Lyell DJ, Carmichael SL. Weight gain during pregnancy and the risk of severe maternal morbidity by prepregnancy BMI. *Am J Clin Nutr*. 2020;111(4):845-853. doi:10.1093/ajcn/nqaa033

42. Osicka DA, Bogaerts A. Life course approach to gestational weight gain. *BMJ*. 2025;391:r2337. doi:10.1136/bmj.r2337

43. Dodd JM, Louise J, Deussen AR, Mitchell M, Poston L. Rethinking causal assumptions about maternal BMI, gestational weight gain, and adverse pregnancy outcomes. *BMC Med*. 2024;22(1):197. doi:10.1186/s12916-024-03410-2

44. Zhang J, Zhang R, Chi J, Li Y, Bai W. Pre-pregnancy body mass index has greater influence on newborn weight and perinatal outcome than weight control during pregnancy in obese women. *Arch Public Health*. 2023;81(1):5. doi:10.1186/s13690-023-01025-2

45. Hutcheon JA, Bodnar LM. Good practices for observational studies of maternal weight and weight gain in pregnancy. *Paediatr Perinat Epidemiol*. 2018;32(2):152-160. doi:10.1111/ppe.12439

46. Sharma AJ, Bulkley JE, Stoneburner AB, et al. Bias in self-reported prepregnancy weight across maternal and clinical characteristics. *Matern Child Health J*. 2021;25(8):1242-1253. doi:10.1007/s10995-021-03149-9

47. Headen I, Cohen AK, Mujahid M, Abrams B. The accuracy of self-reported pregnancy-related weight: a systematic review. *Obes Rev*. 2017;18(3):350-369. doi:10.1111/obr.12486

48. Huang T, Dougan S, Walker M, Armour CM, Okun N. Trends in the use of prenatal testing services for fetal aneuploidy in Ontario: a descriptive study. *CMAJ Open*. 2018;6(4):E436-E444. doi:10.9778/cmajo.20180046

SUPPLEMENT 1.

eTable 1. Institute of Medicine (IOM) Recommendations for Gestational Weight Gain (GWG) in Singleton Pregnancies, Including Parameters Used to Adjust for Gestational Age at Delivery

eTable 2. *ICD-10-CA* and CCI Codes for Severe Maternal Morbidity as Defined by the Canadian Perinatal Surveillance System

eTable 3. Severe Maternal Morbidity Rates per 1000 Births by Gestational Weight Gain Category

eTable 4. Severe Maternal Morbidity Rates per 1000 Births by Prepregnancy BMI and Gestational Weight Gain

eTable 5. Risk Ratio (95% CI) for Severe Maternal Morbidity at 0.1-kg/week Increments of Mean Weekly Gestational Weight Gain, by Prepregnancy BMI Category

eTable 6. Predicted Rate of Severe Maternal Morbidity and 95% CI at Each 0.1-Increment of Mean Weekly Gestational Weight Gain, by Prepregnancy BMI Category

eTable 7. Association Between Prepregnancy BMI Category and Severe Maternal Morbidity

eTable 8. Crude and Adjusted Risk Ratios for Severe Maternal Morbidity by Gestational Weight Gain Category and Prepregnancy BMI (Term Pregnancies Only)

eTable 9. Association Between Gestational Weight Gain and Severe Maternal Morbidity by Morbidity Type

Downloaded from jamanetwork.com by guest on 11/24/2026

eTable 10. Baseline Characteristics of Included and Excluded Participants
eTable 11. Association Between Gestational Weight Gain and Severe Maternal Morbidity Stratified by Race, Within Prepregnancy BMI Groups
eTable 12. Association Between Gestational Weight Gain and Severe Maternal Morbidity Restricted to Individuals With Recorded Race
eFigure 1. Directed Acyclic Graph (DAG) Illustrating the Hypothesized Causal Relationships Between Gestational Weight Gain (GWG) and Severe Maternal Morbidity (SMM)
eFigure 2. Study Flow Diagram of Cohort Selection and Exclusions
eFigure 3. SMM Rate per 1000 Births by Gestational Weight Gain and Preexisting Conditions Across BMI Categories
eFigure 4. Adjusted Estimated Rates of Severe Maternal Morbidity From Restricted Cubic Spline Models of Gestational Weight Gain by BMI Category

SUPPLEMENT 2.
Data Sharing Statement

Downloaded from jamanetwork.com by guest on 11/24/2026