

Original Research

Associations of Gestational Weight Gain at Different Trimesters with Adverse Pregnancy Outcomes. A Prospective Study of 1273 Subjects

Xue-Mei Cai^{1,†}, Qiu-Qi Huang^{1,†}, Ting Zhang^{2,3,4}, Yue Liu¹, Jian-Lin Fu¹, Jun-Yu Chen¹, Ru-Yu Ren¹, Ni Ren¹, Xin-Yang Yu⁵, Yin-Yin Xia^{1,2,*}, Ting-Li Han⁵, Chang Chen⁶, Hong-Bo Qi⁵, Hua Zhang⁵

¹Department of Occupational and Environmental Hygiene, School of Public Health, Research Center for Medicine and Social Development, Innovation Center for Social Risk Governance in Health, Chongqing Medical University, 400016 Chongqing, China

²Stomatological Hospital of Chongqing Medical University, 401147 Chongqing, China

³Chongqing Key Laboratory of Oral Diseases and Biomedical Sciences, 401147 Chongqing, China

⁴Chongqing Municipal Key Laboratory of Oral Biomedical Engineering of Higher Education, 401147 Chongqing, China

⁵Department of Obstetrics and Gynaecology, The First Affiliated Hospital of Chongqing Medical University, 400016 Chongqing, China

⁶Institute of Life Sciences, Chongqing Medical University, 400016 Chongqing, China

*Correspondence: 100118@cqmu.edu.cn (Yin-Yin Xia)

†These authors contributed equally.

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Abstract

Background: The incidence of excessive weight gain during pregnancy continues to increase. Our aim was to compare pregnancy outcomes at different trimesters and different classification criteria of gestational weight gain (GWG) and to examine whether GWG was correlated with adverse outcomes in the population of Southwest China. **Methods:** In the randomized controlled trial of Complex Lipids in Mothers and Babies (CLIMB) conducted in Chongqing, China, data from 1273 women was analyzed. We used two criteria to define GWG as insufficient, appropriate or excessive. The first was based on Chinese, Asian, European Body Mass Index (BMI) and US Institute of Medicine (IOM) guidelines. The second was based on the quantiles of GWG of the subjects studied. **Results:** After adjusting for confounding factors, excessive GWG during gestational periods 12–33 weeks and 12 weeks to delivery was linked to the occurrence of large for gestational age (LGA) infants. The 12 weeks to delivery group was linked to the occurrence of macrosomia, and all periods studied (12–33 weeks, 12 weeks to delivery, and 33 weeks to delivery) were associated with an increased incidence of C-section. Insufficient GWG during 12–33 weeks was associated with the occurrence of small gestational age (SGA) infants. **Conclusions:** Our results support that inappropriate GWG during specific gestational periods was associated with an increased risk of adverse pregnancy outcomes among women in southwestern China. **Clinical Trial Registration:** Clinical Trial Registration number ChiCTR-IOR-16007700.

Keywords: gestational weight gain; pregnancy outcomes; LGA; SGA

1. Introduction

Gestational weight gain (GWG) is the difference between pre-delivery and pre-pregnancy weight and can be assessed during various gestational periods [1]. In 2009, the Institute of Medicine (IOM) updated GWG guidelines recommending specific ranges associated with the initial Body Mass Index (BMI). The recommended GWG for underweight women is 12.5–18 kg, 11.5–16 kg for normal weight women, 7–11.5 kg for overweight women, and 5–9 kg for obese women [2,3]. Twenty one percent, 18% and 31% of pregnant women in the United States, Europe and Asia respectively were below the criteria, while 51%, 51% and 37% were above it [4,5]. Moreover, few studies have been conducted to identify the optimal GWG recommendations specifically for a Chinese population of women.

Previous studies [6–8] have indicated that excessive and insufficient GWG are risk factors for adverse maternal and neonatal outcomes. Excessive GWG may increase the

occurrence of large for gestational age (LGA) in neonates [9–11], while insufficient GWG may lead to preterm delivery and small gestational age (SGA) newborns [12–14]. Moreover, rapid weight gain during pregnancy may increase the occurrence of macrosomia raising the odds for cesarean delivery [15,16]. In addition, a woman's weight gain during pregnancy below the recommended guidelines can result in an elevated risk of low birth weight infants [17,18]. Fetal exposure to excessive GWG can augment the chances of developing cardiovascular disease in childhood [19].

The aim of this study was to evaluate the relationship between GWG and pregnancy outcomes in Chinese women and to compare GWG using different gestational periods and different classification standards. We postulated that excessive or insufficient GWG would increase the risk for adverse pregnancy outcomes.



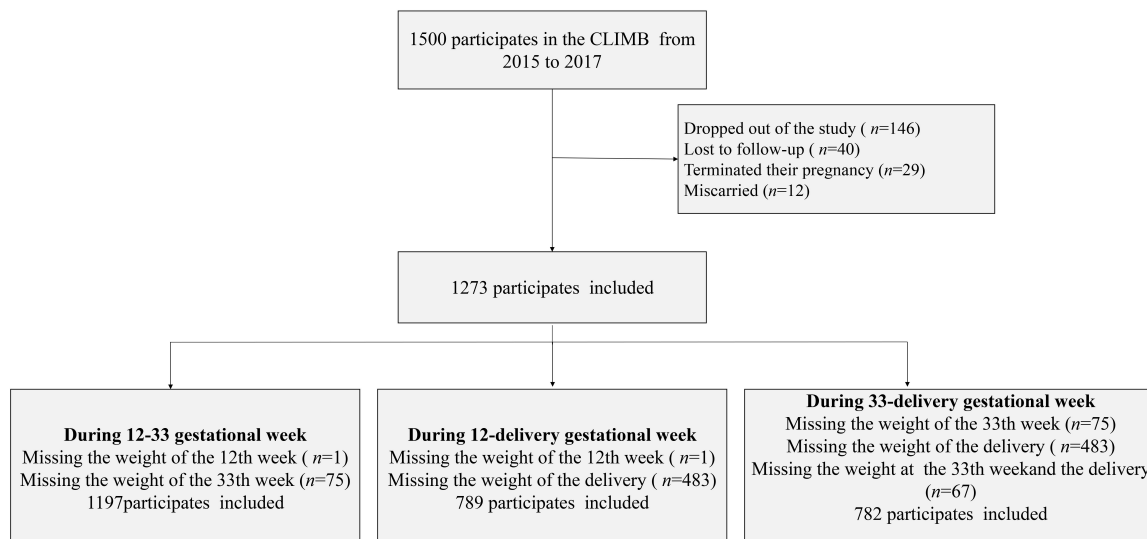


Fig. 1. Flowchart of study participants

2. Materials and Methods

The study participants were recruited in the Complex Lipids in Mothers and Babies (CLIMB) study at the First Affiliated Chongqing, China from September 2015 to June 2017 [20]. All participants received written informed consent at the time of registration. The study was approved by the Ethics Committee of Chongqing Medical University (2014034) and conducted in accordance with the principles of the 1964 Helsinki Declaration and the E6 International Conference on Harmonized Good Clinical Practice (ICH-GCP). This trial was prospectively registered with the Chinese Clinical Trial Register (ChiCTR-IOR-16007700). The CLIMB study included a total of 1500 participants [21]. Women who dropped out of the study ($n = 146$), terminated their pregnancy ($n = 29$), miscarried ($n = 12$), or lost to follow-up ($n = 40$) were excluded from the analysis. A total of 1273 women were included in the final analysis (Fig. 1).

The demographic characteristics of the subjects studied included age, obstetric history, socioeconomic status and assessment of weight and height. Maternal weight was measured at 12 weeks gestation, 33 weeks gestation and at delivery. Gestational age was determined by the last menstrual period and confirmed by B-ultrasound. Delivery and newborn data were obtained from the medical records. Two methods were used to classify GWG. The first method of classification was based on early pregnancy BMI and 2009 IOM GWG recommendations divided into Chinese, World Health Organization (WHO) Asian and WHO European subgroups [22]. The second method was based on quantiles of GWG [9].

2.1 Classification of Early Pregnancy BMI and GWG

BMI was calculated as the weight in kilograms divided by the square of height measured in meters, and classified into four groups according to the Chinese, WHO

Asian and WHO European standard (**Supplementary Table 1**). The study analyzed the relationship between GWG and pregnancy outcomes during periods 12–33 gestation, 12 weeks to delivery, and 33 weeks to delivery. Utilizing the 2009 IOM guidelines and different BMIs, GWG was classified into insufficient, appropriate and excessive if it was below, within, or above the recommendations [23] (**Supplementary Tables 2,3**).

2.2 Diagnostic Criteria for Pregnancy Outcomes

Pregnancy outcomes were obtained from the medical records [24]. Outcomes included premature rupture of membrane (PROM), C-section, preterm birth (PTB), macrosomia, low birth weight (LBW), large for gestational age (LGA), and small for gestational age (SGA). PROM was defined as rupture of the fetal membranes prior to delivery [25]; PTB was defined as delivery before 37 weeks; Macrosomia was a weight greater than 4000 g at delivery; and LBW defined as <2500 g at delivery. Birth weights greater than the 90th or less than the 10th percentile of gestational age were indicated as LGA or SGA [26].

2.3 Statistical Analysis

Data were analyzed in SPSS 26.0 (IBM, Armonk, NY, USA). Demographic characteristics were summarized as mean $\pm$ SD or median (IQR) for continuous variables, or numbers and frequency distributions for categorical and dichotomous variables. Multiple logistic regression models were used to explore the correlation between GWG and pregnancy outcomes and adjusted for confounders, including maternal age, Han ethnicity, primiparity, history of miscarriage or abortion, educational level, participant and partner's income, maternal occupation status, gestational age at delivery, new born gender and Body Mass Index (BMI). Gestational age at delivery and new born gender were not

included as confounding factors in PROM, C-section and PTB. Women with an adequate GWG were used as the reference group for other GWG classifications. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were estimated. $p < 0.05$ was considered statistically significant.

3. Results

3.1 Associations between Pregnancy Outcomes and GWG during 12–33 Weeks Gestational Age

The characteristics of studied participants are shown in Table 1. Due to the lack of some data, the number of patients evaluated at this stage was 1197. The maternal mean (SD) age was 28.7 (3.6) years, mean BMI was 21.5 (2.9) kg/m² and mean GWG was 9.1 (3.6) kg. Among the 1197 women enrolled, 97.8% were Han ethnicity and 77.5% were primiparous. Three hundred and nineteen (26.6%), 349 (29.2%) and 291 (24.3%) of the women had appropriate weight gain based on the 2009 IOM guidelines and BMI in different categories. Adjusted OR (95% CI) for pregnancy outcomes by GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status are shown in Table 2. After adjustment for potential confounders, 12–33 weeks GWG was significantly associated with C-section, PTB and LGA. Compared to women whose GWG was appropriate, women with excessive weight gain had a higher risk of C-section (Chinese GWG category: OR = 1.82, 95% CI: 1.00–3.33; WHO European GWG category: OR = 2.17, 95% CI: 1.11–4.24), PTB (Chinese GWG category: OR = 3.88, 95% CI: 1.04–14.52) and LGA (WHO European GWG category: OR = 2.35, 95% CI: 1.05–5.28). Women with insufficient GWG had a higher risk of PTB (Chinese GWG category: OR = 2.61, 95% CI: 1.06–6.40;) and a lower risk of LGA (WHO Asian GWG category: OR = 0.63, 95% CI: 0.40–0.99). When GWG was classified based on quantiles, women with excessive GWG had a higher risk of LGA (GWG classification 2: OR = 2.26, 95% CI: 1.19–4.27) and women with insufficient GWG had a higher risk of SGA (GWG classification 1: OR = 2.66, 95% CI: 1.06–6.68; GWG classification 2: OR = 2.16, 95% CI: 1.11–4.23) (**Supplementary Table 4**).

3.2 Associations between Pregnancy Outcomes and GWG between 12 Weeks-Delivery

The number of patients evaluated at this stage was 789. The maternal mean GWG was 13.4 (6.1) kg. Among this cohort. 348 (44.1%), 339 (43.0%) and 356 (45.1%) of the women had appropriate weight gain based on the 2009 IOM guidelines and BMI in different categories. Adjusted OR (95% CI) for pregnancy outcomes by GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status are shown in Table 3. After adjustment for potential confounders, 12 weeks to delivery GWG was significantly associated with C-section, PTB, Macrosomia and LGA. Compared to women whose GWG was appropriate, women with excessive GWG had

Table 1. Characteristics of the study participants (n = 1197).

Characteristic	
Maternal characteristics	
Maternal age (years, mean $\pm$ SD)	28.7 $\pm$ 3.6
BMI (kg/m ² , mean $\pm$ SD)	21.5 $\pm$ 2.9
GWG (kg, mean $\pm$ SD)	9.1 $\pm$ 3.6
Han ethnicity (%)	97.8
Marital status (%)	98.7
Primiparity (%)	77.5
History of miscarriage or abortion (%)	46.7
Smoking or drinking during pregnancy (%)	0.4
Chinese BMI category (n, %)	
Underweight	144 (12.0)
Normal weight	850 (71.0)
Overweight	168 (14.0)
Obese	35 (2.9)
Asian BMI category (n, %)	
Underweight	144 (12.0)
Normal weight	756 (63.2)
Overweight	253 (21.1)
Obese	44 (3.7)
WHO BMI category (n, %)	
Underweight	144 (12.0)
Normal weight	919 (76.8)
Overweight	118 (9.9)
Obese	16 (1.3)
Chinese GWG category (n, %)	
insufficient	822 (68.7)
appropriate	319 (26.6)
excessive	56 (4.7)
Asian GWG category (n, %)	
insufficient	774 (64.7)
appropriate	349 (29.2)
excessive	74 (6.2)
WHO GWG category (n, %)	
insufficient	862 (72.0)
appropriate	291 (24.3)
excessive	44 (3.7)
Income grade (n, %)	
low income	257 (21.5)
middle income	436 (36.4)
middle-high income	368 (30.7)
high income	136 (11.4)
Education level (n, %) ^a	
low educational level	23 (1.9)
medium educational level	1043 (87.1)
high educational level	130 (10.9)
Occupations (n, %)	
no occupation/student	267 (22.3)
worker/technicians/clerical/service occupations	578 (48.3)
managers/professionals	352 (29.4)

Abbreviations: BMI, body mass index; GWG, gestational weight gain.

Values are Mean $\pm$ SD or n (%).

^a: Missing 1 data of educational level.

a higher risk of C-section (Chinese GWG category: OR = 1.44, 95% CI: 1.00–2.08; WHO European GWG category: OR = 1.63, 95% CI: 1.12–2.37), Macrosomia (WHO Asian GWG category: OR = 2.23, 95% CI: 1.06–4.71) and LGA (WHO Asian GWG category: OR = 1.97, 95% CI: 1.14–3.41). Women with insufficient GWG had a higher risk of PTB (Chinese GWG category: OR = 3.63, 95% CI: 1.59–8.29; WHO Asian GWG category: OR = 3.36, 95% CI: 1.45–7.77; WHO European GWG category: OR =

Table 2. Adjusted OR (95% CI) for pregnancy outcomes by 12–33 gestational week GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status.

Pregnancy outcomes	GWG	Adjusted OR (95% CI) GWG category		
		Chinese GWG category	Asian GWG category	European GWG category
PROM	insufficient	1.06 (0.78–1.46)	1.07 (0.79–1.47)	1.14 (0.82–1.57)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.58 (0.27–1.25)	0.50 (0.24–1.02)	0.58 (0.25–1.38)
C-section	insufficient	1.33 (0.99–1.79)	1.33 (0.99–1.77)	1.42 (1.05–1.92)*
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.82 (1.00–3.33)*	1.41 (0.83–2.39)	2.17 (1.11–4.24)*
PTB	insufficient	2.61 (1.06–6.40)*	1.94 (0.89–4.24)	2.21 (0.91–5.38)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	3.88 (1.04–14.52)*	2.18 (0.64–7.39)	3.49 (0.82–14.76)
Macrosomia	insufficient	0.58 (0.33–1.03)	0.61 (0.34–1.10)	0.72 (0.40–1.30)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.99 (0.34–2.90)	1.55 (0.68–3.56)	1.62 (0.53–4.95)
LBW	insufficient	1.45 (0.41–5.17)	1.97 (0.54–7.12)	1.12 (0.32–3.90)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.55 (0.03–10.48)	0.56 (0.03–10.21)	0.68 (0.03–14.83)
LGA	insufficient	0.65 (0.41–1.02)	0.63 (0.40–0.99)*	0.71 (0.45–1.12)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.61 (0.76–3.43)	1.73 (0.89–3.35)	2.35 (1.05–5.28)*
SGA	insufficient	1.69 (0.96–2.98)	1.41 (0.83–2.40)	1.61 (0.90–2.86)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.74 (0.16–3.38)	0.46 (0.10–2.02)	0.88 (0.19–4.06)

Values are odds ratios (95% confidence intervals), * $p < 0.05$.

Adjusted for maternal age, Han ethnicity, primiparity, history of miscarriage or abortion, maternal educational level, participant and partner's income, maternal occupation status, gestational age at delivery, new born sex and body mass index (continuous). PROM, C-section and PTB was not adjusted for gestational age at delivery and new born sex.

Abbreviations: BMI, body mass index; GWG, gestational weight gain; OR, Odds ratios; CI, confidence intervals; PROM, premature rupture of membrane; C-section, cesarean section; PTB, preterm birth; LBW, low birth weight; LGA, large for gestational age; SGA, small for gestational age.

3.64, 95% CI: 1.62–8.18) and a lower risk of Macrosomia (Chinese GWG category: OR = 0.27, 95% CI: 0.07–0.97) and LGA (Chinese GWG category: OR = 0.36, 95% CI: 0.16–0.83; WHO European GWG category: OR = 0.45, 95% CI: 0.21–0.96). Women with excessive GWG had a higher risk of C-section (GWG classification 1: OR = 2.42, 95% CI: 1.21–4.83; GWG classification 2: OR = 2.46, 95% CI: 1.48–4.09), Macrosomia (GWG classification 2: OR = 2.82, 95% CI: 1.17–6.80) and LGA (GWG classification 1: OR = 3.73, 95% CI: 1.57–8.86; GWG classification 2: OR = 3.38, 95% CI: 1.75–6.54). Women with insufficient GWG had a higher risk of PTB (GWG classification 2: OR = 2.75, 95% CI: 1.11–6.81) (Supplementary Table 5).

3.3 Associations between Pregnancy Outcomes and GWG during 33 Weeks to Delivery

The number of patients evaluated at this stage was 782. The maternal mean GWG was 4.5 (4.3) kg. Among the 782 women enrolled, 712 (91.0%), 706 (90.3%) and 722 (92.3%) of the women had appropriate weight gain based on the 2009 IOM guidelines and BMI in different categories. Adjusted OR (95% CI) for pregnancy outcomes by GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status are shown in Table 4. After adjustment for potential confounders, 33 weeks to delivery GWG was significantly associated with PROM, C-

section and LGA. Women with insufficient GWG had a higher risk of PROM (WHO European GWG category: OR = 2.80, 95% CI: 1.22–6.42) and a lower risk of C-section (Chinese GWG category: OR = 0.47, 95% CI: 0.26–0.83; WHO Asian GWG category: OR = 0.54, 95% CI: 0.30–0.96) and LGA (WHO European GWG category: OR = 0.40, 95% CI: 0.19–0.87). Women with excessive GWG had a higher risk of C-section (GWG classification 2: OR = 1.76, 95% CI: 1.07–2.90) while those with insufficient GWG had a higher risk of PTB (GWG classification 2: OR = 2.99, 95% CI: 1.13–7.90) (Supplementary Table 6).

4. Discussion

The study demonstrated that inappropriate GWG was associated with adverse pregnancy outcomes including PROM, PTB, Macrosomia, C-section, LGA and SGA. These results depend on GWG for different gestational periods and for different classification methods.

Studies have shown that poor weight gain during pregnancy is associated with PROM [27], which can lead to PTB [28,29]. Our study demonstrated a higher risk of PROM in women whose GWG during 33 weeks to delivery was insufficient. The association between insufficient GWG and increased risk of PROM may be related to the fact that pregnant women lack the nutrients needed for collagen devel-

Table 3. Adjusted OR (95% CI) for pregnancy outcomes by 12-delivery gestational week GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status.

Pregnancy outcomes	GWG	Adjusted OR (95% CI) GWG category		
		Chinese GWG category	Asian GWG category	European GWG category
PROM	insufficient	1.05 (0.72–1.54)	1.07 (0.72–1.58)	0.94 (0.65–1.36)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.83 (0.56–1.21)	0.80 (0.55–1.17)	0.69 (0.46–1.02)
C-section	insufficient	0.87 (0.59–1.29)	0.95 (0.64–1.43)	0.97 (0.66–1.42)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.44 (1.00–2.08)*	1.36 (0.95–1.95)	1.63 (1.12–2.37)*
PTB	insufficient	3.63 (1.59–8.29)**	3.36 (1.45–7.77)**	3.64 (1.62–8.18)**
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.74 (0.25–2.24)	0.82 (0.30–2.22)	0.72 (0.22–2.38)
Macrosomia	insufficient	0.27 (0.07–0.97)*	0.30 (0.07–1.42)	0.38 (0.12–1.19)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.49 (0.73–3.06)	2.23 (1.06–4.71)*	1.88 (0.91–3.87)
LBW	insufficient	0.94 (0.15–5.72)	0.69 (0.12–4.01)	1.72 (0.28–10.58)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.27 (0.20–8.21)	0.47 (0.07–3.17)	1.99 (0.27–14.95)
LGA	insufficient	0.36 (0.16–0.83)*	0.46 (0.19–1.11)	0.45 (0.21–0.96)*
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.52 (0.88–2.62)	1.97 (1.14–3.41)*	1.74 (1.00–3.00)
SGA	insufficient	1.71 (0.88–3.31)	1.94 (0.99–3.80)	1.84 (0.95–3.56)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.97 (0.46–2.05)	1.00 (0.47–2.09)	1.12 (0.53–2.37)

Values are odds ratios (95% confidence intervals), * $p < 0.05$, ** $p < 0.01$.

Adjusted for maternal age, Han ethnicity, primiparity, history of miscarriage or abortion, maternal educational level, participant and partner's income, maternal occupation status, gestational age at delivery, new born sex and body mass index (continuous). PROM, C-section and PTB was not adjusted for gestational age at delivery and new born sex.

Abbreviations: BMI, body mass index; GWG, gestational weight gain; OR, Odds ratios; CI, confidence intervals; PROM, premature rupture of membrane; C-section, cesarean section; PTB, preterm birth; LBW, low birth weight; LGA, large for gestational age; SGA, small for gestational age.

opment and thus have difficulty maintaining the strength of fetal membranes [30]. Both insufficient and excessive GWG have been found to increase the risk of PTB [31,32]. We found that insufficient GWG during 12–33 weeks, 12 weeks to delivery and 33 weeks to delivery increased the risk of PTB. However, excessive GWG was not found to be a risk factor for PTB.

Our findings demonstrated that both insufficient and excessive GWG were associated with Macrosomia and LGA. Consistent with a previous study [33], we found that excessive GWG during 12 weeks to delivery was associated with an increased risk for Macrosomia. In concordance with other reports [34–36], our data showed that excessive GWG during 12–33 weeks, 12 weeks to delivery and 33 weeks to delivery week increased the risk for cesarean delivery. Excessive GWG during periods 12–33 weeks and 12 weeks to delivery increased the risk of LGA and while insufficient GWG during periods 12–33 weeks, 12 weeks to delivery and 33 weeks to delivery week reduced the risk of LGA. These findings confirm previous studies which have indicated similar effects of excessive GWG on LGA [37–41]. Drehmer *et al.* [42] reported that LGA was linked with excessive weight gain in the second trimester which is consistent with the results of our study [38].

Additionally, our results showed that insufficient GWG during 12–33 week increased the risk of SGA, which

is consistent with a recent meta-analysis [4]. Interestingly, only a small number of Chinese women in our study had excessive GWG, which is significantly lower than the proportion noted in Western countries. Another review found that Asian women have significantly lower rates of excessive GWG than in Western countries while Japanese women have an excessive rate of 7% [4]. Reasons may be that there are differences in genetic characteristics, dietary structure and lifestyle between Chinese and Western populations [43]. Currently, the 2009 IOM GWG guidelines were developed based on a Caucasian population with no specific GWG classification criteria for Chinese women [44]. Our study utilized the IOM guidelines but unlike previous studies, we explored the association between GWG at each stage of pregnancy and correlated this with adverse pregnancy outcomes [45].

Limitations of our research are that the subjects were uniformly Chongqing women which may not be representative of all Chinese women and that our sample size was relatively small. Other limitations include that the early pregnancy BMI was self-reported with potential for recall bias and due to the small sample size, the results may be biased when GWG classification was determined based on quantiles.

Table 4. Adjusted OR (95% CI) for pregnancy outcomes by 33-delivery gestational week GWG according to the Chinese, WHO Asian or WHO European maternal early pregnancy BMI status.

Pregnancy outcomes	GWG	Adjusted OR (95% CI) GWG category		
		Chinese GWG category	Asian GWG category	European GWG category
PROM	insufficient	1.85 (0.92–3.72)	1.54 (0.80–2.97)	2.80 (1.22–6.42)*
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.00 (0.00–)	0.00 (0.00–)	0.00 (0.00–)
C-section	insufficient	0.47 (0.26–0.83)*	0.54 (0.30–0.96)*	0.56 (0.30–1.03)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	1.68 (0.43–6.57)	2.23 (0.66–7.55)	3.14 (0.57–17.38)
PTB	insufficient	1.20 (0.27–5.34)	0.80 (0.23–2.80)	2.21 (0.29–16.92)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.00 (0.00–)	0.00 (0.00–)	0.00 (0.00–)
Macrosomia	insufficient	0.75 (0.26–2.16)	0.69 (0.24–1.97)	0.49 (0.18–1.33)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	3.64 (0.59–22.43)	1.83 (0.32–10.48)	0.88 (0.07–11.03)
LBW	insufficient	16158865.9 (0.00–)	1.63 (0.00–)	17370296 (0.00–)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	0.74 (0.00–)	190.94 (0.00–)	0.66 (0.00–)
LGA	insufficient	0.58 (0.27–1.28)	0.63 (0.29–1.38)	0.40 (0.19–0.87)*
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	2.20 (0.49–9.87)	1.53 (0.37–6.29)	0.88 (0.14–5.55)
SGA	insufficient	1.15 (0.33–3.98)	1.85 (0.42–8.14)	1.56 (0.36–6.80)
	appropriate	1 (reference)	1 (reference)	1 (reference)
	excessive	2.24 (0.19–25.89)	5.57 (0.67–46.23)	3.61 (0.27–48.95)

Values are odds ratios (95% confidence intervals), * $p < 0.05$.

Adjusted for maternal age, Han ethnicity, primiparity, history of miscarriage or abortion, maternal educational level, participant and partner's income, maternal occupation status, gestational age at delivery, new born sex and body mass index (continuous). PROM, C-section and PTB was not adjusted for gestational age at delivery and new born sex.

Abbreviations: BMI, body mass index; GWG, gestational weight gain; OR, Odds ratios; CI, confidence intervals; PROM, premature rupture of membrane; C-section, cesarean section; PTB, preterm birth; LBW, low birth weight; LGA, large for gestational age; SGA, small for gestational age.

5. Conclusions

Our study suggests that both insufficient or excessive GWG in different trimesters and different classifications were related to an increased risk of pregnancy complications and adverse pregnancy outcomes but not related to LBW. Our findings highlight the significance of the importance of appropriate GWG in preventing adverse pregnancy outcomes by following healthy lifestyle strategies during pregnancy.

Availability of Data and Materials

The datasets generated during this study are available from the corresponding author on reasonable request.

Author Contributions

YYX, HBQ and HZ conceived and designed research. XMC, QQH and TZ recruited the patients and wrote the draft of manuscript text and prepared the tables. YYX, CC and TLH assisted in statistical analysis, interpretation of results, and reviewed and revised the initial manuscript. YL, JLF, JYC, NR, RYR, XYY and HZ revised the manuscript. All authors read and approved the final version of the article.

Ethics Approval and Consent to Participate

The Ethics Committee of Chongqing Medical University approved the study (No. 2014034). Written informed consent was obtained from all participants.

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Conflict of Interest

The authors declare no conflict of interest. The design and conception of the study were led by the principal investigators. Fonterra Co-operative Group Ltd. had no role in data collection, analysis, and interpretation, or decision to publish.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at <https://doi.org/10.31083/j.ceog5002033>.

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