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Original Research

Association between Trimester-Specific Gestational Weight Gain Rate and Maternal and Neonatal Outcomes

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Abstract

Background: To investigate the associations of adjusting gestational weight gain rate (GWGr) with maternal and neonatal outcomes. **Methods**: We analyzed 6235 singleton pregnancies among women with normal pre-pregnancy body mass index at two medical centers in China during 2016~2018 to figure out whether pregnancy outcomes could be improved by adjusting GWGr timely when the first-trimester weight gain rate (GWGr-1) and/or the second-trimester weight gain rate (GWGr-2) were inappropriate. **Results**: When GWGr-1 was excessive, excessive GWGr during the second and third trimesters of pregnancy (late GWGr) was associated with a higher risk of cesarean section (CS), postpartum hemorrhage (PPH), obstructed and prolonged labor and large for gestational age (LGA), and inadequate late GWGr was associated with a lower prevalence of CS and hypertensive disorders of pregnancy (HDP). In pregnancies with inadequate GWGr-1, excessive late GWGr was related to a higher rate of CS, LGA and HDP. Among women with adequate GWGr-1, excessive GWGr in the third trimester (GWGr-3) was positively associated with CS, HDP, and obstruction and prolongation of labor if their GWGr-2 was excessive, and excessive GWGr-3 was associated with a higher risk of CS even though tFheir GWGr-2 was inadequate. **Conclusions**: Prompt control of GWGr, even during late pregnancy, was beneficial to improving pregnancy outcomes.

Keywords: gestational weight gain; pregnancy complications; pregnancy outcome

1. Introduction

The 2009 Institute of Medicine (IOM) publication established guidelines for gestational weight gain goals based on the maternal pre-pregnancy body mass index (BMI) classification. Afterward, domestic scholars conducted studies to research whether pre-pregnancy BMI and gestational weight gain (GWG) were related to pregnancy outcomes [1]. *Guidelines for Pre-Conception and Pregnatal Care (2018)* categorized BMI and proposed a corresponding range of total GWG based on different pre-pregnancy BMI. However, it did not specify the appropriate ranges of the rates of GWG in the first, second and third trimester, respectively. Previous studies [2–4] regarding pregnancy outcomes were limited by the use of either total GWG or GWG in a specific period and did not observe the influence of the dynamic change of GWGr on adverse outcomes. To figure out whether timely adjustment of GWGr could affect maternal and infant outcomes, a retrospective analysis was performed in this study according to clinical data of 6235 singleton pregnancies with normal pre-pregnancy BMI at two medical centers.

2. Materials and Methods

We conducted a retrospective cohort study of singleton pregnant Chinese women using electronic medical record data from the First Affiliated Hospital of Soochow University and the Fifth People's Hospital of Wujiang District. Those with a history of chronic hypertension, diabetes, cardiovascular disease, high or low BMI before pregnancy were excluded from the study. We additionally excluded mothers who received assisted reproductive techniques or delivered stillbirth or malformed infants.

The adequacy rates of GWG were defined according to the 2009 IOM recommendations as gaining 0.04~0.17 kg per week in the first trimester and gaining 0.35~0.50 kg per week in the second and third trimesters. Maternal weight before gestation, at 13 weeks and 28 weeks of gestation and before delivery were recorded to calculate GWG in the first trimester (weight at 13 weeks gestation—pre-pregnancy weight), second trimester (weight at 28 weeks gestation—13 weeks gestation), and third trimester (weight before delivery—28 weeks gestation). Finally, the trimester-specific rates of GWG could be calculated by dividing the GWG by the corresponding number of weeks.

The rate of gestational weight gain in the first trimester was defined in this study as "GWGr-1", similarly, the rate of gestational weight gain in the second trimester was defined as "GWGr-2" and the rate of gestational weight gain in the third trimester was defined as "GWGr-3". In addition, the rate of gestational weight gain in the second and third trimesters was defined as "late GWGr".

Table 1. Association between late GWGr and pregnancy outcomes in singleton pregnancies with excessive GWGr-1.

Outcomes		Inadequate (n = 651)	Adequate (n = 1096)	Excessive (n = 2299)
Cesarean section	n (%)	206 (31.6)	548 (39.3)	1017 (44.2)
	OR	0.716	1.00	1.228
	(*95% CI*)	(0.588~0.872)*		(1.072~1.405)*
Large for gestational age	n (%)	63 (10.1)	122 (9.2)	374 (16.6)
	OR	1.105	1.00	1.964
	(*95% CI*)	(0.802~1.522)		(1.581~2.439)*
Small for gestational age	n (%)	25 (4.3)	69 (5.4)	44 (2.3)
	OR	0.775	1.00	0.409
	(*95% CI*)	(0.485~1.239)		(0.278~0.600)*
Hypertensive disorders of pregnancy	n (%)	13 (2.0)	92 (8.37)	217 (9.44)
	OR	***0.222***	1.00	1.137
	(*95% CI*)	(0.123~0.401)*		(0.881~1.468)
Gestational diabetes mellitus	n (%)	109 (16.7)	197 (17.97)	354 (15.05)
	OR	0.918	1.00	0.831
	(*95% CI*)	(0.710~1.187)		(0.686~1.006)
Postpartum hemorrhage	n (%)	29 (4.5)	85 (6.1)	218 (9.5)
	OR	0.719	1.00	1.616
	(*95% CI*)	(0.467~1.108)		(1.246~2.095)*
Obstruction and prolongation of labor	n (%)	17 (2.6)	50 (3.6)	170 (7.4)
	OR	0.722	1.00	2.15
	(*95% CI*)	(0.413~1.262)		(1.557~2.968)*
Preterm delivery	n (%)	7 (1.1)	23 (2.10)	38 (1.65)
	OR	0.507	1.00	2.784
	(*95% CI*)	(0.216~1.188)		(0.465~1.323)

"*" indicates $p < 0.05$, statistically significant compared to the control group; GWGr-1, the rate of gestational weight gain in the first trimester; late GWGr, the rate of gestational weight gain in the second and third trimester; OR, odds ratios; CI, confidence intervals.

Pregnancy outcomes were categorized into maternal and neonatal outcomes. Maternal outcomes included cesarean section (CS), post-partum hemorrhage, obstructed and prolonged labor, gestational diabetes mellitus (GDM) and hypertensive disorders of pregnancy (HDP), and neonatal outcomes included preterm delivery, large for gestational age (LGA) and small for gestational age (SGA).

Multivariable logistic regression was conducted to calculate odds ratios (ORs) and 95% confidence intervals (CIs) evaluating the association between trimester-specific GWGr and risk of CS, post-partum hemorrhage, obstructed and prolonged labor, GDM, HDP, preterm delivery, LGA and SGA. The measurement data is expressed as mean and standard deviation (SD) and enumeration data is expressed in percentage. All analyses used SPSS 19.0 statistical software (IBM Corp., Chicago, IL, USA) with statistical significance defined as $p < 0.05$.

3. Results

For the 6235 women included in this study, 4046 and 1043 had GWGr-1 above and below the IOM guidelines. Of the women with adequate GWGr-1, 424 and 56 gained above and below the guidelines in the second trimester. Overall, there were 666 women with adequate rates of weight gain in each trimester during pregnancy.

3.1 Association between Late GWGr and Maternal and Neonatal Outcomes when GWGr-1 was Excessive

Among the 4046 participants with GWGr-1 above the recommendations, 651 and 2299 patients had inadequate and excessive late GWGr, as well as 1096 women whose late GWGr was within the guidelines were used as the reference group. Table 1 showed there were associations between excessive late GWGr and higher risk of CS [Odd ratio (OR) = 1.228, 95% confidence interval (CI): 1.072~1.405], postpartum hemorrhage (OR = 1.616, 95% CI: 1.246~2.095), obstructed and prolonged labor (OR = 2.150, 95% CI: 1.557~2.968) and LGA (OR = 1.974, 95% CI: 1.581~2.439). Moreover, they had lower risk of small for gestational age (SGA) (OR = 0.409, 95% CI: 0.278~0.600). Inadequate late GWGr was associated with a lower prevalence of CS (OR = 0.716, 95% CI: 0.588~0.872) and hypertensive disorders of pregnancy (HDP) (OR = 0.716, 95% CI: 0.123~0.401) among those with GWGr-1 above the IOM guidelines. We found no significant difference in the incidence of GDM and preterm delivery after adjusting late GWGr among women with excessive GWGr-1.

Table 2. Implications of late GWGr in pregnancy outcomes in pregnancies with inadequate GWGr-1.

Outcomes		Inadequate (n = 166)	Adequate (n = 359)	Excessive (n = 518)
Cesarean section	n (%)	66 (39.8)	124 (34.5)	218 (42.1)
	OR	1.251	1.00	1.377
	(*95% CI*)	(0.856~1.828)		(1.042~1.820)*
Large for gestational age	n (%)	20 (13.4)	31 (9.2)	88 (18.1)
	OR	1.535	1.00	2.184
	(*95% CI*)	(0.844~2.794)		(1.413~3.376)*
Small for gestational age	n (%)	17 (11.6)	21 (6.4)	31 (7.2)
	OR	1.927	1.00	1.136
	(*95% CI*)	(0.984~3.771)		(0.640~2.016)
Hypertensive disorders of pregnancy	n (%)	0	9 (2.51)	54 (10.4)
	OR	-	1.00	4.526
	(*95% CI*)			(2.205~9.291)*
Gestational diabetes mellitus	n (%)	27 (16.3)	31 (8.6)	46 (8.9)
	OR	2.055	1.00	1.031
	(*95% CI*)	(1.182~3.572)*		(0.640~1.661)
Postpartum hemorrhage	n (%)	0	55 (15.3)	9 (1.7)
	OR	-	1.00	0.098
	(*95% CI*)			(0.048~0.201)*
Prolongation and stagnation of labor	n (%)	0	17 (4.7)	27 (5.2)
	OR	-	1.00	1.106
	(*95% CI*)			(0.594~2.061)
Preterm delivery	n (%)	0	0	0
	OR	-	1.00	-
	(*95% CI*)			

"*" indicates $p < 0.05$, statistically significant compared to the control group; GWGr-1, the rate of gestational weight gain in the first trimester; late GWGr, the rate of gestational weight gain in the second and third trimester; OR, odds ratios; CI, confidence intervals.

3.2 Effects of late GWGr on Maternal and Neonatal Outcomes among Women with Inadequate GWGr-1

1043 patients with inadequate GWGr-1 were divided into three groups based on the late GWGr (Table 2). Compared with the reference group, excessive late GWGr increased the risk of CS by 1.4 times, LGA by 2.2 times and HDP by 1.6 times, but reduced the risk of postpartum hemorrhage by 90%. Women with persistent inadequate rate of weight gain during pregnancy had a 2.1-fold decreased risk of GDM. However, we observed no association between excessive or inadequate GWGr and obstructed and prolonged labor, preterm delivery and SGA.

3.3 Maternal and Neonatal Outcomes According to GWGr-3 in Pregnancies with Adequate GWGr-1 and Excessive GWGr-2

There were 424 patients with normal GWGr-1 and excessive GWGr-2. Coupled with adequate GWGr-1 and excessive GWGr-2, excessive GWGr-3 was positively associated with CS (OR = 1.675, 95% CI: 1.129~2.486), HDP (OR = 32.35, 95% CI: 4.354~240.438) and obstruction and prolongation of labor (OR = 18.06, 95% CI: 4.255~46.707), and inadequate GWGr-3 was not linked to maternal and neonatal outcomes in this study (see Table 3 for details).

3.4 Pregnancy Outcomes after the Alteration of GWGr-3 in Patients with Adequate GWGr-1 and Inadequate GWGr-2

Among the 56 patients with GWGr-1 within the normal range and inadequate GWGr-2, those with excessive GWGr-3 had a higher risk of developing CS ($p < 0.05$). If their GWGr-3 remained inadequate, no significant difference in adverse pregnancy outcomes was observed (see Table 4 for details).

4. Discussion

In this analysis of 6235 singleton pregnancies, we found associations between adjusting GWGr and several adverse maternal and neonatal outcomes including CS, HDP, GDM, postpartum hemorrhage, obstruction and prolongation of labor, LGA, SGA and preterm delivery. In general, decreasing the GWGr in the second and third trimesters when the GWGr in the first trimester was inappropriate or adjusting GWGr-3 after gaining improper weight in the second trimester would contribute to a varying degree of improved pregnancy outcomes.

Table 3. Obstetric outcomes according to GWGr-3 in women with adequate GWGr-1 and excessive GWGr-2.

Outcomes		Inadequate (n = 102)	Adequate (n = 152)	Excessive (n = 170)
Cesarean section	n (%)	37 (36.3)	50 (32.9)	170 (45.1)
	OR	1.161	1.00	1.675
	(*95% CI*)	(0.686~1.966)		(1.129~2.486)*
Large for gestational age	n (%)	13 (12.7)	16 (7.24)	23 (6.2)
	OR	1.872	1.00	2.006
	(*95% CI*)	(0.804~4.362)		(0.943~4.266)
Small for gestational age	n (%)	0	0	4 (2.35)
	OR	-	1.00	-
	(*95% CI*)			
Hypertensive disorders of pregnancy	n (%)	0	1 (0.66)	30 (8.0)
	OR	-	1.00	32.35
	(*95% CI*)			(4.354~240.438)*
Gestational diabetes mellitus	n (%)	10 (9.8)	10 (4.6)	17 (4.5)
	OR	2.252	1.00	0.978
	(*95% CI*)	(0.828~6.124)		(0.397~2.408)
Postpartum hemorrhage	n (%)	16 (22.5)	12 (7.9)	43 (11.4)
	OR	2.17	1.00	1.502
	(*95% CI*)	(0.98~4.808)		(0.769~2.934)
Prolongation and stagnation of labor	n (%)	6 (5.88)	2 (1.32)	33 (8.8)
	OR	4.687	1.00	18.06
	(*95% CI*)	(0.927~23.703)		(4.255~46.707)*
Preterm delivery	n (%)	0	0	24 (6.4)
	OR	-	1.00	-
	(*95% CI*)			

"*" indicates $p < 0.05$, statistically significant compared to the control group; GWGr-1, the rate of gestational weight gain in the first trimester; GWGr-2, the rate of gestational weight gain in the second trimester; GWGr-3, the rate of gestational weight gain in the third trimester; OR, odds ratios; CI, confidence intervals.

For neonatal birth weight, as long as GWGr-1 was inappropriate, regardless of whether it was excessive or inadequate, maternal late GWGr above the IOM recommendation was associated with a higher risk of LGA. The results were in line with a prospective cohort analysis which consisted of 14,219 Chinese rural nulliparous women [5], suggesting patients with late GWGr in the highest quintile had higher risks of macrosomia (adjusted OR = 1.89, 95% CI: 1.46~2.45) and LGA (adjusted OR = 1.56, 95% CI: 1.31~1.85) compared with those in the middle quintile. In addition, studies among American and Brazilian women were also consistent with our results [6,7]. All the above shows that timely adjustment of late GWGr to the appropriate range was beneficial to neonatal outcomes.

Of note, women with appropriate GWGr-1 in this study were not associated with LGA, SGA or preterm delivery no matter how variable the GWG in the second and third trimesters, indicating that proper preemptive management of early weight gain was necessary to reduce the risk of developing adverse neonatal outcomes. This was also confirmed by a retrospective study conducted in Korea [8].

Earlier prevention and diagnosis of adverse pregnancy complications such as HDP is important for pregnancy. Our study shows women with inadequate GWGr-1 had higher odds of HDP when their late GWGr was excessive, and so did women with appropriate GWGr-1 and excessive GWGr-2 and GWGr-3. The former underwent a rapid increase from GWGr-1 to late GWGr and the GWGr of the latter increased rapidly from the first trimester to the second trimester. However, patients whose GWGr-1 and late GWGr were both excessive were not associated with HDP, and women with excessive GWGr-1 would have lower odds of HDP if they underwent strict weight control in mid and late pregnancy. The reason for this discrepancy might be the rapid increase of GWGr. Compared to the women with higher risk of HDP, the latter has a decrease or a more substantial increase of GWGr. Therefore, avoiding the uncontrolled rapid increase of weight gain rate might be an effective way to prevent HDP.

Our results also indicated that GWGr in late pregnancy was closely related to CS. We found a higher risk of CS in women with excessive late GWGr regardless of GWGr-1 and in patients with excessive GWGr-3 no matter of GWGr-2, suggesting that prompt control of GWGr even during the third trimester was beneficial to improving pregnancy outcomes.

Table 4. Obstetric outcomes according to GWGr-3 in women with adequate GWGr-1 and inadequate GWGr-2.

		Inadequate (n = 9)	Adequate (n = 10)	Excessive (n = 37)
Cesarean section	n (%)	1 (11.11)	0	16 (43.24)
	OR (95% CI)	-	1.00	-
	p	0.279		0.010*
Large for gestational age	n (%)	0	0	6 (16.22)
	OR (95% CI)	-	1.00	-
	p			0.172
Small for gestational age	n (%)	0	0	0
	OR (95% CI)	-	1.00	-
	p			
Hypertensive disorders of pregnancy	n (%)	0	0	0
	OR (95% CI)	-	1.00	-
	p			
Gestational diabetes mellitus	n (%)	1 (11.11)	0	0
	OR (95% CI)	-	1.00	-
	p	0.279		
Postpartum hemorrhage	n (%)	0	0	0
	OR (95% CI)	-	1.00	-
	p			
Prolongation and stagnation of labor	n (%)	0	0	4 (10.81)
	OR (95% CI)	-	1.00	-
	p			0.277
Preterm delivery	n (%)	0	0	0
	OR (95% CI)	-	1.00	-
	p			

"*" indicates $p < 0.05$, statistically significant compared to the control group; GWGr-1, the rate of gestational weight gain in the first trimester; GWGr-2, the rate of gestational weight gain in the second trimester; GWGr-3, the rate of gestational weight gain in the third trimester; OR, odds ratios; CI, confidence intervals.

We acknowledge several limitations to this study. We investigated singleton pregnant women at two medical centers but most of them were from urban areas, thus they may not represent the entire population in Chinese women. Besides, apart from gestational weight, abnormalities of macronutrients, vitamins, and trace elements during pregnancy are closely related to adverse pregnancy outcomes [9]. For example, blood lipid during pregnancy is related to GDM, HDP and intrahepatic cholestasis of pregnancy (ICP) [10]. In addition, Iron deficiency correlates with low birth weight infants and can increase the risk of intrauterine growth retardation and neonatal nutrition neurodevelopmental disorder [11,12]. Moreover, calcium supplementation during pregnancy can also prevent preterm birth, HDP and GDM [13–15]. However, information regarding the dietary structure and lifestyle during pregnancy was not available in our medical records. To fully understand the impact of GWG and GWGr on pregnant women and their offspring, prospective studies are warranted to follow up to specify appropriate ranges of the rates of GWG applicable in the clinical populations.

5. Conclusions

Timely adjustment of GWGr could improve both maternal and neonatal outcomes, therefore, it is critical to managing the rate of gestational weight gain, even during late pregnancy.

Author Contributions

Conceptualization—BH; data curation and writing - original draft preparation—HC and HZ; supervision—BH, YC and LZ. All authors have read and agreed to the published version of the manuscript.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of the First Affiliated Hospital of Suzhou University (protocol code No. 107 and date of approval June 3rd, 2020). Written informed consent was obtained from the individuals.

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Conflict of Interest

The authors declare no conflict of interest.

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