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Original Article

Pregestational body mass index, gestational weight gain, and risks for adverse pregnancy outcomes among Taiwanese women: A retrospective cohort study

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ABSTRACT

Objective: To investigate the associations between maternal pregestational body mass index (BMI), gestational weight gain (GWG), and adverse pregnancy outcomes among Taiwanese women.
Materials and Methods: A retrospective cohort study was conducted among all singletons without fetal anomalies delivered to women at Taipei Chang Gung Memorial Hospital between 2009 and 2015. Two study cohorts were selected for analysis: all deliveries after 24 0/7 weeks of gestation (Cohort 1, $n = 12{,}064$) and all live births after 37 0/7 weeks of gestation excluding maternal overt diabetes mellitus and chronic hypertension (Cohort 2, $n = 10{,}973$). The associations between pregestational BMI, GWG outside the 2009 Institute of Medicine (IOM) guidelines, and adverse pregnancy outcomes were assessed using multivariable logistic regression analysis.
Results: In Cohort 1, the prevalence of pregestational underweight, normal weight, overweight, and obesity was 14.0%, 74.8%, 9.0%, and 2.2%, respectively. Compared with the women with normal weight, maternal underweight was associated with increased risk for placental abruption, small-for-gestational age, and low birth weight (<2500 g). In contrast, overweight and obese women were at risk for gestational diabetes mellitus, preeclampsia, dysfunctional labor, cephalopelvic disproportion, large-for-gestational age, and macrosomia (>4000 g). In Cohort 2, GWG below the IOM guidelines were associated with higher rates of gestational diabetes mellitus, small-for-gestational age, and low birth weight, while GWG above the IOM guidelines were with higher rates of primary cesarean delivery, large-for-gestational age, and macrosomia in women with pregestational underweight or normal weight. Normal weight women were more likely to have placental abruption with GWG below the guidelines and to have preeclampsia with GWG above the guidelines. For overweight and obese women, GWG below the guidelines was associated with a higher rate of gestational diabetes mellitus, but GWG above the guidelines was associated with a higher rate of macrosomia.
Conclusions: Women with abnormal pregestational BMI are at risk for adverse maternal and neonatal outcomes. Moreover, GWG has a differential effect on the rates of adverse pregnancy outcomes between women of different pregestational BMI categories.
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Introduction

The continuum of overweight and obesity is a worldwide epidemic; 33% of pregnant women are overweight or obese in the UK [1], 12–38% of pregnant women are overweight and 11–40% are obese in the US [2–4], and 10–24% of pregnant women are overweight or obese in China [5,6]. At the other end of the spectrum, maternal underweight is also common; 4.3% of pregnant women in the UK [1] and 11–13% of women in China [5,6] are underweight at the first antenatal visit.

Accumulating evidence shows that women with overweight or obesity before pregnancy are at increased risk for adverse maternal and neonatal outcomes compared with normal weight women [7]. These include gestational diabetes mellitus (GDM), gestational hypertensive diseases, preterm birth, large-for-gestational age

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(LGA), macrosomia, stillbirth, and neonatal death [5,6,8–13]. In addition to the increased risk of antenatal complications, there is an increased risk of cesarean delivery and associated morbidities in pregestational overweight or obese women [5,6,10–12]. In contrast, maternal underweight was noted to be associated with suboptimal fetal growth such as small-for-gestational age (SGA) and low birth weight [5,6,10,12,14,15], although the association between maternal underweight and preterm birth is inconsistent [6,10,11,14]. Nevertheless, data on the prevalence of pregestational underweight, overweight, and obesity and whether these women are at risks for similar adverse pregnancy outcomes in Taiwanese women remain scarce [11,16,17]. Furthermore, our recent study shows that women with gestational weight gain (GWG) above or below the 2009 Institute of Medicine (IOM) guidelines are at risk for adverse pregnancy outcomes [18]. It is, however, unclear whether similar associations exist across all women or there is a differential effect of GWG on the rate of adverse pregnancy outcome among women of different pregestational weight categories.

Therefore, the objectives of this study were: (1) to investigate the prevalence of pregestational underweight, normal weight, overweight, and obesity defined by body mass index (BMI) according to the WHO classification; (2) to study the associations between maternal pregestational BMI and adverse maternal and neonatal outcomes; and (3) to evaluate the effect of GWG on the rates of adverse pregnancy outcomes between women of different pregestational BMI categories in a Taiwanese population.

Materials and methods

A retrospective cohort study was conducted among all singleton births to women who delivered at Taipei Chang Gung Memorial Hospital between January 1, 2009 and December 31, 2015. The study data were obtained from a computerized obstetrics database that included demographic characteristics, medical and obstetric histories, and information regarding the course of the index pregnancy and perinatal outcomes. Details of the database have been described previously [18,19]. The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital.

In this hospital, the height of each pregnant woman was measured and her self-reported prepregnancy weight was recorded at the first antenatal visit. Height and the self-reported prepregnancy weight were used to calculate the pregestational BMI [calculated as weight (kg)/height $(m)^2$], which was further categorized into four groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (30.0 kg/m^2 or higher). GWG was calculated by subtracting each woman's pregestational weight from her weight at delivery. Women were categorized into three groups based on pregestational BMI and GWG relative to the 2009 IOM recommendations: (1) weight gain below the IOM guidelines; (2) weight gain within the IOM guidelines; and (3) weight gain above the IOM guidelines. The 2009 IOM GWG recommendation is for underweight, normal weight, overweight, and obese women to gain 12.5–18 kg, 11.5–16 kg, 7–11.5 kg, and 5–9 kg, respectively [20].

To study the prevalence of pregestational underweight, normal weight, overweight, and obesity and the associations between maternal pregestational BMI and adverse pregnancy outcomes, we analyzed all deliveries after 24 0/7 weeks of gestation ($n = 12{,}718$), excluding pregnancies complicated by multiple gestations ($n = 553$) and fetal chromosomal or structural anomalies ($n = 101$). A total of 12,064 deliveries were selected for these purposes and defined as Cohort 1.

To evaluate the effect of GWG on the rates of adverse pregnancy outcomes between women of different pregestational BMI categories, we analyzed all deliveries after 37 0/7 weeks of gestation ($n = 11{,}268$), excluding pregnancies complicated by multiple gestations ($n = 169$), fetal chromosomal or structural anomalies ($n = 78$), and fetal demise ($n = 4$). Women with pregestational diabetes mellitus ($n = 28$) and chronic hypertension ($n = 16$) were also excluded. Overall, a total of 10,973 deliveries were selected as Cohort 2 and analyzed for this purpose.

We examined the following maternal and neonatal outcomes: GDM [21], preeclampsia [22], premature rupture of membranes, acute chorioamnionitis [23], placenta previa [24], placental abruption [25], placenta accreta [26], *postpartum* hemorrhage (>500 mL for vaginal delivery and >1000 mL for cesarean delivery), operative vaginal delivery, severe perineal injury (3^{rd} and 4^{th} degree perineal injury), primary cesarean delivery (defined as a cesarean delivery performed for the 1^{st} time on a pregnant woman), indications for primary cesarean delivery including dysfunctional labor, malpresentation, abnormal fetal heart rate pattern, and cephalopelvic disproportion, preterm delivery (<37 weeks of gestation), low birth weight (<2500 g), SGA (defined as birth weight below the 10^{th} percentile of mean weight corrected for fetal sex and gestational age), LGA (defined as birth weight above the 90^{th} percentile of mean weight corrected for fetal sex and gestational age), macrosomia (>4000 g), 1-minute and 5-minute Apgar scores <7, neonatal intensive care unit (NICU) admission, fetal death (>24 weeks of gestation), and neonatal death.

Statistical analyses were performed using SPSS software, version 20.0 (SPSS Inc., Armonk, NY, USA). The categorical variables were calculated as the number and rate (%) and were compared between groups using the χ^2 test. A p value of <0.05 was considered statistically significant. Multivariable logistic regression analysis was used to control for potential confounding when assessing the associations between pregestational BMI and adverse pregnancy outcomes and evaluating the effect of GWG on the rates of adverse pregnancy outcomes among women of different pregestational BMI category. Adjusted odds ratios (aOR) and 95% confidence intervals (CI) were calculated to describe the relative risk.

Results

Maternal characteristics of the women with singletons delivered after 24 weeks of gestation (Cohort 1) are shown in Table 1. Nearly 14% of the women were categorized as underweight. In contrast, the proportion of overweight and obese women was 9.0% and 2.2%, respectively. Compared with women of a normal weight before pregnancy, the rates of teenage pregnancy, primiparity, and having epidural analgesia during labor were higher in underweight women. By contrast, the rates of a prior history of induced abortion and fetal death, overt diabetes mellitus, and chronic hypertension were higher in overweight and obese women. In addition, women with pregestational overweight were more likely to have genetic amniocentesis than normal weight women.

The associations between pregestational BMI and adverse pregnancy outcomes are demonstrated in Table 2. Underweight women were at increased risk for placental abruption (aOR 1.69, 95% CI 1.18–2.41), SGA (aOR 1.85, 95% CI 1.56–2.19), and delivering of neonates with a low birth weight (aOR 1.57, 95% CI 1.30–1.89) compared with the women of normal weight. Both overweight and obese women were more likely to have GDM (aOR 2.15, 95% CI 1.80–2.56; and aOR 3.77, 95% CI 2.81–5.04, respectively), preeclampsia (aOR 3.74, 95% CI 2.75–5.08; and aOR 7.85, 95% CI 5.13–12.00, respectively), dysfunctional labor (aOR 1.47, 95% CI 1.03–2.11; and aOR 3.14, 95% CI 1.55–6.34, respectively), cephalopelvic disproportion (aOR 2.31, 95% CI 1.47–3.09; and aOR 2.67,

Table 1
Characteristics of women with singleton delivered after 24 weeks of gestation during 2009–2015 (Cohort 1).

	Underweight ($n = 1685$)	Normal weight ($n = 9021$)	Overweight ($n = 1091$)	Obese ($n = 267$)	p
Age (y)					
<20	9 (0.5%)**	10 (0.1%)	1 (0.1%)	1 (0.4%)	<0.001
20–34	1094 (64.9%)***	5037 (55.8%)	553 (50.7%)**	132 (49.4%)*	<0.001
>34	419 (24.9%)***	3315 (36.7%)	469 (43.0%)	112 (41.9%)	<0.001
Primiparity	1094 (64.9%)***	5038 (55.8%)	485 (44.5%)	100 (37.5%)***	<0.001
Prior induced abortion	451 (26.8%)**	2702 (30.0%)	374 (34.3%)***	106 (39.7%)**	<0.001
Prior fetal death	5 (0.3%)*	87 (1.0%)	24 (2.2%)***	7 (2.6%)*	<0.001
Prior preterm birth	6 (0.4%)	48 (0.5%)	11 (1.0%)	3 (1.1%)	0.12
Conception by reproductive technology	24 (1.4%)	181 (2.0%)	19 (1.7%)	4 (1.5%)	0.37
Genetic amniocentesis	460 (27.3%)*	3542 (39.3%)	476 (43.6%)**	111 (41.6%)	<0.001
Smoking during pregnancy	5 (0.3%)	18 (0.2%)	3 (0.3%)	0	0.60
Overt diabetes mellitus	1 (0.1%)	17 (0.2%)	10 (0.9%)***	9 (3.4%)***	<0.001
Chronic hypertension	0	11 (0.1%)	11 (1.0%)***	9 (3.4%)***	<0.001
GBS colonization	238 (14.1%)	1347 (14.9%)	142 (13.0%)	27 (10.1%)*	0.04
Male fetus	844 (50.1%)	4655 (51.6%)	589 (54.0%)	135 (50.6%)	0.25
Epidural analgesia	909 (53.9%)**	4479 (49.7%)	423 (38.8%)***	77 (28.8%)***	<0.001
Induction of labor	281 (16.7%)**	1790 (19.8%)	220 (20.2%)	50 (18.7%)	0.02
Augmentation of labor	709 (42.1%)	3640 (40.4%)	343 (31.4%)***	92 (34.5%)	<0.001

Data presented as n (%). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, compared with women of normal weight before pregnancy.
GBS = group B *Streptococcus*.

Table 2
Adverse pregnancy outcomes and pregestational weight category in women with singletons delivered after 24 weeks of gestation during 2009–2015 (Cohort 1).

Outcome	Underweight ($n = 1685$)	Normal weight ($n = 9021$)	Overweight ($n = 1091$)	Obese ($n = 267$)	Underweight vs. normal weight	Overweight vs. normal weight	Obese vs. normal weight
					Adjusted OR (95% CI)	Adjusted OR (95% CI)	Adjusted OR (95% CI)
GDM	109 (6.5%)	813 (9.0%)	205 (18.8%)	79 (29.6%)	0.78[c] (0.64–0.97)	2.15[c] (1.80–2.56)	3.77[c] (2.81–5.04)
Preeclampsia	12 (0.7%)	147 (1.6%)	68 (6.2%)	36 (13.5%)	0.44[c] (0.24–0.80)	3.74[c] (2.75–5.08)	7.85[c] (5.13–12.00)
Premature rupture of membranes	27 (1.6%)	149 (1.7%)	22 (2.0%)	7 (2.6%)	1.00[c] (0.66–1.52)	1.19[c] (0.76–1.89)	1.58[c] (0.73–3.45)
Chorioamnionitis	9 (0.5%)	79 (0.9%)	11 (1.0%)	1 (0.4%)	0.59[c] (0.29–1.18)	1.25[c] (0.65–2.40)	0.52[c] (0.07–3.79)
Placenta previa	38 (2.3%)	226 (2.5%)	32 (2.9%)	4 (1.5%)	0.96[c] (0.67–1.38)	1.02[c] (0.69–1.50)	0.47[c] (0.17–1.30)
Placental abruption	41 (2.4%)	145 (1.6%)	14 (1.3%)	3 (1.1%)	1.69[c] (1.18–2.41)	0.75[c] (0.43–1.31)	0.64[c] (0.20–2.04)
Placenta accreta	9 (0.5%)	44 (0.5%)	3 (0.3%)	1 (0.4%)	1.18[c] (0.57–2.43)	0.52[c] (0.16–1.69)	0.67[c] (0.91–4.90)
Postpartum hemorrhage	12 (0.7%)	165 (1.8%)	15 (1.4%)	1 (0.4%)	0.41[c] (0.22–0.73)	0.71[c] (0.42–1.22)	0.19[c] (0.03–1.36)
Operative vaginal delivery	68 (4.0%)	352 (3.9%)	24 (2.2%)	5 (1.9%)	0.94[d] (0.72–1.24)	0.72[d] (0.47–1.11)	0.79[d] (0.32–1.96)
Severe perineal injury[a]	130 (11.5%)	607 (11.1%)	38 (7.4%)	7 (6.2%)	0.93[e] (0.75–1.16)	0.73[e] (0.51–1.06)	0.67[e] (0.29–1.53)
Primary cesarean delivery	407 (24.2%)	2224 (24.7%)	324 (29.7%)	68 (25.5%)	0.86[d] (0.74–1.00)	1.57[d] (1.32–1.87)	1.05[d] (0.73–1.50)
Dysfunctional labor[b]	126 (3.1%)	821 (36.9%)	130 (40.1%)	32 (47.1%)	0.89[d] (0.64–1.25)	1.47[d] (1.03–2.11)	3.14[d] (1.55–6.34)
Malpresentation[b]	108 (26.5%)	481 (21.6%)	63 (19.4%)	12 (17.6%)	1.17[d] (0.89–1.54)	0.83[d] (0.60–1.16)	0.70[d] (0.34–1.43)
Abnormal FHR pattern[b]	65 (16.0%)	327 (14.7%)	40 (12.3%)	6 (8.8%)	1.12[d] (0.83–1.51)	0.80[d] (0.56–1.15)	0.55[d] (0.23–1.32)
Cephalopelvic disproportion[b]	23 (5.7%)	165 (7.4%)	43 (13.3%)	11 (16.2%)	0.68[d] (0.43–1.07)	2.31[d] (1.47–3.09)	2.67[d] (1.32–5.40)
Preterm delivery	128 (7.6%)	752 (8.3%)	114 (10.4%)	49 (18.4%)	0.95[c] (0.78–1.16)	1.09[c] (0.88–1.36)	1.89[c] (1.34–2.67)
Low birth weight	162 (9.6%)	594 (6.6%)	832 (7.6%)	25 (9.4%)	1.57[c] (1.30–1.89)	1.03[c] (0.80–1.32)	1.12[c] (0.72–1.76)
SGA	207 (12.3%)	614 (6.8%)	72 (6.6%)	11 (4.1%)	1.85[c] (1.56–2.19)	0.97[c] (0.75–1.25)	0.54[c] (0.29–1.02)
LGA	65 (3.9%)	741 (8.2%)	169 (15.5%)	52 (19.5%)	0.50[c] (0.38–0.64)	1.86[c] (1.55–2.23)	2.32[c] (1.67–3.20)
Macrosomia	13 (0.8%)	156 (1.7%)	35 (3.2%)	12 (4.5%)	0.47[c] (0.27–0.83)	1.81[c] (1.24–2.64)	2.51[c] (1.35–4.64)
1-min Apgar score <7	17 (1.0%)	127 (1.4%)	19 (1.7%)	6 (2.2%)	0.70[c] (0.42–1.17)	1.22[c] (0.75–2.0)	1.71[c] (0.74–3.95)
5-min Apgar score <7	4 (0.2%)	31 (0.3%)	10 (0.9%)	0	0.67[c] (0.23–1.91)	2.46[c] (1.19–5.09)	Not estimable
Fetal death	3 (0.2%)	17 (0.2%)	6 (0.5%)	0	0.84[c] (0.24–2.92)	2.69[c] (1.04–6.95)	Not estimable
Neonatal death	0	4 (0.0%)	3 (0.3%)	0	Not estimable	6.61[c] (1.36–32.15)	Not estimable
NICU admission	64 (3.8%)	363 (4.0%)	47 (4.3%)	25 (9.4%)	0.92[c] (0.70–1.21)	0.96[c] (0.70–1.32)	1.99[c] (1.26–3.14)

Data presented as number (%). [a] Among women with a vaginal delivery; [b] among women with primary cesarean delivery; [c] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, and fetal sex; [d] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, and *intrapartum* epidural analgesia; and [e] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, intrapartum epidural analgesia, and operative vaginal delivery.
CI = confidence interval; FHR = fetal heart rate; GDM = gestational diabetes mellitus; LGA = large-for-gestational age; NICU = neonatal intensive care unit; OR = odds ratio; SGA = small-for-gestational age.

95% CI 1.32–5.40, respectively), LGA (aOR 1.86, 95% CI 1.55–2.23; and aOR 2.32, 95% CI 1.67–3.20, respectively), and macrosomia (aOR 1.81, 95% CI 1.24–2.64; and aOR 2.51 95% CI 1.35–4.64, respectively) than women of normal weight. Furthermore, the risks for primary cesarean delivery, 5-minute Apgar score <7, fetal and neonatal death were increased in women with overweight, while the risks for preterm delivery and NICU admission were higher in obese women.

Maternal characteristics of the women with a live singleton delivered after 37 weeks of gestation with information of GWG (Cohort 2) are shown in Table 3. Noticeably, underweight women were more likely to have GWG below the 2009 IOM guidelines

while overweight and obese women were more likely to have GWG above the guidelines compared with the women with pregestational normal weight.

To investigate whether GWG has a differential effect on the rates of various adverse pregnancy outcomes among women with different pregestational BMI categories, the associations between maternal and neonatal outcomes and GWG with respect to the 2009 IOM guidelines were studied separately in underweight women (Table 4), normal weight (Table 5), and overweight/obesity (Table 6). For underweight women, GWG below the IOM guidelines were associated with higher rates of GDM (aOR 1.66, 95% CI 1.07–2.56), low birth weight (aOR 2.37, 95% CI 1.47–3.82), and SGA (aOR 2.17, 95% CI 1.56–3.02), while GWG above the IOM guidelines were with higher rates of primary cesarean delivery (aOR 2.32, 95% CI 1.45–3.72), LGA (aOR 2.58, 95% CI 1.38–4.81), and macrosomia (aOR 5.69, 95% CI 1.46–22.21). For women with a normal weight before pregnancy, GWG below the IOM guidelines were associated with higher rates of GDM (aOR 1.49, 95% CI 1.25–1.78), placental abruption (aOR 1.84, 95% CI 1.16–2.92), low birth weight (aOR 1.68, 95% CI 1.23–2.29), and SGA (aOR 1.55, 95% CI 1.27–1.89), whereas GWG above the guidelines were with higher rates of preeclampsia (aOR 3.65, 95% CI 2.18–6.10), primary cesarean delivery (aOR 1.35, 95% CI 1.16–1.56), cephalopelvic disproportion (aOR 1.88, 95% CI 1.30–2.71), LGA (aOR 1.80, 95% CI 1.51–2.15), and macrosomia (aOR 2.16, 95% CI 1.53–3.06). As for the overweight and obese women, GWG below the guidelines was associated with a higher rate of GDM (aOR 1.75, 95% CI 1.15–2.68) and GWG above the guidelines was associated with a higher rate of macrosomia (aOR 2.51, 95% CI 1.14–5.52).

Discussion

In this study, 14% of the women were underweight, 9% were overweight, and 2.2% were categorized as obese before pregnancy. The prevalence of underweight, overweight, and obesity in our population is different from European [1,15], American [2–4], and Chinese populations [5,6], but similar to a report from Japan [10]. Nevertheless, our study confirmed most prior reports that inappropriate pregestational weight is associated with increased risks for adverse pregnancy outcomes [5,6,8–15]; pregestational underweight women were at risks for placental abruption, SGA, and low birth weight, whereas overweight and obese women were more likely to have GDM, preeclampsia, primary cesarean delivery, LGA, and macrosomia than women of normal weight. Compared with previous studies on Taiwanese women [11,16,17], the strength of current study lies in its inclusion of both nulliparous and multiparous women, a large sample size, the adjustment for as many confounding factors as possible, and the use of patient interview and medical record data rather than vital statistics or birth certificate data; thus, the associations of pregestational BMI and GWG with respect to the 2009 IOM guidelines with pregnancy outcomes can be investigated objectively.

Another important finding of this study is that we found GWG relative to the IOM guidelines has a differential effect on the rates of adverse pregnancy outcomes among women of different pregestational weight categories. For women with pregestational underweight or normal weight, GWG below the IOM guidelines increased the risks of low birth weight and SGA, while GWG above the IOM guidelines increased the risks of LGA and macrosomia, compared with the women of similar pregestational weight category but with GWG within the IOM guidelines. For women with pregestational overweight or obesity, GWG above the IOM guidelines similarly increased the risk of macrosomia, but GWG below the IOM guidelines was not associated with increased risk of SGA or low birth weight compared with the women with GWG within the IOM guidelines. These results indicate that nutritional plan should be individualized according to pregestational BMI and highlight the importance of adherence to the IOM recommendations to optimize fetal growth.

Consistent with our previous study [25], maternal underweight is associated with 1.7-fold increased risk for placental abruption than normal weight women. Our recent study also showed that GWG below the IOM guidelines was an independent risk factor for placental abruption [18]. In the present study, we further clarify that the effect of inadequate GWG on the development of placental abruption mainly occurred in women of normal weight. Although the exact mechanism remains unclear, these results suggest that nutrition before and during pregnancy may play a role in the occurrence of placental abruption.

Similar to our previous report [22], women with pregestational overweight or obesity carried a 3.7 to 7.9-fold increased risk for preeclampsia. Furthermore, the risk of preeclampsia increased with GWG above the IOM guidelines in women with normal

Table 3
Characteristics of women with live singleton delivered after 37 weeks of gestation during 2009–2015 (Cohort 2).

	Underweight ($n = 1556$)	Normal weight ($n = 8247$)	Overweight ($n = 961$)	Obese ($n = 209$)	p
Age (y)					
<20	8 (0.5%)**	9 (0.1%)	1 (0.1%)	0	0.02
20–34	1163 (74.7%)***	5253 (63.7%)	546 (56.8%)**	124 (59.3%)	<0.001
>34	385 (24.7%)***	2985 (63.7%)	414 (43.1%)***	85 (40.7%)	<0.001
Weight gain during pregnancy					
Below IOM guideline	691 (44.4%)***	2304 (27.9%)	126 (13.1%)***	35 (16.7%)***	<0.001
Within IOM guideline	718 (46.4%)	3824 (46.4%)	333 (34.7%)***	70 (33.5%)***	<0.001
Above IOM guideline	147 (9.4%)***	2116 (25.7%)	502 (52.2%)***	104 (49.8%)***	<0.001
Primiparity	1009 (64.8%)***	4635 (56.2%)	429 (44.6%)***	73 (34.9%)***	<0.001
Prior induced abortion	419 (26.9%)*	2452 (29.7%)	332 (34.5%)**	76 (36.4%)*	<0.001
Prior fetal death	5 (0.3%)*	77 (0.9%)	17 (1.8%)*	3 (1.4%)	<0.001
Prior preterm birth	1 (0.1%)	24 (0.3%)	4 (0.4%)	0	0.14
Conception by reproductive technology	18 (1.2%)	150 (1.8%)	14 (1.5%)	2 (1.0%)	0.18
Genetic amniocentesis	417 (26.8%)***	3214 (39.0%)	416 (43.3%)*	83 (39.7%)	<0.001
Smoking during pregnancy	5 (0.3%)	16 (0.2%)	2 (0.2%)	0	0.62
Placenta previa	28 (1.8%)	166 (2.0%)	24 (2.5%)	3 (1.4%)	0.61
GBS colonization	233 (15.0%)	1309 (15.9%)	138 (14.4%)	26 (12.4%)	0.29
Male fetus	771 (49.6%)	4251 (51.5%)	512 (53.3%)	99 (47.4%)	0.18
Epidural analgesia	871 (56.0%)**	4270 (51.8%)	402 (41.8%)*	70 (33.5%)*	<0.001
Induction of labor	268 (17.2%)**	1713 (20.8%)	207 (21.5%)	45 (21.5%)	0.01
Augmentation of labor	667 (42.9%)	3423 (41.5%)	319 (33.2%)***	77 (36.8%)	<0.001

Data presented as n (%). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, compared with women of normal weight before pregnancy.
GBS = group B streptococcus; IOM = Institute of Medicine.

Table 4
Adverse pregnancy outcomes associated with gestational weight gain according to Institute of Medicine (IOM) guidelines in women with pregestational underweight in Cohort 2.[a]

Outcome	Below IOM guidelines	Within IOM guidelines	Above IOM guidelines	Below vs. within	Above vs. within
	($n = 691$)	($n = 718$)	($n = 147$)	Adjusted OR (95% CI)	Adjusted OR (95% CI)
Gestational diabetes mellitus	60 (8.7%)	36 (5.0%)	3 (2.0%)	1.66[d] (1.07–2.56)	0.36[d] (0.11–1.19)
Preeclampsia	3 (0.4%)	2 (0.3%)	2 (1.4%)	1.72[d] (0.28–10.48)	4.58[d] (0.62–34.14)
Premature rupture of membranes	3 (0.4%)	3 (0.4%)	1 (0.7%)	1.28[d] (0.24–6.85)	1.15[d] (0.11–12.48)
Chorioamnionitis	2 (0.3%)	3 (0.4%)	3 (2.0%)	0.68[d] (0.11–4.14)	4.34[d] (0.83–22.72)
Placental abruption	16 (2.3%)	15 (2.1%)	1 (0.7%)	0.96[d] (0.46–2.00)	0.32[d] (0.04–2.53)
Placenta accreta	3 (0.4%)	3 (0.4%)	1 (0.7%)	0.80[d] (0.15–4.23)	1.95[d] (0.17–22.10)
Postpartum hemorrhage	5 (0.7%)	7 (1.0%)	0	0.64[d] (0.20–2.13)	Not estimable
Operative vaginal delivery	29 (4.2%)	32 (4.5%)	5 (3.4%)	1.00[e] (0.59–1.71)	0.72[e] (0.27–1.94)
Severe perineal injury[b]	53 (11.0%)	68 (13.3%)	6 (7.8%)	0.84[f] (0.57–1.25)	0.34[f] (0.14–0.83)
Primary cesarean delivery	143 (20.7%)	151 (21.0%)	54 (36.7%)	0.94[e] (0.68 −1.29)	2.32[e] (1.45–3.72)
Dysfunctional labor[c]	33 (23.1%)	55 (36.4%)	30 (55.6%)	0.60[e] (0.28–1.31)	1.72[e] (0.63–4.70)
Malpresentation[c]	45 (31.5%)	35 (23.2%)	6 (11.1%)	1.11[e] (0.61–2.03)	0.46[e] (0.16–1.33)
Abnormal FHR pattern[c]	18 (12.6%)	27 (17.9%)	5 (9.3%)	0.65[e] (0.33–1.30)	0.39[e] (0.13–1.17)
Cephalopelvic disproportion[c]	13 (9.1%)	6 (4.0%)	3 (5.6%)	2.19[e] (0.79–6.07)	1.77[e] (0.41–7.60)
Low birth weight	59 (8.5%)	27 (3.8%)	2 (1.4%)	2.37[d] (1.47–3.82)	0.35[d] (0.08–1.50)
SGA	117 (16.9%)	63 (8.8%)	10 (6.8%)	2.17[d] (1.56–3.02)	0.73[d] (0.36–1.47)
LGA	8 (1.2%)	34 (4.7%)	18 (12.2%)	0.22[d] (0.10–0.49)	2.58[d] (1.38–4.81)
Macrosomia	3 (0.4%)	4 (0.6%)	5 (3.4%)	0.83[d] (0.18–3.80)	5.69[d] (1.46–22.21)
1-min Apgar score <7	4 (0.6%)	5 (0.7%)	0	0.76[d] (0.19–3.07)	Not estimable
NICU admission	9 (1.3%)	11 (1.5%)	1 (0.7%)	0.75[d] (0.30–1.84)	0.44[d] (0.06–3.51)

Data presented as *n* (%). [a] No cases of 5-minute Apgar score <7 and neonatal death; [b] among women with a vaginal delivery; [c] among women with primary cesarean delivery; [d] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, and fetal sex; [e] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, and intrapartum epidural analgesia; and [f] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, *intrapartum* epidural analgesia, and operative vaginal delivery.
CI = confidence interval; FHR = fetal heart rate; LGA = large-for-gestational age; OR = odds ratio; NICU = neonatal intensive care unit; SGA = small-for-gestational age.

Table 5
Adverse pregnancy outcomes associated with gestational weight gain according to Institute of Medicine (IOM) guidelines in women with pregestational normal weight in Cohort 2.

Outcome	Below IOM guidelines	Within IOM guidelines	Above IOM guidelines	Below vs. within	Above vs. within
	($n = 2304$)	($n = 3827$)	($n = 2116$)	Adjusted OR (95% CI)	Adjusted OR (95% CI)
GDM	264 (11.5%)	299 (7.8%)	145 (6.9%)	1.49[c] (1.25–1.78)	0.89[c] (0.72–1.10)
Preeclampsia	14 (0.6%)	22 (0.6%)	47 (2.2%)	1.13[c] (0.58–2.22)	3.65[c] (2.18–6.10)
Premature rupture of membranes	8 (0.3%)	16 (0.4%)	7 (0.3%)	0.81[c] (0.34–1.91)	0.81[c] (0.33–2.00)
Chorioamnionitis	14 (0.6%)	35 (0.9%)	16 (0.8%)	0.77[c] (0.41–1.45)	0.68[c] (0.37–1.24)
Placental abruption	38 (1.6%)	36 (0.9%)	20 (0.9%)	1.84[c] (1.16–2.92)	1.02[c] (0.58–1.77)
Placenta accreta	7 (0.3%)	19 (0.5%)	12 (0.6%)	0.56[c] (0.23–1.34)	1.22[c] (0.59–2.52)
Postpartum hemorrhage	42 (1.8%)	74 (1.9%)	39 (1.8%)	0.92[c] (0.62–1.35)	0.97[c] (0.65–1.44)
Operative vaginal delivery	97 (4.2%)	162 (4.2%)	80 (3.8%)	1.10[d] (0.84–1.43)	0.82[d] (0.62–1.08)
Severe perineal injury[a]	191 (12.4%)	283 (11.7%)	122 (10.0%)	1.12[e] (0.91–1.38)	0.76[e] (0.60–0.97)
Primary cesarean delivery	412 (17.9%)	882 (23.0%)	644 (30.4%)	0.76[d] (0.65–0.89)	1.35[d] (1.16–1.56)
Dysfunctional labor[b]	138 (33.5%)	377 (42.7%)	284 (44.1%)	0.77[d] (0.54–1.09)	0.96[d] (0.71–1.29)
Malpresentation[b]	90 (21.8%)	193 (21.9%)	102 (15.8%)	0.74[d] (0.54–1.03)	0.66[d] (0.49–0.90)
Abnormal FHR pattern[b]	63 (15.3%)	112 (12.7%)	88 (13.7%)	1.32[d] (0.94–1.86)	1.06[d] (0.78–1.43)
Cephalopelvic disproportion[b]	24 (5.8%)	60 (6.8%)	76 (11.8%)	0.77[d] (0.47–1.27)	1.88[d] (1.30–2.71)
Low birth weight	86 (3.7%)	87 (2.3%)	29 (1.4%)	1.68[c] (1.23–2.29)	0.58[c] (0.38–0.90)
SGA	199 (8.6%)	233 (6.1%)	90 (4.3%)	1.55[c] (1.27–1.89)	0.65[c] (0.50–0.83)
LGA	103 (4.5%)	306 (8.0%)	274 (12.9%)	0.52[c] (0.41–0.65)	1.80[c] (1.51–2.15)
Macrosomia	17 (0.7%)	63 (1.6%)	74 (3.5%)	0.46[c] (0.27–0.79)	2.16[c] (1.53–3.06)
1-min Apgar score <7	19 (0.8%)	24 (0.6%)	14 (0.7%)	1.37[c] (0.75–2.52)	1.05[c] (0.54–2.04)
5-min Apgar score <7	0	2 (0.1%)	2 (0.1%)	Not estimable	1.73[c] (0.24–12.50)
Neonatal death	0	0	1 (0.0%)	Not estimable	Not estimable
NICU admission	41 (1.8%)	50 (1.3%)	30 (1.4%)	1.45[c] (0.95–2.20)	1.03[c] (0.65–1.63)

Data presented as *n* (%). [a] Among women with a vaginal delivery; [b] among women with primary cesarean delivery; [c] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, and fetal sex; [d] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, and intrapartum epidural analgesia; and [e] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, *intrapartum* epidural analgesia, and operative vaginal delivery.
CI = confidence interval; FHR = fetal heart rate; GDM = gestational diabetes mellitus; LGA = large-for-gestational age; OR = odds ratio; NICU = neonatal intensive care unit; SGA = small-for-gestational age.

Table 6
Adverse pregnancy outcomes associated with gestational weight gain according to Institute of Medicine (IOM) guidelines in women with pregestational overweight and obesity in Cohort 2.[a]

Outcome	Below IOM guidelines	Within IOM guidelines	Above IOM guidelines	Below vs. within	Above vs. within
	($n = 161$)	($n = 403$)	($n = 606$)	Adjusted OR (95% CI)	Adjusted OR (95% CI)
GDM	49 (30.4%)	80 (19.9%)	82 (13.5%)	1.75[d] (1.15–2.68)	0.61[d] (0.43–0.87)
Preeclampsia	5 (3.1%)	15 (3.7%)	28 (4.6%)	0.76[d] (0.27–2.16)	1.24[d] (0.64–2.41)
Premature rupture of membranes	2 (1.2%)	1 (0.2%)	1 (0.2%)	6.98[d] (0.53–92.45)	0.43[d] (0.03–7.16)
Chorioamnionitis	1 (0.6%)	3 (0.7%)	7 (1.2%)	0.66[d] (0.06–7.16)	1.36[d] (0.33–5.60)
Placental abruption	2 (1.2%)	6 (1.5%)	5 (0.8%)	1.04[d] (0.19–5.67)	0.55[d] (0.16–1.92)
Placenta accreta	1 (0.6%)	1 (0.2%)	2 (0.3%)	2.43[d] (0.14–42.02)	1.95[d] (0.17–22.53)
Postpartum hemorrhage	4 (2.5%)	5 (1.2%)	7 (1.2%)	1.91[d] (0.49–7.40)	1.16[d] (0.36–3.79)
Operative vaginal delivery	3 (1.9%)	12 (3.0%)	14 (2.3%)	0.70[e] (0.19–2.62)	0.67[e] (0.30–1.51)
Severe perineal injury[b]	8 (9.3%)	21 (10.2%)	16 (5.6%)	0.96[f] (0.36–2.51)	0.38[f] (0.18–0.80)
Primary cesarean delivery	34 (21.1%)	89 (22.1%)	197 (32.5%)	0.95[e] (0.55–1.64)	1.32[e] (0.92–1.90)
Dysfunctional labor[c]	11 (32.4%)	42 (47.2%)	95 (48.2%)	0.76[e] (0.23–2.52)	1.25[e] (0.58–2.67)
Malpresentation[c]	9 (26.5%)	14 (15.7%)	32 (16.2%)	1.20[e] (0.39–3.72)	1.01[e] (0.45–2.28)
Abnormal FHR pattern[c]	4 (11.8%)	13 (14.6%)	19 (9.6%)	0.85[e] (0.24–3.00)	0.65[e] (0.29–1.45)
Cephalopelvic disproportion[c]	4 (11.8%)	12 (13.5%)	33 (16.8%)	0.69[e] (0.19–2.51)	1.26[e] (0.57–2.78)
Low birth weight	7 (4.3%)	8 (2.0%)	14 (2.3%)	2.25[d] (0.78–6.44)	1.09[d] (0.44–2.68)
SGA	12 (7.5%)	23 (5.7%)	24 (4.0%)	1.30[d] (0.62–2.72)	0.64[d] (0.35–1.16)
LGA	18 (11.2%)	61 (15.1%)	107 (17.7%)	0.66[d] (0.37–1.16)	1.30[d] (0.91–1.86)
Macrosomia	6 (3.7%)	9 (2.2%)	30 (5.0%)	1.72[d] (0.59–5.03)	2.51[d] (1.14–5.52)
1-min Apgar score <7	1 (0.6%)	1 (0.2%)	2 (1.0%)	2.59[d] (0.16–42.64)	4.23[d] (0.50–35.63)
NICU admission	0	6 (1.5%)	8 (1.3%)	Not estimable	0.77[d] (0.25–2.36)

Data presented as *n* (%). [a] No cases of 5-minute Apgar score less than 7 and neonatal death; and [b] among women with a vaginal delivery. [c] Among women with primary cesarean delivery; [d] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, and fetal sex; [e] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, and intrapartum epidural analgesia; and [f] adjusted for maternal age at delivery, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tract, fetal sex, *intrapartum* epidural analgesia, and operative vaginal delivery.
CI = confidence interval; FHR = fetal heart rate; GDM = gestational diabetes mellitus; LGA = large-for-gestational age; OR = odds ratio; NICU = neonatal intensive care unit; SGA = small-for-gestational age.

pregestational weight but not in the women who were underweight, overweight, or obese. Together, these findings imply that the obstetric complications of maternal obesity such as preeclampsia are generally related to issues of pregestational obesity rather than excessive weight gain during pregnancy that results in a nonobese women becoming obese.

Our study confirms most prior studies that pregestational overweight and obesity are independent risk factors for GDM [13]. However, women with GWG below the IOM guidelines were associated with a higher rate of GDM compared with the women with GWG within the guidelines in all women of different pregestational BMI categories. Because diagnosis of GDM are usually established at 24–28 weeks of gestation, it is likely that less total weight gain at delivery in women with GDM is due to the result of treatment of GDM, including nutritional therapy, modification of life style, regular monitoring of blood sugar levels, and insulin treatment [21].

Several limitations of our study merit attention. First, our results were derived from data from women living in Taipei metropolitan area, thus limiting the generalizability to women in rural areas. Second, when assessing the association between GWG and adverse pregnancy outcomes, this study has a limited sample size of some important but rare pregnancy complications, such as birth injury, low Apgar score at 5 minutes, and neonatal death, in women with pregestational overweight and obesity. Third, the prepregnancy weight was self-reported, which is subject to recall error and can lead to underestimation or overestimation of GWG.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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