European Journal of Obstetrics & Gynecology and Reproductive Biology 233 (2019) 64–69

Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

journal homepage: www.elsevier.com/locate/ejogrb

Correlation between second trimester weight gain and perinatal outcomes in dichorionic twin pregnancies: The LoTiS cohort study

Li Wen[a,b,c], Xiyao Liu[a,b,c], Lan Wang[d], Yangxi Zheng[a,b,c], Jie Li[a,b,c], Chao Tong[a,b,c,*], Hongbo Qi[a,b,c,*], Richard Saffery[e], Philip Baker[b,f]

[a] Department of Obstetrics, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, China
[b] International Collaborative Jointed Laboratory of Maternal and Fetal Medicine, Ministry of Education, Chongqing Medical University, Chongqing 400016, China
[c] Sate Key Laboratory of Maternal and Fetal Medicine of Chongqing Municipality, Chongqing Medical University, Chongqing 400016, China
[d] Department of Obstetrics, Chongqing Women and Children's Health Center, Chongqing 401147, China
[e] Cancer, Disease and Developmental Epigenetics, Murdoch Children's Research Institute, and Department of Paediatrics, University of Melbourne, Parkville Victoria 3052, Australia
[f] College of Life Sciences, University of Leicester, Leicester LE1 7RH, UK

ARTICLE INFO

Article history:
Received 27 June 2018
Received in revised form 8 December 2018
Accepted 14 December 2018

Keywords:
Gestational weight gain
Perinatal outcomes
Twin pregnancies

ABSTRACT

Purpose: To investigate how second trimester gestational weight gain relates to perinatal outcomes in twin pregnancies of the LoTiS cohort in Chongqing, China.
Methods: A cohort study was conducted among women with dichorionic twin pregnancies; pregnancies that culminated in delivery at ≥20 gestational weeks were included in the analysis (n = 177). Data were collected through the Longitudinal Twin Study (LoTiS). The second trimester was divided into two periods: 12–20 and 21–28 gestational weeks. Correlations between maternal weight gain and perinatal outcomes were estimated using linear or logistic regression models; the crude OR and adjusted OR were calculated.
Results: The average total gestational weight gain for the whole pregnancy was 17.71 ± 4.98 kg and average gestational weight gains during 12–20 gestational weeks and 20–28 gestational weeks were 5.11 ± 1.81 kg and 5.84 ± 2.05 kg, respectively. Insufficient gestational weight gain was associated with higher risk of preterm birth (OR = 0.92, 95% CI 0.86-0.99) and spontaneous preterm birth (OR = 0.89, 95% CI 0.82–0.97). Reduced gestational weight gain during 12–20 gestational weeks was associated with higher risk of small for gestational age. Additionally, the mean birth weight of a twin pair increased by 45.78 g or 13.03 g when gestational weight gain during 12–20 weeks or total gestational weight gain increased by 1 kg.
Conclusion: Maternal weight gain in the early second trimester was correlated with birth weight in dichorionic twins.

Introduction

Increasing prevalence of twin pregnancies has been observed worldwide, at least partially because of rising maternal age at conception and the development of assisted reproductive technology [1]. Women who conceive twins are believed to undergo more complicated physiological changes during pregnancy [2] and have higher risks of preterm birth and other adverse pregnancy outcomes, as compared with singleton pregnancies [3]. Previous studies have reported that pre-gestational body mass index (pBMI) and gestational weight gain is associated with improved obstetric outcomes in singletons [4,5], exploration of the impact on twin pregnancies has been limited.

In 2009, the US Institute of Medicine (IOM) revised its recommendations on the optimal range of gestational weight gain (GWG) for both singleton and twin pregnancies [6]. Since the recommendation for twin pregnancies was based on descriptive percentiles of weight gain, the guidelines pertaining to twin pregnancies were termed provisional; later studies reported on the applicability of the IOM guidelines by showing associations of inadequate and/or excessive GWG (according to the IOM criteria)

* Corresponding authors at: Department of Obstetrics, The First Affiliated Hospital of Chongqing Medical University, No.1 Youyi Road, Yuzhong District, Chongqing 400016, China.
E-mail addresses: chaotongcqmu@163.com (C. Tong), qihongbo728@163.com (H. Qi).

https://doi.org/10.1016/j.ejogrb.2018.12.014
0301-2115/

with adverse obstetrical and neonatal outcomes in twin pregnancies [7–10]. Nonetheless, in a study of a Japanese population, the optimal weight gain associated with favorable perinatal outcomes in twin pregnancies differed markedly from the IOM guidelines [11]. These differences may have been due to the fact that the IOM guidelines were based on a Western population; the optimal range of gestational weight gain for twin pregnancies in Asian populations has not yet been determined.

Although prior studies have investigated the relationship between inadequate or excessive maternal weight gain and pregnancy complications or delivery outcomes according to the IOM guidelines, these prominently focused on weight gain over the entire gestation; the impact of early or late pregnancy GWG has not been explored. Maternal weight gain has been observed to be minimal in the first trimester, accelerate in the second trimester and decelerate in late pregnancy, thus weight gain during the second trimester may be the determinant of GWG and profoundly impact the pregnancy outcomes.

China, the country that has the largest population in the world, is changing its birth control policy, and more twin pregnancies have occurred in recent years. However, the Chinese population BMI cutoff standards for normal, overweight and obese categories are lower than those found in IoM guidelines [12], and the IoM guidelines do not provide recommendations for underweight women, thus the IOM guideline may not be applicable to Chinese populations [13,14]. Therefore, in the present study, we aimed to investigate the relationship between trimester-specific gestational weight gain and perinatal outcomes in dichorionic twin pregnancies by the use of the world's largest prospective longitudinal twin birth cohort.

Methods

Patients

The Longitudinal Twin Study (LoTiS) is a prospective mother-twins offspring cohort study where 439 twin pregnant women between 11 weeks and 16 weeks gestation have thus far been recruited at two public tertiary hospitals in Chongqing, China since 2016. Four antenatal clinic visits were undertaken during pregnancy and eight pediatric follow-up visits were conducted thereafter. The study was approved by the Ethics Committee of Chongqing Medical University (No.201530), and the protocol has been previously described [15]. Women who were enrolled into the present study are free of mental or chronic diseases and conceive dichorionic twin pregnancies; monochorionic twin pregnancies were excluded due to higher risks of maternal and fetal complications [9]. Pregnancies that culminated in delivery at < 20 gestational weeks or that were complicated by fetal demise were excluded, as were cases of unknown birth outcomes and incomplete records detailing GWG.

Data collection

Maternal sociodemographic data (age, height, education, occupation, parity), lifestyle behaviours (smoking and alcohol use), gestational age at first visit, chorionicity (confirmed by ultrasound assessment), maternal weight at 12 weeks, 20 weeks, 28 weeks, and weight prior to delivery were collected from LoTiS database (Medscinet AB, Sweden). Neonatal outcomes and other perinatal outcomes were obtained from medical records.

Total GWG and second trimester GWG (divided into earlier: 12–20 weeks, and later: 21–28 weeks) were calculated (25th, 50th and 75th percentiles).

The primary outcomes was neonatal outcomes including mean birth weight and small for gestational age (SGA). The secondary outcomes were preterm birth (PTB) < 37 weeks, spontaneous preterm birth (sPTB) < 37 weeks, preterm premature rupture of membranes (PPROM) < 37 weeks, and the incidence of pregnancy complications included gestational diabetes mellitus (GDM) and gestational hypertensive disorders (GHD).

SGA was defined as neonatal birth weight was below the 10th percentile for gestational age and sex compared to twin birth weight curves in Chinese twins [16]. GDM was diagnosed when at least one of the following was found after a 75-g oral glucose tolerance test: fasting blood glucose level of $\geq$ 5.1 mmol/L, blood glucose level at 1 h of $\geq$10.0 mmol/L, blood glucose level at 2 h $\geq$ 8.5 mmol/L. GHD included gestational hypertension (diagnosed when systolic blood pressure $\geq$ 140 mmHg and/or diastolic blood pressure $\geq$ 90 mmHg after 20 weeks of gestation) and preeclampsia (defined by the onset of hypertension $\geq$140/90 mmHg and proteinuria after 20 weeks of gestation).

Statistical analysis

All statistical analyses were performed with SPSS version 19.0 (IBM, Armonk, NY, USA). Continuous variables were compared among groups using One Way ANOVA and categorical variables were assessed by Chi-square test or Fischer's exact test. A linear regression analysis was used to explore the correlation between total or second trimester GWG and birth weight which adjusted for confounders with 0.1 inclusion and 0.15 exclusion criteria. Logistic regression analysis was conducted in order to evaluate the correlation of total or second trimester GWG and perinatal outcomes. Separate logistic regression models were built for each primary and secondary outcome and included adjustments for potential confounders. The potential confounders included in multivariable analyses including maternal age at recruitment, pBMI, education level, smoking or alcohol use, parity, mode of conception, offspring sex. Crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated. $p < 0.05$ was considered statistically significant.

Results

254 dichorionic twin pregnancies from LoTiS were initially recruited into this subcohort. During the follow-up period, 10 women had miscarriages, 7 pregnancies were complicated by the fetal death of one twin, 22 women were lost to follow-up, 25 women did not return to the two centers for delivery, and 7 women had incomplete data records. Six obese women were excluded due to the limited size of this BMI-specific group. A total of 177 cases were thus included in this study (Fig. 1). The maternal characteristics of study participants are shown in Table 1. The average maternal age at recruitment was 30.16 $\pm$ 3.58 years. The average total GWG for the whole pregnancy was 17.71 $\pm$ 4.98 kg. The average GWG in each time period was: 12 to 20 gestational weeks: 5.11 $\pm$ 1.81 kg; 21 to 28 gestational weeks: 5.84 $\pm$ 2.05 kg. There was a significant difference between maternal weight gain during 12 to 20 and 21 to 28 gestational weeks ($p < 0.001$).

Perinatal outcomes according to maternal total GWG showed that the mean birth weight and incidences of PTB, sPTB and PPROM were significantly different between the total GWG quartiles groups. No significant differences were found in the occurrence of SGA, GDM and GHD among the four GWG groups (Table 2). After controlling for potential confounders, the result suggested that total GWG was correlated with mean birth weight and the mean birth weight increased by 13.03 g when total gestational weight gain increased by 1 kg (95% CI 11.66–33.56), while reduced total GWG was associated with higher risk of PTB (OR = 0.92, 95% CI 0.86-0.99) and sPTB (OR = 0.89, 95% CI 0.82-0.97), as presented in Table 3.

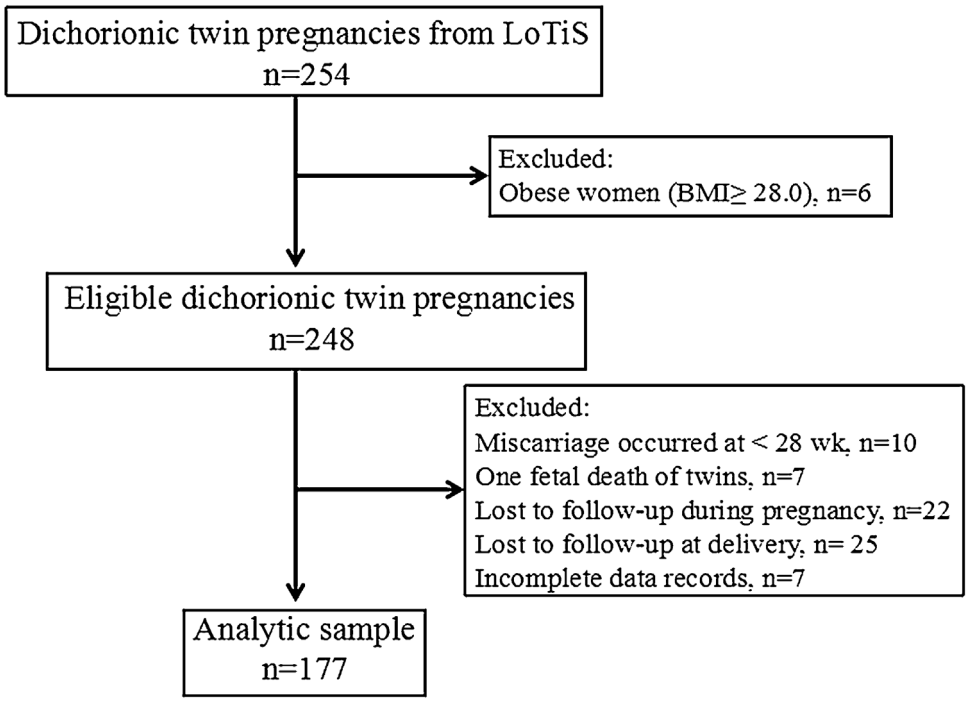

Fig. 1. Analytic sample flow chart.

Table 1
Maternal characteristics of participants according to gestational weight gain.

	All participants (n = 177)	1st Quartile (n = 35)	2nd Quartile (n = 43)	3rd Quartile (n = 34)	4th Quartile (n = 65)	P value
Age at recruitment, years	30.16 ± 3.58	30.80 ± 2.98	31.26 ± 3.43	29.56 ± 3.81	29.52 ± 3.81	0.045
pBMI	21.64 ± 2.61	22.06 ± 3.11	21.95 ± 2.57	21.18 ± 2.58	21.45 ± 2.35	0.413
Education						
≤Senior high school	36 (20.34)	7 (20.0)	9 (20.9)	9 (26.5)	11 (16.9)	0.741
>Senior high school	141 (79.66)	28 (80.0)	34 (79.1)	25 (73.5)	54 (83.1)	0.741
Smoking or alcohol use						
No	152 (85.88)	28 (80.0)	39 (90.7)	28 (82.4)	57 (87.7)	0.515
Before pregnancy only	25 (14.12)	7 (20.0)	4 (9.3)	6 (17.6)	8 (12.3)	0.515
Parity						
Primiparous	137 (77.40)	29 (82.9)	34 (79.1)	30 (88.2)	44 (67.7)	0.089
Multiparous	40 (22.60)	6 (17.1)	9 (20.9)	4 (11.8)	21 (32.3)	0.089
Mode of conception						
Spontaneous	68 (38.42)	11 (31.4)	14 (32.6)	15 (44.1)	28 (43.1)	0.500
ART	109 (61.58)	24 (68.6)	29 (67.4)	19 (55.9)	37 (56.9)	0.500
Gestational age, weeks	36.51 ± 1.54	35.97 ± 1.79	36.66 ± 1.43	36.07 ± 1.82	36.95 ± 1.15	0.005
Total GWG, kg	17.71 ± 4.98	11.00 ± 2.36	15.27 ± 1.19	18.03 ± 0.89	22.78 ± 3.03	0.000
12 to 20 weeks GWG	5.11 ± 1.81	3.74 ± 1.39	4.38 ± 1.58	5.27 ± 1.47	6.24 ± 1.60	0.000
21 to 28 weeks GWG	5.84 ± 2.05	4.17 ± 1.60	5.28 ± 1.77	6.04 ± 1.67	7.00 ± 1.88	0.000

Abbreviations: ARTassisted reproductive technology, including in vitro fertilization and ovulation induction; GWGgestational weight gain.

Table 2
Perinatal outcomes according to maternal total GWG.

Variable	WG<14 (n = 35)	14 ≤ WG<17 (n = 43)	17 ≤ WG<20 (n = 34)	WG ≥20 (n = 65)	*P* value
Mean birth weight	2395.71 ± 403.49	2503.72 ± 386.99	2385.88 ± 383.98	2685.31 ± 309.05	**0.000**
SGA	5 (14.3)	13 (30.2)	5 (14.7)	8 (12.3)	0.093
PTB	23(65.7)	23 (53.5)	21 (61.8)	19 (29.2)	**0.001**
sPTB	11 (31.4)	6 (14.0)	15 (44.1)	6 (9.2)	**0.000**
PPROM	8 (22.9)	5 (11.6)	10 (29.4)	4 (6.2)	**0.010**
GDM	11 (31.4)	11 (25.6)	8 (23.5)	17 (26.2)	0.894
GHD	3 (8.6)	4 (9.3)	0 (0)	9 (13.9)	0.124

Table 3
Unadjusted and adjusted correlations between total GWG and perinatal outcomes.

Variable	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Mean birth weight[a]	22.61 (11.66, 33.56)	0.000	13.03 (5.57, 20.50)	**0.001**[b]
SGA	0.927 (0.855, 1.006)	0.069	0.929 (0.851, 1.051)	0.102[c]
PTB	0.921 (0.865, 0.981)	0.010	0.923 (0.863, 0.986)	**0.018**[d]
sPTB	0.916 (0.848, 0.988)	0.023	0.893 (0.821, 0.971)	**0.008**[d]
PPROM	0.940 (0.865, 1.021)	0.142	0.918 (0.837, 1.008)	0.073[d]
GDM	1.004 (0.938, 1.073)	0.917	1.015 (0.945, 1.090)	0.683[d]
GHD	1.037 (0.935, 1.150)	0.490	1.105 (0.987, 1.236)	0.082[d]

[a] The mean birth weight outcome was analyzed using linear regression, the corresponding effect estimates are a mean difference (95% CI) instead of OR (95% CI).
[b] Adjusted for pBMI, gestational age and fetal sex.
[c] Adjusted for maternal age, educational level, pBMI, parity, smoking or alcohol use, mode of conception and fetal sex.
[d] Adjusted for maternal age, educational level, pBMI, parity, smoking or alcohol use and mode of conception.

To investigate whether particular periods of pregnancy GWG could influence the perinatal outcomes, GWG during 12 to 20 weeks and from 21 to 28 weeks was determined. Mean birth weight and the incidence of SGA was significant different between the different groups categorized by GWG during 12 to 20 gestational weeks quartiles groups. No significant difference were found in the occurrence of PTB, sPTB, PPROM, GDM and GHD among the four groups (Table 4). After controlling for potential confounders, the result suggested that GWG during 12 to 20 gestational weeks was correlated with mean birth weight and the mean birth weight increased by 45.78 g when GWG during 12 to 20 gestational weeks increased by 1 kg (95% CI 28.62–89.17), while insufficient GWG during 12 to 20 gestational weeks has higher risk of SGA (OR = 0.76, 95% CI 0.59- 0.99), as presented in Table 5.

The incidence of GDM significantly differed between groups according to GWG during 21–28 gestational weeks. No differences were found in the mean birth weight and the rate of SGA, PTB, sPTB, PPROM, GHD (Table 6). However, after controlling for potential confounders, there was no significant correlation between GWG during 21–28 gestational weeks and perinatal outcomes, as presented in Table 7.

Discussion

In this study, we present the correlations between total or second trimester gestational weight gain and incidence of perinatal outcomes in dichorionic twin pregnancies from LoTiS cohort in Chongqing, China. Our results showed that a reduction in the total GWG was associated with a higher risk of preterm birth and spontaneous preterm birth. Reduced weight gain between 12 to 20 gestational weeks was associated with a higher risk of small for gestational age (SGA) babies. The mean birth weight of a twin pair increased by 45.78 g or 13.03 g when gestational weight gain during 12 to 20 weeks or total gestational weight gain increased by 1 kg.

Table 5
Unadjusted and adjusted correlations between GWG during 12–20 gestational week and perinatal outcomes.

Variable	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Mean birth weight[a]	58.90 (28.62, 89.17)	0.000	45.78 (25.70, 65.87)	**0.000**[b]
SGA	0.748 (0.591, 0.948)	0.016	0.760 (0.585, 0.987)	**0.039**[c]
PTB	0.924 (0.784, 1.089)	0.346	0.912 (0.763, 1.091)	0.314[d]
sPTB	0.939 (0.769, 1.146)	0.535	0.963 (0.778, 1.191)	0.725[d]
PPROM	0.949 (0.759, 1.186)	0.644	0.971 (0.763, 1.236)	0.814[d]
GDM	0.930 (0.771, 1.122)	0.449	0.935 (0.767, 1.141)	0.510[d]
GHD	0.913 (0.683, 1.221)	0.541	0.983 (0.714, 1.354)	0.917[d]

[a] The mean birth weight outcome was analyzed using linear regression, the corresponding effect estimates are a mean difference (95% CI) instead of OR (95% CI).
[b] Adjusted for pBMI, gestational age, fetal sex and GWG during 21–28 gestational weeks.
[c] Adjusted for maternal age, pBMI, parity, smoking or alcohol use, mode of conception, fetal sex and GWG during 21–28 gestational weeks.
[d] Adjusted for maternal age, educational level, pBMI, parity, smoking or alcohol use, mode of conception and GWG during 21–28 gestational weeks.

Previous studies have reported that gestational weight gain is associated with neonatal birth weight in twin pregnancies. Fox NS et al. reported that patients with normal pBMIs, and whose weight gain met the IOM recommendations, delivered significantly larger neonates compared with patients who did not meet the IOM guidelines [17] and excessive weight gain has been found to be associated with increased birth weight in term twin pregnancies [10]. Similar results have been reported by other researchers [18–21]. Moreover, Pettit KE et al. reported that infants born to mothers with excessive GWG were less likely to be SGA than those born to women with adequate GWG [21]; neonates of women whose GWG was below the IOM recommendations have also been reported to have 44% increased likelihood of being SGA than those of women with GWG above the IOM recommendations [22]. A large cohort conducted in China studied 6925 twin pregnancies and found that GWG below the IOM and Chinese recommendations was associated with an increased risk of SGA/SGA pairs [14]. The result of this current study showed that increased total GWG correlated with larger fetal size; this was consistent with previous studies. To the best of our knowledge, this study is first to demonstrate that maternal weight gain between 12 to 20 gestational weeks was correlated with fetal size, and that reduced weight gain between 12 to 20 gestational weeks was associated with a higher risk of SGA in twin pregnancies (odds ratio: 0.76, [95% CI: 0.59, 0.99]). Similarly, a prospective study of 1164 Chinese women with singleton pregnancies demonstrated that only maternal weight gain from pre-pregnancy to 14 weeks and from 14 to 18 weeks was associated with infant birth weight [23]. Interestingly, a prospective cohort study which focused on the association of GWG and longitudinal fetal growth suggested that GWG in the second trimester influenced fetal growth in dichorionic twin pregnancies [24]. Taken together, these results

Table 4
Perinatal outcomes according to GWG during 12–20 gestational weeks.

Variable	WG<4 (n = 40)	4 ≤ WG<5 (n = 33)	5 ≤ WG< 6 (n = 33)	WG≥6 (n = 71)	*P* value
Mean birth weight	2385.00 ± 346.92	2471.97 ± 382.21	2496.21 ± 424.32	2645.42 ± 351.99	**0.004**
SGA	13(32.5)	5(15.2)	6(18.2)	7 (9.9)	**0.025**
PTB	24(60.0)	16(48.5)	16(48.5)	30 (42.3)	0.358
sPTB	10 (25.0)	11 (33.3)	5 (15.2)	12 (16.9)	0.194
PPROM	8 (20.0)	8 (24.2)	1(3.0)	10 (14.1)	0.084
GDM	11(21.5)	12(36.4)	8(24.2)	16(22.5)	0.508
GHD	5(12.5)	3(9.1)	3(9.1)	5(7.0)	0.764

Table 6
Perinatal outcomes according to GWG during 21–28 gestational weeks.

Variable	WG < 4.5 (n = 42)	4.5 ≤ WG< 6 (n = 42)	6 ≤ WG<7 (n = 30)	WG ≥7 (n = 63)	*P* value
Mean birth weight	2464.17 ± 316.92	2490.60 ± 392.81	2560.50 ± 395.59	2575.56 ± 408.57	0.433
SGA	10 (23.8)	6 (14.3)	5 (16.7)	10 (15.9)	0.690
PTB	20 (47.6)	25 (59.5)	15 (50.0)	26 (41.3)	0.334
sPTB	12 (28.6)	11 (26.2)	6 (20.0)	9 (14.3)	0.283
PPROM	7 (16.7)	9 (21.4)	3(10.0)	8 (12.7)	0.520
GDM	16 (38.1)	14 (33.3)	2 (6.7)	15 (23.8)	**0.017**
GHD	5 (11.9)	3 (7.1)	2 (6.7)	6 (9.5)	0.867

provide evidence that the optimal interventional window for influencing twin birth weight is in earlier stages of pregnancy.

There have been several studies of GWG and preterm birth in twin pregnancies. For example, a prospective study reported no associations between GWG and preterm birth or very preterm birth in 2008 [25]. However, following the revision of IOM recommendations, the results of subsequent studies have shown consistent associations; women with GWG that met the IOM recommendations were less likely to have preterm birth or very preterm birth than women whose GWG was below or above the IOM recommendations [17,7,19,26,27]. Lal AK et al. showed a positive correlation between increasing GWG and the gestational age at delivery [20]. In addition, an observational study in 2017 reported a linear relationships between GWG ratio and very preterm birth [9]. Previous studies were limited to study of total GWG or the total GWG ratio. In the present study, increasing total GWG was associated with higher risk of preterm birth and spontaneous preterm birth, and increased GWG between 21 to 28 weeks was associated with higher risk of spontaneous preterm birth despite the OR value (odds ratio: 0.834, [95% CI: 0.683, 1.019]); this was consistent with a previous finding that higher risk of very preterm birth might result from inadequate mid-pregnancy weight gain [28].

Results from this study found no differences in the incidence of gestational diabetes and hypertensive disorders consequent on differences in second trimester GWG. However, previous studies have reported that excessive weight gain was associated with increased risk of gestational hypertensive disorders [8,29]. Regarding GDM, the previous findings have been inconsistent; the proportion of women with GDM did not increase significantly despite of poor, normal, or excessive weight gain [9,10], however, obese women with low weight gain have been found to have an increased risk of GDM [8].

Table 7
Unadjusted and adjusted correlations between GWG during 21–28 gestational weeks and perinatal outcomes.

Variable	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Mean birth weight[a]	20.21 (-7.47, 47.90)	0.151	11.61 (-6.41, 29.62)	0.205[b]
SGA	0.883 (0.727, 1.073)	0.210	0.921 (0.739, 1.148)	0.466[c]
PTB	0.976 (0.845, 1.128)	0.741	1.039 (0.888, 1.217)	0.631[d]
sPTB	0.859 (0.718, 1.029)	0.099	0.834 (0.683, 1.019)	0.076[d]
PPROM	0.939 (0.771, 1.143)	0.530	0.917 (0.737, 1.140)	0.434[d]
GDM	0.936 (0.794, 1.104)	0.433	0.987 (0.826, 1.179)	0.884[d]
GHD	0.961 (0.746, 1.237)	0.756	1.106 (0.832, 1.469)	0.489[d]

[a] The mean birth weight outcome was analyzed using linear regression, the corresponding effect estimates are a mean difference (95% CI) instead of OR (95% CI).
[b] Adjusted for pBMI, gestational age, fetal sex and GWG during 12–20 gestational weeks.
[c] Adjusted for maternal age, pBMI, parity, smoking or alcohol use, smoking or alcohol use, mode of conception, fetal sex and GWG during 12–20 gestational weeks.
[d] Adjusted for maternal age, educational level, pBMI, parity, smoking or alcohol use, mode of conception and GWG during 12–20 gestational weeks.

This study contributes new knowledge regarding the relationship between GWG and prenatal outcomes. However, several limitations of this study should be taken into consideration. The study is retrospective in design, and quartile division were used to divide women into sub-groups, rather than any standard guideline. Not all of the maternal weight in different gestational weeks was measured by trained assistants; errors in calculation of GWG may have resulted. Another limitation is the relatively small sample size, and the exclusion of obese women. Finally, it may have been beneficial to incorporate additional potential confounding factors, such as a history of miscarriage, or the duration of smoking cessation before pregnancy.

Additional understanding of the key periods of maternal weight gain maybe useful for obstetricians to provide clinical recommendations about weight management during pregnancy and to anticipate perinatal outcomes of twin pregnancies.

Conflicts of interest

The authors have no conflicts of interest.

Acknowledgements

This work was supported by grants from Ministry of Science and Technology (2016YFC1000407, 2018YFC1002901), the National Natural Science Foundation of China (No. 81520108013, 81771613, 81671488), Chongqing Municipal Education Commission (CXTDX201601014), Commission of Science and Technology of Chongqing Municipality (cstc2017jcyjBX0045), and Chongqing Entrepreneurship and Innovation Supporting Program for Returned Overseas Students (cx2017104).

References

[1] Collins J. Global epidemiology of multiple birth. Reprod Biomed Online 2007;15(Suppl 3):45–52.
[2] Rosello-Soberon ME, Fuentes-Chaparro L, Casanueva E. Twin pregnancies: eating for three? Maternal nutrition update. Nutr Rev 2005;63:295–302.
[3] Yoo EH, Chun D, Kim MJ, et al. Comparison of perinatal outcomes in late preterm birth between singleton and twin pregnancies. Obstet Gynecol Sci 2017;60:421–6.
[4] Alberico S, Montico M, Barresi V, et al. The role of gestational diabetes, pre-pregnancy body mass index and gestational weight gain on the risk of newborn macrosomia: results from a prospective multicentre study. BMC Pregnancy Childbirth 2014;14:23.
[5] Gante I, Amaral N, Dores J, et al. Impact of gestational weight gain on obstetric and neonatal outcomes in obese diabetic women. BMC Pregnancy Childbirth 2015;15:249.
[6] Institute of Medicine. Weight gain during pregnancy: reexamining the guidelines. Washington, DC: National Academies Press; 2009.
[7] Algeri P, Pelizzoni F, Bernasconi DP, et al. Influence of weight gain, according to Institute of Medicine 2009 recommendation, on spontaneous preterm delivery in twin pregnancies. BMC Pregnancy Childbirth 2018;18:6.
[8] Ozcan T, Bacak SJ, Zozzaro-Smith P, et al. Assessing weight gain by the 2009 institute of medicine guidelines and perinatal outcomes in twin pregnancy. Matern Child Health J 2017;21:509–15.
[9] Kosinska-Kaczynska K, Szymusik I, Kaczynski B, et al. Observational study of associations between gestational weight gain and perinatal outcomes in dichorionic twin pregnancies. Int J Gynaecol Obstet 2017;138:94–9.

[10] Fox NS, Saltzman DH, Kurtz H, et al. Excessive weight gain in term twin pregnancies: examining the 2009 Institute of Medicine definitions. Obstet Gynecol 2011;118:1000–4.
[11] Suzuki S. Optimal weight gain during twin pregnancy in Japanese women with favorable perinatal outcomes. J Matern Fetal Neonatal Med 2017;1–7.
[12] Chen C. FC Lu and PRC Department of Disease Control Ministry of Health. The guidelines for prevention and control of overweight and obesity in Chinese adults. Biomed Environ Sci 2004;17(Suppl):1–36.
[13] Jiang X, Liu M, Song Y, et al. The Institute of Medicine recommendation for gestational weight gain is probably not optimal among Non-American pregnant women: a retrospective study from China. J Matern Fetal Neonatal Med 2017;1–6.
[14] Chen Y, Liu Y, Zhang Y, et al. Gestational weight gain per pre-pregnancy body mass index and birth weight in twin pregnancies: a cohort study in Wuhan, China. Sci Rep 2018;8:12496.
[15] Tong C, Wen L, Xia Y, et al. Protocol for a longitudinal twin birth cohort study to unravel the complex interplay between early-life environmental and genetic risk factors in health and disease: the Chongqing Longitudinal Twin Study (LoTiS). BMJ Open 2018;8:e017889.
[16] Zhang B, Cao Z, Zhang Y, et al. Birthweight percentiles for twin birth neonates by gestational age in China. Sci Rep 2016;6:31290.
[17] Fox NS, Rebarber A, Roman AS, et al. Weight gain in twin pregnancies and adverse outcomes: examining the 2009 Institute of Medicine guidelines. Obstet Gynecol 2010;116:100–6.
[18] Gavard JA, Artal R. Gestational weight gain and maternal and neonatal outcomes in term twin pregnancies in obese women. Twin Res Hum Genet 2014;17:127–33.
[19] Shamshirsaz AA, Haeri S, Ravangard SF, et al. Perinatal outcomes based on the institute of medicine guidelines for weight gain in twin pregnancies. J Matern Fetal Neonatal Med 2014;27:552–6.
[20] Lal AK, Kominiarek MA. Weight gain in twin gestations: are the Institute of Medicine guidelines optimal for neonatal outcomes? J Perinatol 2015;35:405–10.
[21] Pettit KE, Lacoursiere DY, Schrimmer DB, et al. Maternal and neonatal outcomes in women with twin pregnancies with excessive gestational weight gain. J Matern Fetal Neonatal Med 2016;29:2182–5.
[22] Lutsiv O, Hulman A, Woolcott C, et al. Examining the provisional guidelines for weight gain in twin pregnancies: a retrospective cohort study. BMC Pregnancy Childbirth 2017;17:330.
[23] Retnakaran R, Wen SW, Tan H, et al. Association of timing of weight gain in pregnancy with infant birth weight. JAMA Pediatr 2018;172:136–42.
[24] Hinkle SN, Hediger ML, Kim S, et al. Maternal weight gain and associations with longitudinal fetal growth in dichorionic twin pregnancies: a prospective cohort study. Am J Clin Nutr 2017;106:1449–55.
[25] Simoes T, Cordeiro A, Julio C, et al. Perinatal outcome and change in body mass index in mothers of dichorionic twins: a longitudinal cohort study. Twin Res Hum Genet 2008;11:219–23.
[26] Gonzalez-Quintero VH, Kathiresan AS, Tudela FJ, et al. The association of gestational weight gain per institute of medicine guidelines and prepregnancy body mass index on outcomes of twin pregnancies. Am J Perinatol 2012;29:435–40.
[27] Fox NS, Stern EM, Saltzman DH, et al. The association between maternal weight gain and spontaneous preterm birth in twin pregnancies. J Matern Fetal Neonatal Med 2014;27:1652–5.
[28] Pettit KE, Lacoursiere DY, Schrimmer DB, et al. The association of inadequate mid-pregnancy weight gain and preterm birth in twin pregnancies. J Perinatol 2015;35:85–9.
[29] Pecheux O, Garabedian C, Mizrahi S, et al. Maternal and neonatal outcomes according to gestational weight gain in twin pregnancies: are the IOM guidelines associated with better issues? Gynecol Obstet Fertil Senol 2017;45:366–72.