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Relationship between gestational weight gain during different phases and maternal complications or neonatal outcomes

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Short title: GWG during different pregrent phases

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ABSTRACT

Objectives: Improper gestational weight gain (GWG) causes many adverse obstetrical and neonatal outcomes. This study evaluates the relationship between weight gain in different phases and maternal outcomes or neonatal outcomes.

Material and methods: Finally, this study recruited 2,608 women delivered at Fujian Provincial Maternity and Child Health, affiliated hospital of Fujian Medical University from December 2017 to January 2019. To evaluate the relationship between maternal outcome and neonatal outcome, the participants were divided into four groups based on their baseline BMI and weight gain in the second/third trimester of pregnancy.
Results: This study demonstrated that neonate weight, small-for-gestational-age infants, macrosomia, neonatal death, cesarean delivery, and GDM significantly differed across the baseline BMI, weight gain in the second and third trimester. The umbilical cord's abnormality, bulging membrane, abruptio placentae, and postpartum hemorrhage were significantly related to baseline BMI. Furthermore, gestational hypertension and pre-eclampsia/eclampsia were significantly correlated with baseline BMI and weight gain in the second trimester. The maternal and infant outcomes are different, and the GWG curves are significantly different. Finally, multivariate regression analysis showed that baseline BMI and weight gain in the second/third trimester were the independent risk factors for GDM and macrosomia. Also, baseline BMI and weight gain in the third trimester were the independent risk factors for developing gestational hypertension and pre-eclampsia/eclampsia, respectively.
Conclusions: The baseline BMI and weight gain in the second/third trimester are significant with maternal outcomes and neonatal outcomes to a varying degree. Thus, maintaining appropriate baseline BMI and weight gain in different phases are essential in preventing pregnancy complications and maternal and neonatal prognosis.
Key words: gestational weight gain; pregnancy; maternal complications; neonatal outcomes; risk

INTRODUCTION

Gestational weight gain (GWG) is a significant indicator representing pregnant women's nutritional status and is closely related to t maternal and fetal growth health [1, 2]. Improper GWG includes excessive and insufficient weight gain during pregnancy and causing many short- and long-term adverse obstetrical and neonatal

outcomes, such as gestational hypertension, gestational diabetes, postpartum hemorrhage, and considerable gestation age new-born, and premature birth [3].

It is reported that excessive GWG is the most prominent phenomenon, which seriously endangers mothers' and babies' health and increases social, medical, and economic burdens [4]. The survey showed that 38.2%–54.7% of pregnant women in the United States have excessive weight gain during pregnancy [5]. The proportions of Canadian and Australian women who gain excessive weight during pregnancy are 57% and 49%, respectively [3, 6]. Inappropriate GWG has become a prominent health issue with changes in lifestyle in China. It is reported that the excessive weight gain of pregnant women is about 37–50.9%, and there is an imbalance between regions [7]. Therefore, it is essential to control effectively weight during pregnancy. However, in recent years, we have been still applying the recommendation for pregnancy guidance of the Institute of Medicine (IOM) [8] provided, and there is no specific recommendation for Chinese women. It is necessary to formulate body mass index (BMI) and GWG standards during pregnancy that meet the national conditions as soon as possible.

In 2009, the recommendations for GWG based on BMI categories of the IOM had been updated [8]. However, the guideline has been questioned by some healthcare providers. Some articles researching these recommendations have revealed contradictory results that women whose GWG exceeds the IOM guidelines still achieve good maternal and infant outcomes [9, 10]. What is more, research suggests that exceeding GWG may improve newborn birth weight without increasing poor maternal outcomes [10–12]. In Japan, the classification of obesity is different due to the increasing number of underweight women. Therefore, the recommendations issued by the Japanese on GWG are other from the recommendations made by the IOM [13].

It is recommended that race, ethnic conditions, and many other factors be considered for the guidelines because established guidelines on GWG are inconsistent and controversial. Studies on appropriate GWG and intervention methods for

pregnant women's weight management have also increased year by year in recent years. Still, there is a lack of safe, reliable, and high-quality randomized controlled studies. What is more, there are few studies to explore appropriate weight gain in different trimesters during pregnancy. Thus, this study analyzes the relationship between baseline BMI, weight gain during different phases, and maternal complications or neonatal outcomes in Southeast China.

MATERIAL AND METHODS

Study population

We finally included 2608 women who received perinatal care and delivered at the Fujian Provincial Maternity and Child Health, affiliated hospital of Fujian Medical University from December 2017 to January 2019. All the participants should meet the following criteria: 1) Singleton pregnancy; 2) The women without chronic diseases, such as hypertension, diabetes, or diagnosed before pregnancy; 3) All of them had complete medical records with maternal and neonatal information. All women with insufficient information about their GWG and multiple pregnancies were excluded. The study was approved by the Hospital Ethics Committee (FMCH2017-030), and all participants provided written informed consent.

Data collection

The detail data about each pregnant woman included maternal sociodemographic characteristics, maternal weight at the 12^{th} and 28^{th} weeks of pregnancy and weight at delivery, adverse maternal outcomes (preterm birth, placental abruption, postpartum hemorrhage, chorioamnionitis, bulging membrane), accessory abnormality (abnormality of the umbilical cord), neonatal outcomes [macrosomia, small-for-gestational-age infants, fetal growth restriction (FGR), neonatal jaundice, sepsis, mortality, patent ductus arteriosus (PDA)], complications of gestation (GDM, gestational hypertension, pre-eclampsia/eclampsia).The above data were collected from electronic medical records.

The definitions of variables

We calculated the baseline BMI (kg/m^2) based on the self-reported pre-pregnancy weights and heights. Delivery weight, third-trimester weight, was defined as the weight at delivery or within one week of delivery. Thus, the GWG equaled the delivery weight minus the pre-pregnancy weight. The first and second-trimester weight refers to weight at 12th week and 28th week, respectively. Weight gain during the second trimester equaled the difference between the first and second-trimester weight. Similarly, weight gain during the third trimester equaled the third-trimester weight minus the second-trimester weight. And then, according to the Chinese standard [14], we classified the baseline BMIs into the following categories: underweight group (< $18.5kg/m^2$), normal weight group (18.5–23.9 kg/m^2), overweight group (24.0–27.9 kg/m^2), and obesity group (≥ 28.0 kg/ m^2). We further divided the participants into four groups in line with weight gain in different trimesters of pregnancy.

Statistical analysis

SPSS version 22.0 (IBM, Armonk, NY, USA) was used for statistical analysis. The software R (R version 4.0.4) was applied to draw the curve of weight gain at different stages during pregnancy. The qualitative data were presented as rates and used to analyzed with the chi-square test. The measurement data were expressed as means ± standard deviation and analyzed with t-tests. Multivariate analysis of variance and multiple comparisons are used to compare the GWG in different groups. Multivariable logistic regression analysis was applied to investigate the relationship between the baseline BMI and maternal and neonatal outcomes. The relationship between GWG and the maternal and neonatal outcome was also analyzed. In all statistical tests, the differences were considered statistically significant at p values < 0.05.

RESULT

Characteristics of included women

Finally, a total of 2,608 pregnant women were included in this study. The specific information of the participants are shown in Table 1. The average age of delivery, height, and baseline weight was 28.2 ± 4.1 years, 159.9 ± 8.4 cm and 52.0 ± 7.4 kg. And the baseline BMI was 20.4 ± 2.7 kg/m^2. According to the Chinese standard, 616 (23.6%) women belonged to the under-weight group (< 18.5 kg/m^2). Most women [1738 (66.6%)] belonged to the normal weight group (18.5–23.99 kg/ m^2), 214 (8.2%) women to the normal weight group overweight group (24.0–27.9 kg/m^2), and 40 (1.5%) women to the obesity group (≥ 28.0 kg/ m^2). Furthermore, the average GWG, weight gain in the second trimester, and weight gain in the third trimester for the population were 15.5 ± 4.3, 11.0 ± 3.5, and 4.4 ± 2.1, respectively.

Among 2,608 pregnant women, some women developed adverse obstetric outcomes, including bulging membrane (22.8%), Cesarean delivery (37.0%), chorioamnionitis (2.2%), placental abruption (0.6%), and postpartum hemorrhage (3.5%). And some women developed pregnant complications, including GDM (20.0%), gestational hypertension (3.1%).

Relationship between the GWG curves and maternal or neonatal outcomes

The results in Figure 1 show that the weight gain curves during pregnancy have distinct characteristics for different maternal or neonatal outcomes. The normal birth weight group served as control, the results indicate that the GWG curve in the SGA group has been increasing slowly, and the GWG curve in the macrosomia group has been increasing rapidly. In the GDM group, the weight gain during the first trimester was fast, whereas the weight gain sharply fell during the third trimester after medical nutrition intervention. In the gestational hypertension group, the weight gain during the first trimester to the second trimester was normal, while the weight gain during the third trimester increased significantly. After multivariate analysis of variance and multiple comparison (LSD method), it was found that the GWG in the SGA group was significantly lower than that of the control group ($p = 0.047$), and the GWG of the macrosomia group was significantly higher than that of the control group ($p <$

0.001). The GWG in the GDM group and the hypertensive disease group during pregnancy was also significantly different from that of the control group (p values were 0.001 and 0.047, respectively).

Relationship between baseline BMI, weight gain in the second trimester/third trimester, and maternal or neonatal outcomes

As shown in Table 2, GWG ($p < 0.001$), weight gain in the second trimester ($p < 0.001$), neonate weight ($p = 0.001$), small-for-gestational-age infants ($p = 0.038$), development of macrosomia ($p = 0.009$), FGR ($p = 0.033$), neonatal death ($p = 0.004$), abnormality of the umbilical cord ($p = 0.021$), development bulging membrane ($p = 0.006$), abruptio placentae ($p = 0.017$) and postpartum hemorrhage ($p = 0.005$), the morbidity of cesarean delivery ($p < 0.001$), GDM ($p < 0.001$), gestational hypertension ($p < 0.001$) and pre-eclampsia/eclampsia ($p < 0.001$) significantly differed across the baseline BMI groups according to the Chinese standard.

Analysis of the relationship between weight gain in the second trimester and maternal or neonatal outcomes is shown in Table 3. It revealed that weight gain during the second trimester was positively correlated with neonate weight ($p = 0.001$), small-for-gestational-age infants ($p = 0.013$), the incident of macrosomia ($p < 0.001$) and FGR ($p < 0.001$), neonatal death ($p = 0.006$), the development of bulging membrane ($p = 0.028$), the morbidity of cesarean delivery ($p = 0.004$) and GDM ($p < 0.001$).

This study further analyzed the relationship between weight gain in the third trimester and maternal or neonatal outcomes. In Table 4, results demonstrated that GWG was significantly associated with neonate weight ($p = 0.001$), small-for-gestational-age infants ($p < 0.001$), the incident of macrosomia ($p = 0.006$), and preterm birth ($p < 0.001$), the morbidity of cesarean delivery ($p = 0.015$), GDM ($p < 0.001$), gestational hypertension ($p < 0.001$) and pre-eclampsia/eclampsia ($p < 0.001$).

Analysis on the relationship between baseline BMI, weight gain in different phases, and maternal or neonatal outcomes

It is presented in Table 5. It shows the relationships between baseline BMI, weight gain in a different phase, and maternal or neonatal outcomes in multivariable

logistic regression analysis. The results revealed that baseline BMI is an independent risk factor for gestational hypertension in pregnant women [OR = 3.401; 95% CI (1.827–7.599), p = 0.001], GDM [OR = 3.795; 95% CI (2.630–5.475), p < 0.001 and macrosomia [OR = 1.190; 95% CI (1.058–2.732), p = 0.033]. Also, weight gain in the second trimester was the independent risk factor for neonatal death [OR = 1.303; 95% CI (1.015–2.937), p = 0.027], GDM [OR = 2.464; 95% CI (1.339–4.635), p = 0.002] and macrosomia [OR = 1.112; 95% CI (1.028–2.847), p = 0.038]. Furthermore, Weight gain in the second trimester was the independent risk factor for preterm birth [OR = 1.388; 95% CI (1.076–3.976), p = 0.034], GDM [OR = 1.308; 95% CI (1.031–3.298), p = 0.001], pre-eclampsia/eclampsia [OR = 1.163; 95% CI (1.018–3.513), p = 0.021] and macrosomia [OR = 1.497; 95% CI (1.261–3.947), p = 0.034].

DISCUSSION

Our study demonstrated the relationship between baseline BMI, weight gain in the second/third trimester, and maternal or neonatal outcomes. The weight gain curves during pregnancy have distinct characteristics for different maternal or neonatal outcomes. Baseline BMI, weight gain in the second/ third trimester were independent risk factors for macrosomia development and GDM. What is more, Baseline BMI was positively related to gestational hypertension. Weight gain in the second trimester was positively related to neonatal death. And weight gain in the third trimester was positively related to preterm birth and pre-eclampsia/eclampsia.

As we know, excessive or insufficient GWG can cause adverse pregnancy outcomes. In 2009, the IOM [8] in America revised the guideline on GWG and recommended range of GWG for underweight women (BMI < 18.5 kg/m^2), normal weight (BMI: 18.5–24.9 kg/m^2), overweight (BMI: 25–29.9 kg/m^2), and obesity (BMI ≥ 30 kg/m^2) was 12.5–18, 11.5–16, 7–11.5, 5–9 kg, respectively. Unfortunately, there is no specific recommendation for Chinese women. Therefore, there is an urgent need for guidelines applicable to Chinese women. This study revealed that the average GWG for all women was 15.5 ± 4.3 kg. GWG exceeds recommended weight gain in

overweight and obese women. This revealed the high GWG prevalence among Chinese pregnant women.

This study demonstrated that the development of macrosomia, the morbidity of GDM, and cesarean delivery were positively correlated with baseline BMI, weight gain in the second trimester, and weight gain in the third trimester, consistent with previous studies. Mamun et al. [15] reported future research about the relationship between weight gain during pregnancy and GDM in 3386 women. The results showed that the prevalence of gestational diabetes in women with excessive weight gain during pregnancy was 1.47 times that of women with normal weight gain during pregnancy. Increased body weight is a risk factor for abnormal blood glucose levels in pregnant women [15]. Some studies [16] also indicated that excessive weight gain during pregnancy significantly increases macrosomia risk. It is reported that the risk of development of macrosomia in the extreme weight gain group during pregnancy is 6% higher than that in the normal weight gain group during pregnancy. Obesity leads to maternal metabolic disorders, which is the main factor in the occurrence of giant babies. Goldstein et al. [17, 18] found that the risk of cesarean section increased by 14% for women with excessive weight gain during pregnancy compared with the recommended value of IOM for weight gain Because the pelvic soft tissues of obese pregnant women are thickened. The birth canal diameter becomes narrower, which increases the risk of dystocia, giant babies, and imbalance of the head-pelvic ratio, thereby increasing the chance of cesarean section.

Interestingly, our study showed a potential relationship between bulging membrane, placental abruption, postpartum hemorrhage, and baseline BMI but not the weight gain in the second /third trimester. The study of Ma et al. [19] showed a similar result. The study revealed that obese women have a significantly increased risk of postpartum hemorrhage than normal-weight pregnant women, and flaccid bleeding after forceps assisted delivery is more prominent. The reasons are that uterine contraction is weak. The labor process progresses slowly, and the relative space in the pelvis shrinks during childbirth, which often causes relative

cephalopelvic disproportion and causes postpartum hemorrhage. The study also revealed the potential relationship between gestational hypertension, pre-eclampsia/eclampsia, and baseline BMI. The weight gain in the second trimester but not the weight gain in the third trimester. Obesity is an independent risk factor for gestational hypertension and pre-eclampsia/eclampsia. Haugen et al. [20] conducted a cohort study of 56,101 pregnant women. They found that pregnant women whose weight gain during pregnancy higher than the IOM standard significantly increased pregnancy-induced hypertension risk. Also, Salihu et al. [21] found that the risk of obesity women suffering from gestational hypertension and pre-eclampsia/eclampsia was 4.5 to 8.7 times and 3 to 10 times normal-weight women, respectively.

Recommendations from the IOM in America suggested that recommended weight gain in the second trimester and third trimester of the women who belonged to the underweight group, normal weight group, overweight group, and obesity group were 0.44–0.58 kg/week, 0.35–0.50 kg/week, 0.23–0.33 kg/week, 0.17–0.27 kg/week, respectively. However, there are currently no specific recommendations for weight gain ranges in the second/third trimesters in China. Therefore, it is essential to carry out more extensive cohort research about the relationship between the weight gain in a different phase and the maternal outcome or neonatal outcome. It is urgent to explore the appropriate weight gain in a different stage to achieve the best pregnancy outcomes in China.

As we knew, these are a few studies to analyze the relationship between baseline BMI, weight gain in the second /third trimester, and maternal outcomes and neonatal outcomes in China. Therefore, we evaluate the relationship between baseline BMI, weight gain during the different phases, maternal complications, or neonatal outcomes in Southeast China. However, there are some limitations to this study. First, the task is designed as a single-center, cross-sectional study. Thus, the data cannot represent the entire area in China. It is necessary for further studies with multiple centers. Second, all women included have complete prenatal care data in our research, and those who have incomplete prenatal care data were excluded. Thus, the study patients may be

more focused on weight management than less compliant pregnant women, which may have contributed to selection bias.

CONCLUSIONS

In conclusion, our results demonstrate a significantly positive relationship between baseline BMI, weight gain in the second/third trimester and neonate weight, small-for-gestational-age infants, cesarean delivery, macrosomia, and GDM. And then, neonatal death and pregnancy complications with abruptio placentae and postpartum hemorrhage are significant with the baseline BMI and weight gain in the second trimester, but not weight gain in the third trimester. Furthermore, gestational hypertension and pre-eclampsia/eclampsia are significant with the baseline BMI, weight gain in the third trimester, but not the second trimester. Thus, maintaining appropriate baseline BMI and weight gain in different phases are essential in preventing pregnancy complications and maternal and neonatal prognosis.

Ethics

The study was approved by the Hospital Ethics Committee (FMCH2017-030).

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Authors' contributions

All authors of the articles agree on which journal to submit the report to, determine the final published version, and agree to be responsible for all work.

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Conflicts of interest

The authors declare that they have no competing interests.

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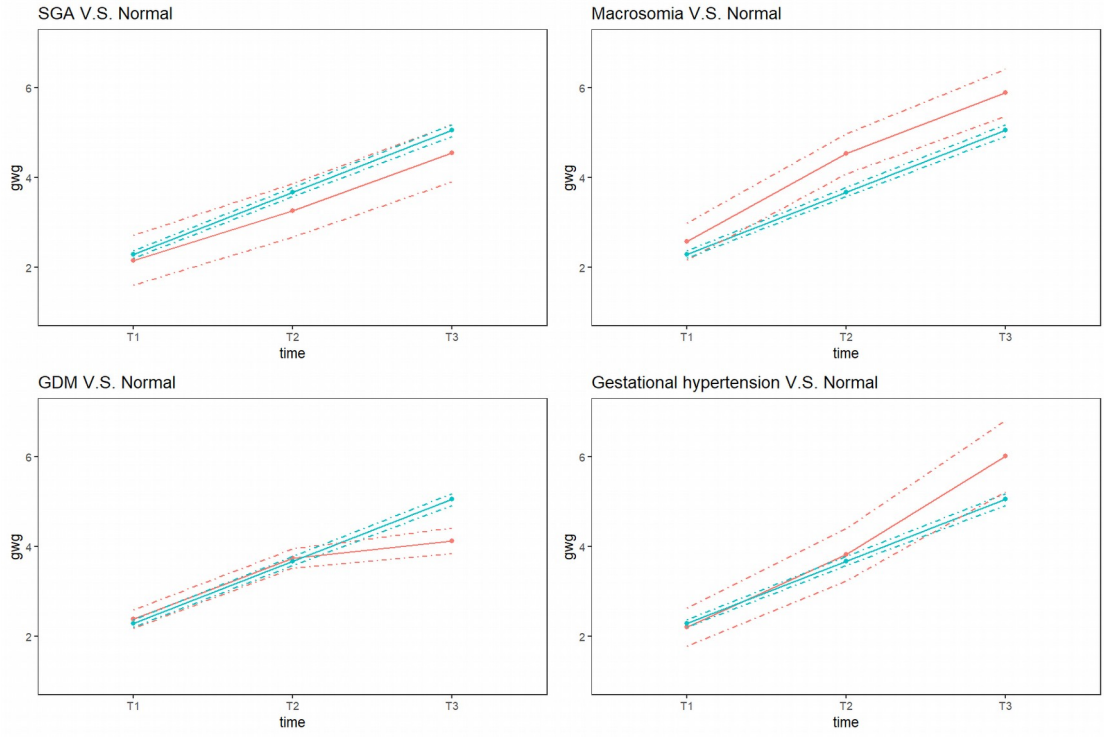

Figure 1. Weight gain curves of different groups during pregnancy. The green lines denote the mean and mean ± 2SD of the normal group，the red lines denote the mean and mean ± 2SD of the case group; SGA — small-for-gestational-age infants; GDM —gestational diabetes mellitus

Table 1. Baseline characteristics of all mothers (n = 2608)

Baseline characteristics		Number of cases (%)
Age [years], mean (SD)		28.2 ± 4.1
Education n [%]	Primary school	7 (0.3%)
	Secondary school	36 (1.4%)
	High school	936 (35.9%)
	College/University	1629 (62.5%)
Gravida		1.9 ± 1.2
Parity		1.3 ± 0.5
Bulging membrane		595 (22.8%)
Cesarean delivery		966 (37.0%)
GDM		521 (20.0%)
Gestational hypertension		81 (3.1%)
Chorioamnionitis		57 (2.2%)
Placenta abruptio		15 (0.6%)
Postpartum hemorrhage		92 (3.5%)
Assisted conception		60 (2.3%)
Height [cm], mean (SD)		159.9 ± 8.4
Baseline weight [kg], mean (SD)		52.0 ± 7.4
Baseline BMI [kg/m^2], mean (SD)		20.4 ± 2.7
Baseline BMI [kg/m^2], n (%)	< 18.5	616 (23.6%)
	≥ 18.5 to < 23.9	1738 (66.6%)
	≥ 24 to < 27.9	214 (8.2%)
	≥ 28	40 (1.5%)
Weight gain during pregnancy		15.5 ± 4.3
Weight gain in the second trimester		11.0 ± 3.5
Weight gain in the third trimester		4.4 ± 2.1

SD — standard deviation; GDM — gestational diabetes mellitus; BMI — body mass index

Table 2. Relationship between baseline body mass index (BMI) and maternal complications, neonatal outcomes

	BMI < 18.5 (n = 616)	18.5 ≤ BMI < 24.0 (n = 1738)	24.0 ≤ BMI < 28.0 (n = 214)	BMI ≥ 28.0 (n = 40)	p value
Weight gain during pregnancy [kg]	16.1 ± 4.1	15.7 ± 4.2	13.4 ± 4.8	12.3 ± 3.4	< 0.001

Weight gain in the T2 [kg]	11.3 ± 3.0	11.1 ± 3.4	9.3 ± 3.8	8.4 ± 2.7	< 0.001
Weight gain in the T3 [kg]	4.7 ± 2.2	4.4 ± 2.0	4.0 ± 2.3	3.9 ± 2.1	0.170
Neonate weight [kg]	3218.1 ± 417.1	3312.4 ± 436.4	3352.8 ± 432.5	3219.9± 409.9	0.001
Small-for-gestational-age infants	26 (4.2%)	44 (2.5%)	9 (4.2%)	2 (5.0%)	0.038
Macrosomia	22 (3.6%)	93 (5.4%)	16 (7.5%)	1 (2.5%)	0.009
Preterm birth	21 (3.2%)	54 (3.1%)	13 (6.1%)	3 (7.5%)	0.074
FGR	26 (4.2%)	45 (2.6%)	2 (0.9%)	0 (0.0%)	0.033
Neonatal jaundice	161 (26.1%)	481 (27.7%)	58 (27.1%)	15 (37.5%)	0.454
Sepsis	7 (1.1%)	11 (0.6%)	1 (0.5%)	0 (0.0%)	0.545
Neonatal death	4 (0.6%)	7 (0.4%)	5 (2.3%)	2 (5.0%)	0.004
PDA	16 (2.6%)	44 (2.5%)	7 (3.3%)	0 (0.0%)	0.685
Abnormality of umbilical cord	151 (24.5%)	497 (28.6%)	50 (23.4%)	5 (12.5%)	0.021
Abnormal fetal position	49 (8.0%)	125 (7.2%)	18 (8.4%)	5 (12.5%)	0.553
Bulging membrane	132 (21.4%)	192 (11.0%)	58 (27.1%)	9 (22.5%)	0.006
Chorioamnionitis	14 (2.3%)	37 (2.1%)	5 (2.3%)	1 (2.5%)	0.993
Placentae abruptio	1 (0.2%)	9 (0.5%)	4 (1.9%)	1 (2.5%)	0.017
Postpartum hemorrhage	26 (4.2%)	50 (2.9%)	13 (6.1%)	3 (7.5%)	0.005
Cesarean delivery	176 (28.6%)	652 (37.5%)	111 (51.9%)	27 (67.5%)	< 0.001
GDM	80 (13.0%)	342 (19.7%)	81 (37.9%)	18 (45.0%)	< 0.001
Gestational hypertension	9 (1.5%)	49 (2.8%)	14 (6.5%)	9 (22.5%)	< 0.001
Pre-eclampsia/eclampsia	5 (3.1%)	30 (1.7%)	8 (3.7%)	4 (10.0%)	< 0.001

T2 **—** in the second trimester; T3 — in the third trimester; FGR — fetal growth restriction; PDA — patent ductus arteriosus; GDM — gestational diabetes mellitus

Table 3. Relationship between weight gain (WG) in the second trimester and maternal complications, neonatal outcomes

	WG < 7.0 (n = 251)	7.0 ≤ WG < 9.0 (n = 434)	9.0 ≤ WG < 11.0 (n = 629)	WG ≥ 11.0 (n = 1294)	p value
Neonate weight [kg]	3203.2 ± 444.9	3190.5 ± 424.6	3250.7 ± 399.0	3364.0 ± 439.2	0.001
Small-for-gestational-age infants	12 (4.8%)	22 (5.1%)	2.2 (4.2%)	33 (2.6%)	0.013
Macrosomia	12 (4.8%)	9 (2.1%)	22 (3.5%)	89 (6.9%)	< 0.001
Preterm birth	9 (3.6%)	22 (5.1%)	18 (2.9%)	42 (3.2%)	0.242
FGR	14 (5.6%)	23 (5.3%)	18 (2.9%)	18 (1.4%)	< 0.001
Neonatal jaundice	75 (29.9%)	118 (27.2%)	157 (25.0%)	365 (28.2%)	0.378
Sepsis	0 (0.0%)	2 (0.6%)	5 (0.8%)	12 (0.9%)	0.389
Neonatal death	6 (2.4%)	3 (0.7%)	2 (0.3%)	7 (0.5%)	0.006
PDA	8 (3.2%)	11 (2.5%)	14 (2.2%)	34 (2.6%)	0.873
Abnormality of umbilical cord	78 (31.1%)	129 (29.76%)	175 (27.8%)	361 (27.9%)	0.680
Abnormal fetal position	17 (6.8%)	29 (6.7%)	40 (6.4%)	111 (8.6%)	0.270
Bulging membrane	46 (18.3%)	91 (21.0%)	132 (21.0%)	326 (25.2%)	0.028
Chorioamnionitis	4 (1.6%)	9 (2.1%)	9 (1.4%)	35 (2.7%)	0.290
Placentae abruptio	1 (0.4%)	3 (0.7%)	2 (0.3%)	9 (0.7%)	0.730
Postpartum hemorrhage	7 (2.8%)	12 (2.7%)	26 (4.1%)	47 (3.6%)	0.601
Cesarean delivery	94 (37.5%)	153 (35.3%)	209 (33.2%)	510 (39.4%)	0.004
GDM	74 (29.5%)	108 (24.9%)	122 (19.4%)	217 (16.8%)	< 0.001
Gestational hypertension	8 (3.2%)	13 (3.0%)	15 (2.4%)	45 (3.5%)	0.636
Pre-eclampsia/eclampsia	6 (2.4%)	6 (1.4%)	10 (1.6%)	25 (1.9%)	0.751

FGR — fetal growth restriction; PDA — patent ductus arteriosus; GDM— gestational diabetes mellitus

Table 4. Relationship between weight gain (WG) in the third trimester and maternal complications, neonatal outcomes

	WG < 4.0 (n = 1059)	4.0 ≤ WG < 6.0 (n = 971)	6.0 ≤ WG < 7.9 (n = 427)	WG ≥ 7.9 (n = 151)	p value
Neonate weight [kg]	3248.6 ± 453.9	3313.9 ± 405.6	3340.9 ± 423.4	3322.6 ± 473.4	0.001
Small-for-gestational-age infants	51 (4.8%)	15 (1.5%)	11 (2.6%)	4 (2.6%)	< 0.001
Macrosomia	46 (4.3%)	37 (3.8%)	31 (7.2%)	18 (11.9%)	0.006
Preterm birth	65 (6.1%)	19 (2.0%)	4 (0.9%)	3 (2.0%)	< 0.001
FGR	27 (2.5%)	25 (2.6%)	15 (3.5%)	6 (4.0%)	0.575
Neonatal jaundice	305 (28.8%)	263 (27.1%)	104 (24.4%)	43 (28.5%)	0.366
Sepsis	5 (0.5%)	9 (0.9%)	4 (0.9%)	1 (0.7%)	0.625
Mortality	11 (1.0%)	2 (0.2%)	3 (0.7%)	2 (1.3%)	0.108
PDA	31 (2.9%)	26 (2.7%)	6 (1.4%)	4 (2.6%)	0.407
Abnormality of umbilical cord	325 (30.7%)	258 (26.6%)	120 (28.1%)	40 (16.5%)	0.204
Abnormal fetal position	71 (6.7%)	77 (7.9%)	37 (8.7%)	12 (8.0%)	0.552
Bulging membrane	258 (24.4%)	224 (23.1%)	90 (21.1%)	23 (15.2%)	0.068
Chorioamnionitis	23 (2.2%)	20 (2.1%)	9 (2.1%)	5 (3.3%)	0.806
Abruptio placentae	9 (0.8%)	4 (0.4%)	2 (0.5%)	0 (0.0%)	0.422
Postpartum hemorrhage	47 (4.4%)	23 (2.4%)	18 (4.2%)	4 (2.6%)	0.332
Cesarean delivery	413 (39.0%)	330 (34.0%)	164 (38.4%)	59 (39.1%)	0.015
GDM	274 (25.9%)	166 (17.1%)	60 (14.1%)	21 (13.9%)	< 0.001
Gestational hypertension	18 (1.7%)	27 (2.8%)	26 (6.1%)	10 (6.6%)	< 0.001
Pre-eclampsia/eclampsia	10 (0.9%)	12 (1.2%)	16 (3.7%)	9 (6.0%)	< 0.001

FGR — fetal growth restriction; PDA — patent ductus arteriosus; GDM — gestational diabetes mellitus

Table 5. Multivariable regression analysis on the association between baseline body mass index (BMI), weight gain (WG) in the second trimester (T2)/third trimester (T3) and maternal complications, neonatal outcomes

	OR	95% CI	p value
Baseline BMI			
Macrosomia	1.190	1.058–2.732	0.033
GDM	3.795	2.630–5.475	< 0.001
Gestational	3.401	1.827–7.599	0.001

hypertension			
WG in the T2			
Macrosomia	1.122	1.028–2.847	0.038
Neonatal death	1.303	1.015–2.937	0.027
GDM	2.464	1.339–4.635	0.002
WG in the T3			
Macrosomia	1.497	1.261–3.947	0.034
Preterm birth	1.388	1.076–3.976	0.030
GDM	1.308	1.031–3.298	0.001
Pre-eclampsia/eclampsia	1.163	1.018–3.513	0.021

OR — odds ratios; CI — confidence interval; GDM — gestational diabetes mellitus