

# Examining the Effect of Second- and Third-trimester Rate of Gestational Weight Gain on Perinatal Outcomes Among Chinese Twin Gestations Based on the Provisional Guidelines: A Retrospective Cohort Study

**Li-hua Lin**

Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical University

**Yi-lin Weng**

Obstetrics and Gynecology Hospital of Fudan University

**Ying-ying Lin**

Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical University

**Xiu-xian Huang**

Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical University

**Yang Lin**

Fujian Obstetrics and Gynecology Hospital

**Xiao-yan Xiu**

Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical University

**Juan Lin**

Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical University

**Jianying Yan** (✉ [yanjy2019@fjmu.edu.cn](mailto:yanjy2019@fjmu.edu.cn))

Fujian Provincial Maternity and Children's Hospital, Affiliated Hospital of Fujian Medical University

<https://orcid.org/0000-0003-4289-3444>

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## Research article

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# Abstract

**Background:** This paper investigated how second and third trimester gestational weight gain relates to perinatal outcomes among normal weight women with twin pregnancies in Fujian, China.

**Methods:** A retrospective study on the medical records of 931 normal weight twin pregnant women was conducted in Fujian Maternity and Child Health Hospital from 2014 to 2018. The 2<sup>nd</sup> and 3<sup>rd</sup> trimester weekly weight gain rate were calculated and categorized women as gaining below, within, or above the 2009 Institute of Medicine (IOM) recommended rates. The association between trimester-specific weight gain rate and perinatal outcome was performed by traditional regression analysis among groups.

**Results:** A total of 931 pregnant women and 1862 neonates were included for analysis. 25.9%, 19.8% and 54.3% of women had less than, greater than and within the recommended rates of gain in the 2<sup>nd</sup> and 3<sup>rd</sup> trimester, respectively. Multivariate Logistic regression analysis showed that greater than recommended rates of weight gain in 2<sup>nd</sup> trimester decreased the risks of preeclampsia (adjusted OR: 0.458, 95% CI: 0.255~0.824). Less than recommended rates of weight gain in 3<sup>rd</sup> trimester increased the risk of premature delivery [adjusted OR = 1.926, 95% CI: 1.403~2.644], gestational diabetes mellitus (adjusted OR = 2.052, 95% CI: 1.417~2.972), intrahepatic cholestasis syndrome (adjusted OR = 3.016, 95% CI: 1.057~8.606), premature rupture of the membrane (adjusted OR = 1.722, 95% CI: 1.180~2.512) and neonatal respiratory distress syndrome (adjusted OR = 5.135, 95% CI: 1.701~15.498) and decreased the risk of cesarean section (adjusted OR = 0.587, 95% CI: 0.385~0.893). In addition, greater than recommended rates of weight gain in 3<sup>rd</sup> trimester was associated with increased risks in premature delivery (adjusted OR = 1.818, 95% CI: 1.307~2.527), and gestational hypertension (adjusted OR = 2.098, 95% CI: 1.018~4.324) as well as preeclampsia (adjusted OR = 2.029, 95% CI: 1.331~3.093). The stratified analysis of weight gain in 3<sup>rd</sup> trimester showed that there was no significant difference in the incidence of adverse pregnancy outcomes compared to weight gain rate groups in 2<sup>nd</sup> trimester.

**Conclusions:** While this study showed gestational weight gain rate less than or greater than in 3<sup>rd</sup> trimester were associated with some adverse maternal and neonatal outcomes, further studies of prospective and multi-center researches are required to explore alternate ranges of gestational weight gain rate in twin pregnancies.

## Introduction

Gestational Weight gain (GWG) is an important indicator for assessing the nutritional status of pregnant women, and is closely related to fetal growth health<sup>[1, 2]</sup>. Excessive or inadequate weight gain during pregnancy can affect the short- and long-term health of the mother and fetus. Both excessive and inadequate weight gain during pregnancy are associated with adverse pregnancy outcomes. Studies have shown that excessive gestational weight gain increases the risk of hypertensive disorders of pregnancy, gestational diabetes, macrosomia, large for gestational age, cesarean section, and even affects the future growth trajectory of the child including childhood and adolescent obesity; while inadequate weight gain during pregnancy increases the risk of miscarriage, preterm delivery, fetal growth restriction or stillbirth<sup>[3-6]</sup>. The

Institute Of Medicine (IOM) had published guidelines on appropriate weight gain ranges during pregnancy in 1990, and revised them in 2009 to establish appropriate weight gain ranges for singleton pregnancies and temporary weight gain ranges for twins based on pre-pregnancy body mass index<sup>[1]</sup>. The revised guidelines included recommended rates of second- and third-trimester weight gain in pounds per week for singleton pregnancy but not for twin pregnancies. Compared with singleton pregnancies, twin pregnancies have attracted much attention due to their more complex physiological characteristics and higher incidence of adverse pregnancy outcomes. Numerous studies have devoted to the study of gestational weight gain in twin pregnancies, trying to explore the applicability of the IOM recommendations for twin pregnancies in China, but no consensus has been reached. Gestational weight gain and adverse events in twin pregnancies are often confounded with the length of gestation. Most studies mainly focus on total weight gain throughout pregnancy, while there are relatively a few studies devoted on the relationship between weight gain rates at different trimester with pregnancy outcomes. It was clinically observed that gestational weight gain was not linear throughout pregnancy, with slower increases in the first trimester and becoming uniform in 2nd and 3rd trimester<sup>[7]</sup>. Given that, this study aimed at to assess the effect of 2nd and 3rd trimester rate of gestational weight gain on maternal and neonatal outcomes using the 2009 revised Institute of Medicine guidelines for twin pregnancies. Due to sample size limitations, only the population of twin pregnancies with normal pre-pregnancy body mass index(BMI) was analyzed in this study.

## Methods

### Study population

We retrospectively reviewed medical records of women with normal pre-pregnancy body mass indexes who received perinatal care and delivered twins at the Fujian Provincial Maternity and Children's Hospital between 2014 and 2018. The inclusion criteria were: (1) maternal age between 18 and 45 years; (2) both twin were alive at birth; (3) complete medical records with pre-pregnancy weight, height, twin birth weights, gestational age, and weight measurements within 1 week of delivery and so on; (4) the mothers had no chronic diseases, such as diabetes or hypertension diagnosed before pregnancy. We excluded women with twin pregnancies that had been reduced from multiple pregnancies or those whose weight records were missed. The use of weight gain rates also allowed for the inclusion of women who gave birth prematurely.

As this was a retrospective study that did not involve interactions with the study women or data that could be used to identify them, the Ethics Committee of the Fujian Provincial Maternity and Children's Hospital approved it and waived the requirement for informed consents.

### Information collection and Definitions

We extracted demographic information and maternal characteristics, including age, height, education, pre-pregnancy weight, gestational age at delivery, details information of each perinatal visit, medical diagnosis and neonatal data from hospital's electronic medical record system. Pre-pregnancy weight is recorded by the physician at the first antenatal visit, or in the absence of a pre-pregnancy weight record, the weight at the first antenatal visit is used instead. The women were weighed wearing light clothes at each perinatal visit using an electronic weighing scale; the weight measurements were accurate to 0.1 kg. Pre-pregnancy BMI was

calculated as [pre-pregnancy weight (kg)]/ height<sup>2</sup>(m<sup>2</sup>). Due to the sample size limitation, only normal weight pregnant women (BMI 18.5–24.9 kg/m<sup>2</sup>) were included in this study. Delivery weight was defined as the weight at delivery or the last measured weight closest to and within 1 week before delivery. The gestational ages had been estimated from the last menstrual period and were confirmed by ultrasonography during the first trimester. Assuming the same weekly rate of weight gain in 2nd and 3rd trimester, the weekly rate of gestational weight gain was calculated according to the formula: (pregnancy weight at delivery- 13th pregnancy weight) / (weeks at labor - 13weeks). According to the IOM guidelines[1], the recommended total gestational weight gain for twin pregnancies is 16.8–24.5 kg for normal weight women who deliver twins at term (37–42 weeks of gestation) with an average newborn birth weight  $\geq$  2500 g, and the average weight gain in first trimester weight gain is 3.6 kg. The first trimester was defined as before 14 weeks of pregnancy. Referring to the relevant literature<sup>[8]</sup>, and taking into account the actual week of delivery of the included sample, it was assumed that a term twin pregnancy is 38 weeks. On this basis, we calculated and compared the 2nd and 3rd trimester weekly rate of weight gain for IOM guidelines and actual value in each woman, and accordingly, women were categorized as less than, within and greater than the recommended rate of 2nd or 3rd trimester weight gain of the IOM guidelines.

Perinatal outcomes in this study included maternal outcomes: gestational hypertension, defined as blood pressure of  $\geq$  140/90 mmHg occurred after 20 weeks gestation but without proteinuria. Preeclampsia was diagnosed when a new development of blood pressure of  $\geq$  140/90 mmHg and proteinuria of  $\geq$  300 mg/24 h after 20 weeks gestation. Gestational diabetes mellitus was reported after a 75 g OGTT at 24–28 weeks gestation when when at least one of the following blood glucose level: fasting blood glucose level  $\geq$  5.1 mmol/L, a 1-h blood glucose level  $\geq$  10.0 mmol/L, or a 2-h blood glucose level  $\geq$  8.5 mmol/L. Rupture of membranes before delivery was called premature rupture of membranes. Intrahepatic cholestasis of pregnancy is a common pregnancy-specific liver disorder associated with elevated bile acids, pruritus, abnormal liver function tests, and increased incidence of adverse fetal outcomes. Postpartum hemorrhage was defined as bleeding of more than 500 ml in 24 hours after vaginal delivery or more than 1000 ml in 24 hours after caesarean delivery. Other pregnancy outcomes in this study included cesarean delivery, preterm delivery < 37 weeks, low birth weight(LBW, average twin birth weight < 2500 g), small for gestational age(SGA), inconsistent birth weight of twins (twin birth weight difference  $\geq$  20%), and neonatal respiratory distress syndrome. Small for gestational age(SGA) was defined as birth weight less than the tenth percentile gestational age at delivery. Neonatal respiratory distress syndrome was defined as an infant displaying an apgar score  $\leq$  7 at 1 or 5 min after birth<sup>[9]</sup>.

Additional maternal demographic characteristics and perinatal factors were available including maternal age and height, level of maternal education, gravidity, nulliparity, chorionic, infant sex. Nulliparity was defined as no prior births greater than 20 weeks of gestation. Chorionic included monochorionic and dichorionic membrane.

## Statistical analyses

Baseline characteristics were compared across to groups of 2nd and 3rd trimester weekly rate of gestational weight gain: less than, within and greater than the IOM guidelines. Continuous variables were described as mean  $\pm$  SD and compared with the analysis of variance (ANOVA) or Kruskal-Wallis test. Categorical variables

were described as frequency and compared with a chi-square test or Fisher's exact test. We performed multiple comparison (Scheffe method) to assess the differences between every two groups if the result of ANOVA or Chi-squared analysis were statistically significant. Logistic regression analysis were applied to estimate independent effect of 2nd or 3rd trimester weekly rate of gestational weight gain on perinatal outcomes. Adjusted odds ratios (OR) and 95% confidence intervals were used to report the effect estimates. The multivariable analysis were performed adjusted for maternal age, gestational age, infant sex, pre-pregnancy BMI, nulliparity, and education level. All the effect estimates were presented graphically as forest plots.  $P < 0.05$  was considered a statistically significant difference. Statistical analysis was performed using STATA15.0.

## Results

There were 2399 pregnant women received perinatal care and delivered twins at the Fujian Provincial Maternity and Children's Hospital during the study period from 2014 to 2018. Of these, there were 1226 normal weight pregnant women. We excluded 29 women as a result of Maternal age  $< 18$  or  $> 45$ , preexisting diabetes ( $n = 14$ ), chronic hypertension ( $n = 5$ ), gestational age under 20 weeks ( $n = 20$ ), multiple gestation ( $n = 6$ ), stillbirth in one of twins ( $n = 31$ ), missing records of gestational age, pre-pregnancy weight or height, or delivery weight ( $n = 190$ ). There were 931 pregnant women and 1862 infants included (figure.1).

The majority of twin pregnant women in this study had the 2nd and 3rd trimester rates of weight gain within the Institute of Medicine recommendations. That was, 54.3% women had estimated 2nd and 3rd trimester rates of weight gain, while 25.9% women were less than, and 19.8% women were greater than the recommended rates. Table 1 shows the baseline characteristics difference among the three groups. The average maternal ages was  $30.1 \pm 4.3$  years, pre-pregnancy BMI was  $21.1 \pm 1.6$ , height was  $160.4 \pm 5.1$  cm, and the mean year of education was  $12.6 \pm 3.3$  years, and significant differences was found in age, pre-pregnancy BMI, height, and years of education among women with weekly rate of gestational weight gain in 2nd and 3rd trimester less than, within and greater than recommended rates ( $P < 0.05$ ). There were no significant difference among the three groups for the proportions of nulliparity, monochorionic membrane and infant sex. The gestational age and average birth weight of the infants were statistically significant between any two groups ( $P < 0.001$ ). Women who were excluded from this study due to missing information had similar baseline characteristics as that included (data not shown).

Table 1

Baseline characteristics of women with twin pregnancies according to the 2nd and 3rd trimester gestational weight gain rate.

	<b>All participants (N = 931)</b>	<b>Within recommendations (N = 506,54.4%)</b>	<b>Less than recommendations (N = 241,25.9%)</b>	<b>Greater than recommendations (N = 184,19.8%)</b>	<b>p</b>
Maternal age(years)	30.1 ± 4.3	30.3 ± 4.2	31.2 ± 4.4	28.3 ± 3.9	< 0.001 <sup>a</sup>
Prepregnancy BMI	21.1 ± 1.6	21.0 ± 1.6	21.5 ± 1.6	20.9 ± 1.6	< 0.001
Maternal height(cm)	160.4 ± 5.1	160.3 ± 5.0	159.6 ± 4.8	161.8 ± 5.3	< 0.001
Education degree(years)	12.6 ± 3.3	12.6 ± 3.2	12.9 ± 3.6	12.1 ± 3.0	0.028
Prepregnancy weight(kg)	54.4 ± 5.3	54.0 ± 5.3	54.8 ± 5.4	54.7 ± 5.3	0.104
Gravidity(N,%)					0.489
1	403(43.3)	208(41.1)	109(45.2)	86(46.7)	
2	253(27.2)	148(29.2)	58(24.1)	47(25.5)	
≥ 3	275(29.5)	150(16.1)	74(30.7)	51(27.7)	
Nulliparity(N,%)	588(63.2)	307(60.7)	152(63.1)	129(70.1)	0.076
Monochorionic membrane(N,%)	236(25.3)	129(25.5)	51(21.2)	56(30.4)	0.093
Infant sex(N,%)					0.598
Both boys	363(39.0)	197(38.9)	102(42.3)	64(34.8)	
Both girls	305(32.8)	169(33.4)	73(30.3)	63(34.2)	
Boy + girl	263(28.2)	140(27.7)	66(27.4)	57(31.0)	
Gestational age at delivery (week)	36.2 ± 2.0	36.4 ± 1.7	35.5 ± 2.6	36.4 ± 1.6	< 0.001
Average birth weight(g)	2506.5 ± 451.8	2533.2 ± 404.0	2385.8 ± 553.6	2591.1 ± 396.0	< 0.001 <sup>a</sup>
<sup>a</sup> P value is statistically significant between any two groups.					

## Perinatal outcomes according to IOM classification of GWG in the second trimester

According to the IOM, 22.7% and 24.0% of pregnant women gained weight at rates less than and greater than the recommendations in the 2nd trimester, respectively. After controlling for potential confounders in multivariable logistic regression models, greater than recommended 2nd trimester estimated rates of weight gain decreased the risks of preeclampsia (adjusted OR:0.458,95% CI:0.255 ~ 0.824). However, after adjusting for maternal age, gestational age, infant sex, pre-pregnancy BMI, nulliparity, and education level, we did not find evidence of interaction between less than recommended 2nd trimester estimated rates of weight gain was associated with maternal and neonatal outcomes (shown in figure.2)

## **Perinatal outcomes according to IOM classification of GWG in the third trimester**

Compared in the 3rd trimester, 33.2% of the pregnant women gained weight at rates less than the recommendations. After controlling for potential confounders in multivariable logistic regression models, they had a higher odds of gestational diabetes mellitus(adjusted OR:2.052,95%CI:1.417 ~ 2.972) than pregnant women who gained weight at rates within the recommendations. They also had higher odds of intrahepatic cholestasis syndrome(adjusted OR:3.016,95%CI:1.057 ~ 8.606) and premature rupture of membranes (adjusted OR:1.722,95%CI:1.180 ~ 2.512) ,while decreased the risks of caesarean section (adjusted OR:0.587,95%CI:0.385 ~ 0.893)and preeclampsia(adjusted OR:0.491,95%CI:0.288 ~ 0.837).When analyzed neonates outcomes, we found increases odds in preterm delivery (adjusted OR:1.926,95%CI:1.403 ~ 2.644) ,and average twin birth weight < 2500 g(adjusted OR:1.513,95%CI:1.105 ~ 2.070) as well as neonatal respiratory distress syndrome(adjusted OR:5.135,95%CI:1.701 ~ 15.498).

As for 28.9% of pregnant women who gained weight at rates greater than the recommendations, the adjusted odds of gestational hypertension (adjusted OR = 2.098,95%CI:1.018 ~ 4.324) ,preterm delivery (adjusted OR:1.818,95%CI:1.307 ~ 2.527) and preeclampsia(adjusted OR:2.029,95%CI:1.331 ~ 3.093) was significantly different and higher compared to those who gained weight at rates within the recommendations. Other perinatal outcomes did not differ in women who gained weight at rates greater than the guidelines in 3rd compared to those who gained within (shown in figure.2).

## **The impact of second trimester rate on third trimester**

To further compare whether the 2nd trimester weight gain rate affected the 3rd trimester weight gain rate and its impact on perinatal outcomes, we stratified 309 pregnant women gained weight at rates less than the recommendations in 3rd trimester (referred to as "T3L"), of which 53 pregnant women gained weight at rates greater than the recommendations (referred to as "T2H"),156 pregnant women gained weight at rates within recommendations (referred to as "T2N"), and 100 pregnant women gained weight at rates less than the recommendations (referred to as "T2L") in the 2nd trimester, respectively. The results showed no statistically significant difference in the incidence of perinatal outcomes between the three groups ( $P > 0.05$ ). Similarly, of 269 pregnant women gained weight at rates greater than the recommendations in 3rd trimester (referred to as "T3H"), the incidence of pregnancy outcomes was computed based on the classification of weight gain rates in the 2nd trimester, but no statistically insignificant difference was found between the three groups (all  $P$ -value  $> 0.05$ ) (Table 2).

Table 2

Incidence rate of adverse outcomes stratified by weekly weight gain greater than and within or less than IOM recommendations in 2nd trimester of less than or greater than the IOM recommendations in 3rd trimester.

Adverse outcomes of maternal and infants	T3L				T3H			
	T2N (N = 156)	T2L (N = 100)	T2H (N = 53)	P1	T2N (N = 141)	T2L (N = 34)	T2H (N = 94)	P2
Gestational hypertension	2(1.3)	4(4.0)	2(3.8)	0.343	13(9.2)	1(2.9)	5(5.3)	0.286
Gestational diabetes mellitus	49(31.4)	36(36.0)	14(26.4)	0.468	19(13.5)	8(23.5)	8(8.5)	0.081
Pre-eclampsia	12(7.7)	3(3.0)	7(13.2)	0.060	36(25.5)	9(26.5)	18(19.1)	0.476
Premature delivery	78(50.0)	47(47.0)	30(56.6)	0.527	66(46.8)	17(50.0)	48(51.1)	0.804
Premature rapture of membrane	39(25.0)	25(25.0)	17(32.1)	0.567	23(16.3)	6(17.6)	18(19.1)	0.854
Intrahepatic cholestasis of pregnancy	8(5.1)	2(2.0)	3(5.7)	0.404	2(1.4)	0(0.0)	1(1.1)	0.646
Caesarean section	122(78.2)	82(82.0)	44(83.0)	0.650	123(87.20)	29(85.3)	86(91.5)	0.489
Postpartum hemorrhage	13(8.3)	3(3.0)	2(3.8)	0.161	14(9.9)	1(2.9)	3(3.2)	0.071
Average birth weight < 2500 g	74(47.4)	49(49.0)	29(54.7)	0.657	61(43.3)	13(38.2)	35(37.2)	0.627
SGA of at least one twin	60(38.5)	49(49.0)	17(32.1)	0.090	61(43.3)	14(41.2)	30(31.9)	0.209
Delivery weight discordance ≥ 20%	18(11.50)	14(14.0)	8(15.1)	0.745	22(15.6)	3(8.8)	9(9.6)	0.299

IOM:institute of medicine;T3L:gained weight at rates less than the recommendations in 3rd trimester;T3H:gained weight at rates greater than the recommendations in 3rd trimester;T2N:gained weight at rates within the recommendations in 2nd trimester;T2L:gained weight at rates less than the recommendations in 2nd trimester;T2H:gained weight at rates greater than the recommendations in 2nd trimester;SGA:small for gestation;NA: The low incidence of neonatal respiratory distress syndrome prohibited their exploration with chi-square test .

Adverse outcomes of maternal and infants	T3L				T3H			
	T2N	T2L	T2H	<i>P1</i>	T2N	T2L	T2H	<i>P2</i>
	(N = 156)	(N = 100)	(N = 53)		(N = 141)	(N = 34)	(N = 94)	
Neonatal respiratory distress syndrome	8(5.1)	3(3.0)	6(11.3)	0.095	0(0.0)	0(0.0)	2(2.1)	NA
IOM:institute of medicine;T3L:gained weight at rates less than the recommendations in 3rd trimester;T3H:gained weight at rates greater than the recommendations in 3rd trimester;T2N:gained weight at rates within the recommendations in 2nd trimester;T2L:gained weight at rates less than the recommendations in 2nd trimester;T2H:gained weight at rates greater than the recommendations in 2nd trimester;SGA:small for gestation;NA: The low incidence of neonatal respiratory distress syndrome prohibited their exploration with chi-square test .								

## Discussion

It has been reported that the incidence of twin pregnancies has been increasing worldwide by year with the changing of people's concept of fertility and the development and popularization of assisted reproductive technology. The fact that twin pregnancies face more complex physiological processes than singleton pregnancies<sup>[10]</sup>, coupled with the importance of the impact of gestational weight gain on perinatal outcomes, makes it important to examine the recommendations of the IOM guidelines on pregnancy outcomes. Previous studies have mainly focused on the effect of total gestational weight gain on pregnancy outcome, in which gestational age may be a major confounding factor. One study found that total gestational weight gain was positively correlated with pregnancy length in all BMI groups<sup>[11]</sup>. That is, women with shorter gestational ages have fewer chances to gain weight and may suffer adverse pregnancy outcomes such as preterm birth, which may lead false correlations between gestational weight gain and pregnancy outcomes<sup>[12]</sup>. To this end, we introduced weight gain rates as study variables to evaluate the associations between gestational weight gain rate in 2nd and 3rd trimester and perinatal outcomes among Chinese twin gestations. The 2009 IOM recommended an appropriate weight gain rate for singleton pregnancy in 2nd and 3rd trimester of pregnancy, but there was no clear recommendation for twin pregnancies, so our study were of some value for the recommendation of weight gain rates for twin pregnancies in 2nd and 3rd trimester of pregnancy.

In this retrospective study, the findings showed that maternal and neonatal outcomes were affected by the rate of 2nd and 3rd trimester weight gain. We found that a weight gain rate greater than the recommendations in 2nd trimester decreased the risk of preeclampsia, while the weight gain rate in 3rd trimester directly affected the incidence of adverse pregnancy outcomes. On one hand, weight gain rate in 3rd trimester less than the recommendations was associated with significant increases in gestational diabetes mellitus, intrahepatic cholestasis syndrome, premature rupture of membranes ,average twin birth weight < 2500 g, neonatal respiratory distress syndrome and lower the rate of caesarean section; On the other hand, weight gain rate in 3rd trimester greater than the recommendations was associated with higher rate of gestational hypertension and preterm delivery and preeclampsia. Previous studies have demonstrated that inadequate weight gain during pregnancy was a risk factor for preterm birth, and our results suggested that a low or high weight gain

rate in 3rd trimester was related to an increased risk of preterm birth. The results of the study by Carnero A M and Shamshirsaz AA et al<sup>[13, 14]</sup> also showed that both very low and very high weight gain rate were associated with an increase incidence of preterm delivery<sup>[13]</sup>. This may also be one of the reasons why many international studies are now questioning the current IOM guidelines for twin pregnancies. It was noteworthy that in our study we found that a low weight gain rate in 3rd trimester associated with an increased incidence of gestational diabetes mellitus, which may be contrary to clinical findings. The conflicting results, which could be due to the medical nutritional therapy guidance and intervention by obstetricians based on their experience in managing nutrition clinics for pregnant women who were gaining too much weight or who have been diagnosed with gestational diabetes mellitus. These pregnant women adhered to strict diet and increase exercise, ultimately resulting in a low weight gain rate in 3rd trimester or even below the guideline recommended range. Conversely, women who didn't diagnosed with gestational diabetes mellitus may be less likely to follow a diet or exercise, which could lead to more weight gain. This result was similar to the findings of domestic and foreign academics<sup>[15, 16]</sup>. In addition, it has been reported<sup>[17]</sup> that excessive weight gain in first trimester was relative to an increased risk of gestational diabetes mellitus, regardless of pre-pregnancy weight. We did not make a consideration of weight gain in first trimester, thus it may lead to an inconsistency between our findings and those of some studies<sup>[18]</sup>. This also suggested that we should not neglect weight management in first trimester of pregnancy.

In this study, we found higher incidence of neonatal respiratory distress syndrome, average twin birth weight < 2500 g and intrahepatic cholestasis syndrome in pregnant women whose weight gain rate in 3rd trimester were less than the recommendations. We considered that neonatal respiratory distress syndrome may have a secondary association with preterm birth, while intrahepatic cholestasis syndrome may also be a secondary association with other comorbidities or complications that warrant further study and analysis in the future.

For gestational hypertensive disorders, our findings showed that gaining weight rate greater than the recommendations associated with lower odds of preeclampsia in 2nd trimester, while a higher odds in 3rd trimester of gestational hypertension and preeclampsia. LUKE B's research showed no difference in weight gain rate in the first half pregnancy between pregnant women diagnosed with preeclampsia and no-preeclampsia in secondary half pregnancy<sup>[19]</sup>. The reason why it was inconsistent with our results, we thought, might be limited by our sample size and the limitations of a single-center study. Domestic and foreign academics have also not reached consensus on the relationship between weight gain in twin pregnancies and hypertensive disorders of pregnancy as the confusion whether weight gain was the cause of or the result of preeclampsia. It may be that pregnancy comorbidities may affect gestational weight gain<sup>[11, 20, 21]</sup>, for example, gestational diabetes and preeclampsia affect total weight gain during pregnancy<sup>[22, 23]</sup>. Maternal weight gain in the second half of pregnancy was mainly associated with the increase in fetal weight, placental factors and the increase in maternal body weight, and was most closely related to the growth and development of the fetus, especially in the 2nd trimester<sup>[24]</sup>. In this study, the weight gain in the 2nd trimester has little effect on perinatal outcomes. It may be due to the more complex physiological changes in twin pregnancy, which cannot be explained reasonably at present, and further exploration is needed to clarify the mechanism of physiological changes in twin pregnancy.

There were some limitations in this study. Firstly, it was a retrospective study and it was impossible to consider all potential confounding variables, such as the use of assisted reproductive technology, the race/ethnicity of pregnant women, tobacco use, etc., which may lead to confounding bias. And the study data were drawn from data on women with twin pregnancies receiving perinatal care at one hospital, possibly leading to poor representation of the general population. Secondly, the limited sample size led to limitations in analyzing for underweight, overweight, and obese women and the small sample size might result in statistically significant differences in demographic characteristics. Additionally, as the weight gain in twin pregnancies was not linear<sup>[25]</sup>, we were unable to eliminate the correlation between pregnancy length and total weight gain by calculating the weight gain rates<sup>[26]</sup>. Therefore, our computational approach may therefore introduce some bias, and thus our study may not be sufficient to check the association of certain outcomes.

Subsequent studies should actively explore prospective and multi-center researches. All pregnant women can receive similar prenatal care and monitoring, which reduces the possibility of sampling bias and contributing to the generalizability of the results, thus clarifying the trajectory of weight gain in twin pregnancies and thus making them more clinically useful.

In summary, we conclude that suboptimal and excessive rates of gestational weight gain were associated with adverse pregnancy outcomes in normal weight women, especially in the 3rd trimester. Our findings were useful for obstetricians to understand the key periods of maternal weight gain and provide clinical recommendations to anticipate perinatal outcomes of twin pregnancies. Further studies of prospective and multi-center researches are required to explore alternate ranges of gestational weight gain rate in twin pregnancies to lower adverse perinatal outcomes.

## Abbreviations

GWG  
Gestational Weight gain  
BMI  
body mass index  
IOM  
institute of medicine  
SD  
standard deviation  
ANOVA  
analysis of variances

## Declarations

### Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the ethics committee of the Fujian Provincial Maternity and Children Hospital and with the 1964

Helsinki declaration and its later amendments or comparable ethical standards. All of the data were obtained from patient records. Formal consent was not required.

### **Consent for publication**

Not applicable

### **Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### **Competing interests**

The authors declare that they have no competing interests.

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### **Authors' contributions**

LHL, YLW and JYY designed the study. YYL,XXH collected the data. YL,XYX were involved in data analysis;LHL and YLW prepared the manuscript; JL edit the manuscript; all authors read and approved the final manuscript.

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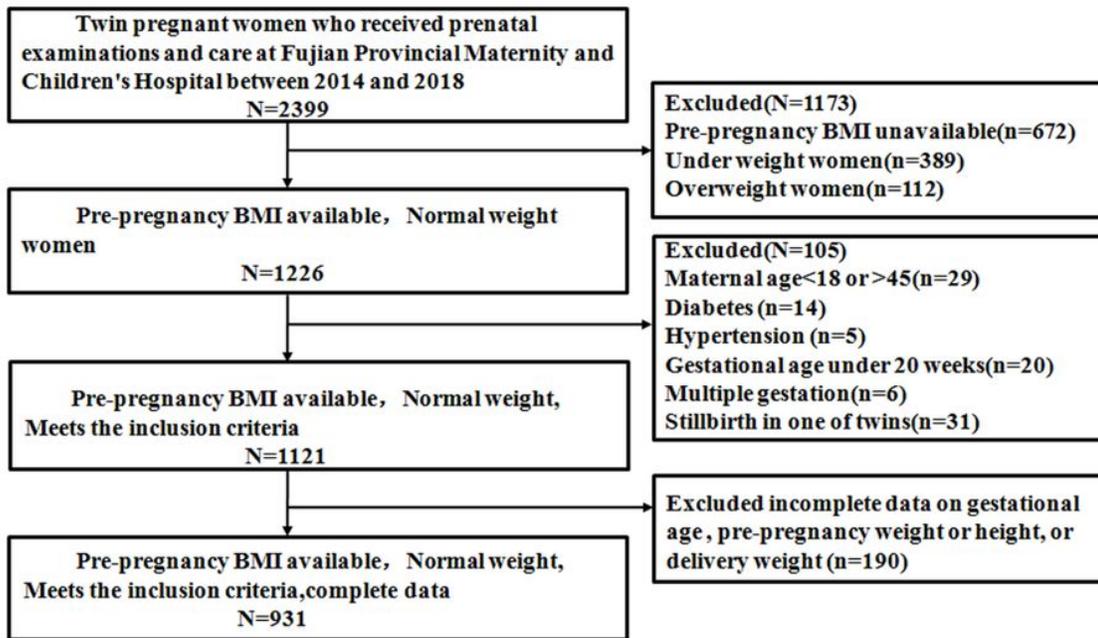
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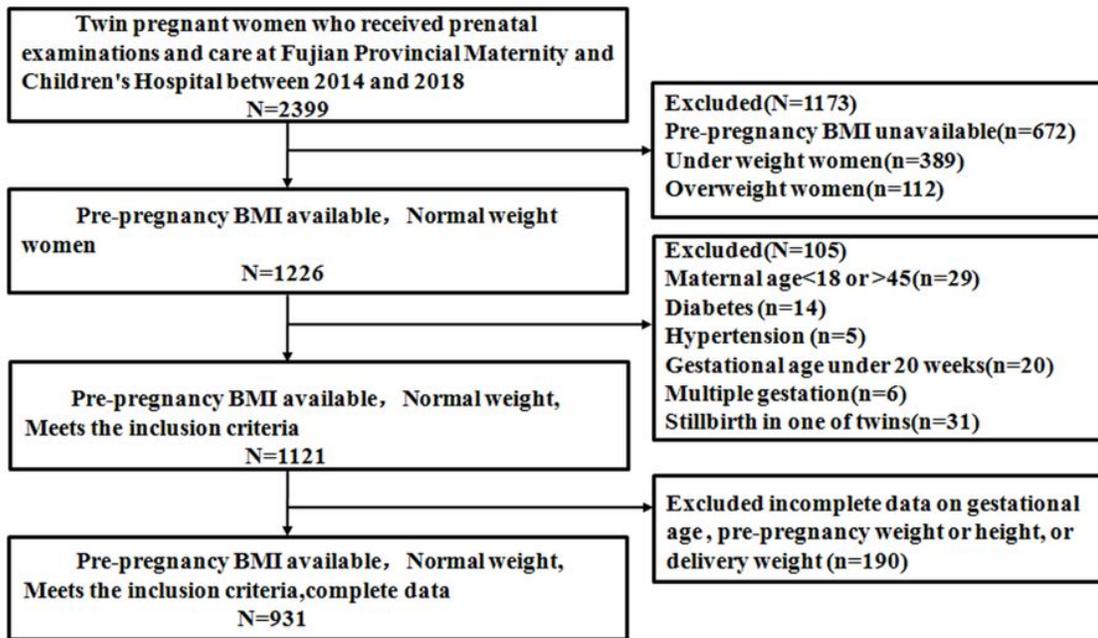
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## Figures



**Figure 1**

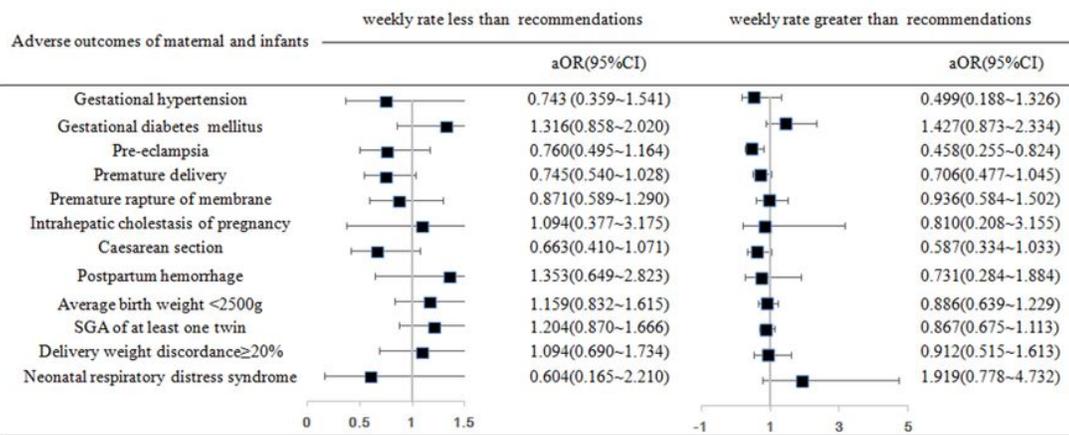
Flowchart of Subject selection.



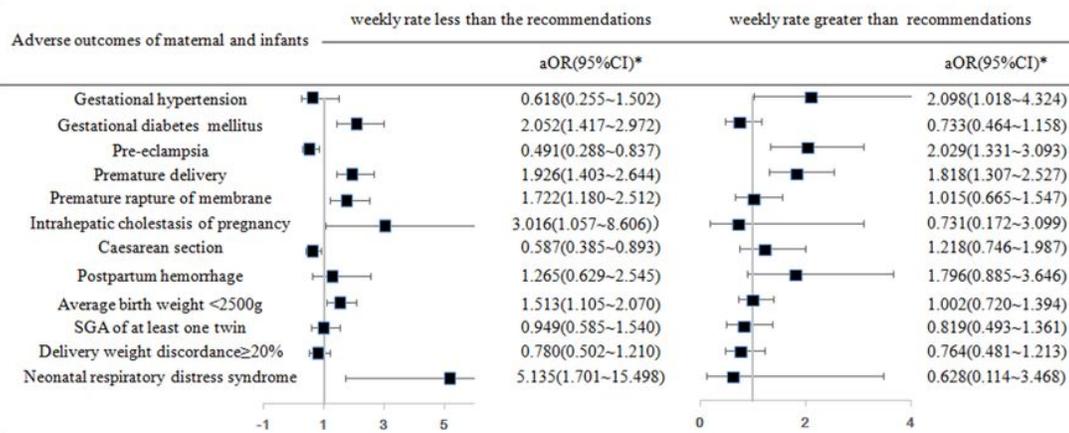
**Figure 1**

Flowchart of Subject selection.

**The second trimester**



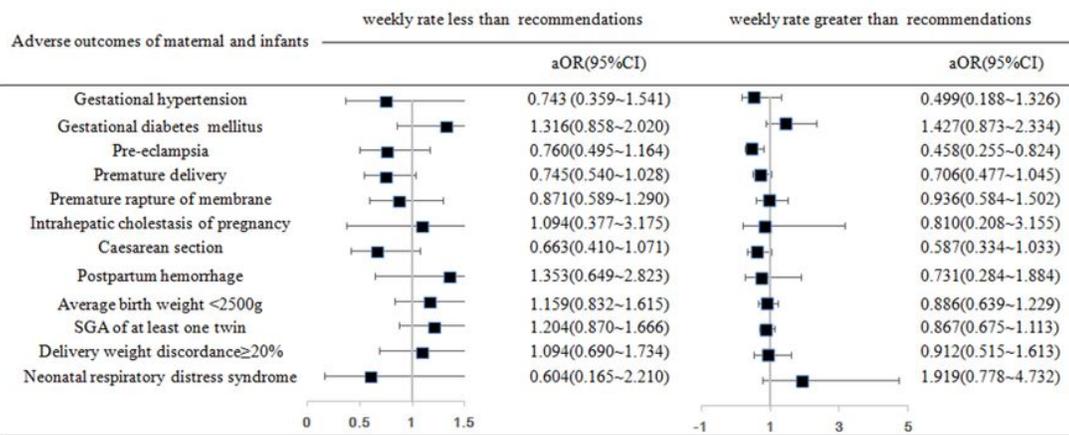
**The third trimester**



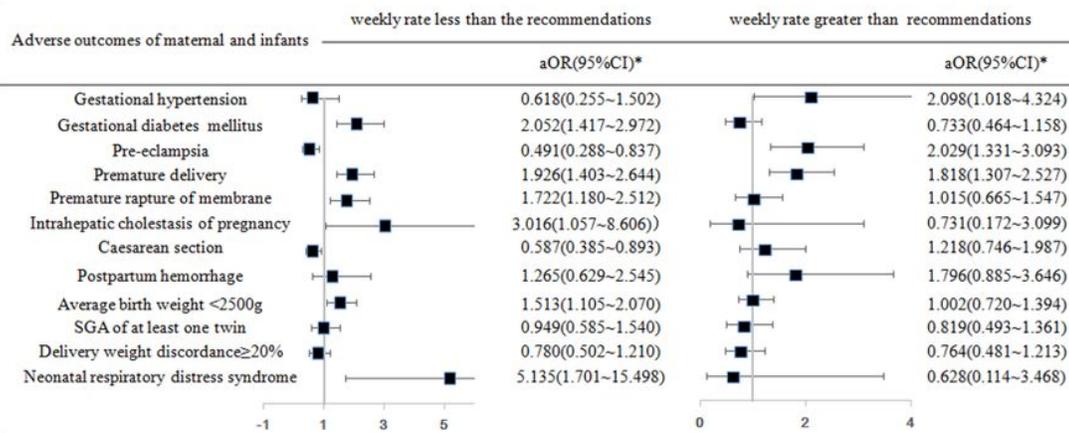
**Figure 2**

Forest plots of multivariable logistic analysis of associations between perinatal outcomes and the 2nd and 3rd trimester gestational weight gain rate. SGA: small for gestation; aOR: adjusted odds ratio; CI: confidence interval; \*adjusted for maternal age, gestational age, infant sex, pre-pregnancy BMI, nulliparity, and education level.

**The second trimester**



**The third trimester**



**Figure 2**

Forest plots of multivariable logistic analysis of associations between perinatal outcomes and the 2nd and 3rd trimester gestational weight gain rate. SGA: small for gestation; aOR: adjusted odds ratio; CI: confidence interval; \*adjusted for maternal age, gestational age, infant sex, pre-pregnancy BMI, nulliparity, and education level.