

Impact of Gestational Weight Gain on Perinatal Outcomes: Appropriateness of IOM Recommendations in Mainland China

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Research Article

Keywords: Gestational Weight Gain, Perinatal Outcomes

Posted Date: December 1st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-114855/v1>

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Abstract

Abstract The study was conducted to evaluate the clinical feasibility of Institute of Medicine (IOM) recommendations on gestational weight gain (GWG) in mainland China. 88,297 singleton pregnancies from a nationwide birth registry study were included. GWG per week was calculated and grouped into within, below and above IOM (IOM) guidelines based on first trimester Chinese body weight index (BMI) status. Univariable and multivariable analyses were performed to determine the relationship between GWG category and perinatal outcomes. We found that excessive GWG was associated with increased risk in pregnancy induced hypertensive disorders (aOR 2.41, 95%CI 2.16-2.69), cesarean section (aOR 1.55, 95%CI 1.47–1.63 for nulliparas, aOR 1.51, 95%CI 1.38–1.65 for multiparas with no prior cesarean section), severe postpartum hemorrhage (aOR 1.15, 95%CI 1.06-1.26), large for gestational neonates (aOR 1.76, 95%CI 1.69-1.85) and macrosomia (aOR 1.83, 95%CI 1.72-1.96), while inadequate GWG was correlated with higher risk in placenta abruption (aOR 1.54, 95%CI 1.29-1.85), fetal distress (aOR 1.19, 95%CI 1.12-1.26), and small for gestational neonates (aOR 1.50, 95%CI 1.41-1.60). Either GWG above or below was associated with increased risk in preterm birth (aOR 1.48, 95%CI 1.38-1.58 for above, aOR 1.47, 95%CI 1.31–1.64 for below), and neonatal asphyxia (aOR 2.28, 95%CI 2.00-2.61 for above, aOR 1.42, 95%CI 1.25-1.61 for below). GWG within IOM recommendations may help prevent various adverse perinatal outcomes and seemed suitable in Chinese population.

Introduction

Inappropriate GWG has remained to be a pronounced problem in both Western and Eastern countries.^{1,2,3} Insufficient weight gain has been linked with increased risk of poor fetal growth,^{1,4} preterm birth,^{1,5,6} and difficulty in establishing breastfeeding.^{7,8,9} While excessive GWG has been associated with a range of conditions, including gestational diabetes,^{10,11} pregnancy-induced hypertension,^{1,12,13,14} cesarean birth,^{1,15,16} and macrosomia.^{1,5,6,10} In 1970, the Institute of Medicine (IOM) reviewed the evidence concerning GWG that achieved optimal pregnancy outcomes, with revised versions published in 1990 and 2009.^{17,18} The latest version examined the trade offs between maternal and neonatal outcomes and GWG. In consideration that GWG has found to be differed by maternal pre-pregnancy weight status,^{19,20} the recommendations on GWG was based on WHO weight status criteria.^{21,22} In Jan 2018, the national prenatal care guideline for Chinese women was officially published,²³ it accepted the IOM recommendations for Chinese with little sample sized evidence and ignored the difference between Westerners and Chinese in BMI characteristics.²⁴ Chinese ethics possess a higher rate of body fat compared with Caucasian at the same BMI,^{25,26} therefore BMI cutoffs of ≥ 24 for overweight and ≥ 28 for obesity for Chinese population have been chosen based on the epidemiology evidence.²⁷ Under different weight status classification system, some Chinese women would be classified as lower weight status and assigned to larger GWG targets. The appropriateness of recommending the IOM GWG guidelines for Chinese should be evaluated by large population evidence. We aim to assess the suitability of generalizing the IOM recommendations using localized BMI category criteria through evaluating the association between IOM GWG category and perinatal outcomes.

Methods

Subjects

Our study was performed in compliance with the Declaration of Helsinki (as revised in 2013). The retrospective birth registry study protocol was approved by the Ethics Committee of Peking Union Medical College Hospital (reference number PUMCH-JS-1151) under a waiver of informed consent from individual patients. Data were abstracted from the nationwide multicenter birth registry study carried out in 14 representative medical centers (including 2 secondary and 12 tertiary, 7 general hospitals, and 7 maternal and child health care centers) from 10 provinces in the four major economic regions of China from October 1, 2016 to September 30, 2017. Specially assigned clinicians at each hospital were responsible for collecting and reporting information of pregnant women who delivered after 20 weeks of gestation. Complete medical information for each birth, including maternal demographics, medical and obstetrical history, maternal and perinatal outcome information were retrospectively registered into a prospectively designed network-based standardized data acquisition system depending on digital and written form of medical records. The data acquisition system was prospectively designed with clear and detailed field definition by information center of National Research for Family Planning Institute. The accuracy and validity of data entered were reviewed and verified by a second researcher on a monthly basis. Data entered into the data collection system were ultimately exported from the central network-based database system.

Only ethnically Chinese women over 18 years old with a singleton pregnancy who gave birth at 24 or more completed weeks of gestation were included. Women were eligible if they had a height, weight at delivery and either self-reported or recorded first trimester weight (11-14 gestational weeks), the later was mostly extracted from first trimester aneuploidy screening reports. Those with extreme values were excluded from analysis (maternal age at delivery older than 60 years old, height outside a range of 120–200 cm, first trimester weight lower than 25kg, GWG outside of a range of -25–50 kg). In this study, we have used first trimester BMI instead of pre-pregnancy BMI, in consideration that there has no reliable source of pre-pregnancy weight since most women came to obstetric units only after they became pregnant. BMI (kg/m^2) was calculated as the ratio of the weight (kg) at first trimester divided by height squared (m^2). GWG was calculated by weight before delivery minus weight recorded at first-trimester. In order to account for gestational age at delivery, we use average GWG per week for the second and the third trimester instead of total GWG. The WHO weight status criteria, the corresponding Chinese version and the associated IOM recommended GWG per week for the second and third trimester are listed in table1.

Table 1. IOM GWG recommendations for the second and the third trimester by pre-pregnancy weight status

Weight status	WHO BMI category criteria(kg/m ²) ^{21,22}	Chinese BMI category criteria(kg/m ²) ²⁷	IOM-recommended weight gain per week(kg/week) ¹⁸
Underweight	≤18.5	≤18.5	0.44-0.58
Normal weight	18.5-24.9	≥18.5 and ≤24	0.35-0.50
Overweight	25.0-29.9	≥24 and ≤28	0.23-0.33
Obese	≥30	≥28	0.17-0.27

Perinatal outcomes

Maternal outcomes included, pregnancy induced hypertensive disorders (PIH), including gestational hypertension, preeclampsia, HELLP (hemolysis elevated liver enzymes and low platelets syndrome), or eclampsia, premature rupture of membrane before onset of labor (PROM), cesarean section, severe postpartum hemorrhage (PPH, defined as estimated blood loss ≥1000 mL within 24 hours after delivery, or requires a blood transfusion, interventional or operational therapy for hemorrhage), placenta abruption, and operational vaginal birth. Occurrences of gestational diabetes mellitus (GDM, diagnosed using the oral glucose tolerance test at 24-28 weeks of pregnancy in accordance with 2013 WHO criteria²⁸) were reported, but not evaluated as outcomes due to the nutritional counseling and dietary adjustments that occur after such a diagnosis and the consequent effect on GWG. Neonatal outcomes included, preterm birth (PTB), large for gestational age and small for gestational age (LGA and SGA) defined as birthweight above or below the 90th and 10th centiles of our local population standard chart after adjusting for gender and gestation,²⁹ macrosomia (birth weight greater than 4000 g), fetal distress was defined as either meconium stained amniotic fluid or persistent abnormal fetal heart rate, and newborn asphyxia defined as a postnatal Apgar score lower than 7 at five minute after birth. Preterm birth was considered for medically-indicated PTB and spontaneous PTB (sPTB), the later was further subdivided by whether premature rupture of membrane has occurred, namely, preterm premature rupture of membranes (PPROM) and sPTB without PROM.

Statistical analyses

Maternal demographics and characteristics were assessed and compared between individuals in different GWG categories using the Kruskal-Wallis test for continuous variables and the chi-square test for categorical variables. A multivariate logistic regression of the GWG categories and other variables was performed to estimate the adjusted odds ratio (OR) with 95% CI intervals of the maternal adverse outcomes and neonatal adverse outcomes whereby “within” IOM recommendation was reference. Multinomial logistics for analysis for the risk of each subgroup of preterm birth. Covariates included maternal age, conception method, parity, previous cesarean section, gestational diabetes, pre-gestational diabetes and chronic hypertension. Two-

sided test alpha=0.05. Missing values processed censoring. All data analyses were performed using R version 4.0.2 (2020-06-22).

Results

A total of 99,960 women having delivery at or more than 20 completed weeks of gestation were identified in the national birth registry database, those non ethnically Chinese, with missing data or implausible data concerning GWG or twin pregnancy were excluded. A total of 88,297 singleton pregnancies were therefore available for final analysis, only 0.2% of them presented in labor without prenatal care. Figure 1 summarizes the Flow chart for selection of eligible subjects.

Of the available 88,97 cases for analysis, 51,428 (58.2%) were nulliparas. The median of maternal age at delivery was 30 years (IQR: 28–34). 71.7% (n = 63,351) of the women were normal weight in first trimester, less than half (44.1%) of the total population gained within the IOM guidelines, 36.5% and 19.4% gained below and above the guidelines, respectively. Between the three GWG categories, there were differences in maternal age, parity, baseline BMI, conception method, prior cesarean birth, chronic hypertension and pre-gestational diabetes, ($p \leq 0.001$ for all comparisons). (maternal demographic and characteristics information are listed in Table 2)

Table 2. Maternal demographic and characteristics

Characteristics	GWG				p-value
	All	Below	Within	Above	
n	88,297	32,210(36.5)	38,935(44.1)	17,152(19.4)	
Maternal age(years)	30.00(28, 34)	30(27,34)	30(28,34)	30(28,34)	<0.001
≥16 and <20	349 (0.4)	157(0.5)	139(0.4)	53(0.3)	
20≥ and <25	5,459 (6.2)	2,131(6.6)	2,338(6.0)	990(5.8)	
25≥ and <30	33,709 (38.2)	12,289(38.2)	15,063(38.7)	6,357(37.1)	
30≥ and <35	30,540 (34.6)	11,308(35.1)	13,349(34.3)	5,883(34.3)	
35≥ and <40	15,087 (17.1)	5,253(16.3)	6,642(17.1)	3,192(18.6)	
≥40	3,153 (3.6)	1,072(3.3)	1,404(3.6)	6,77(3.9)	
Prenatal examination	88,077 (99.8)	32,131(99.8)	38,835(99.7)	17,111(99.8)	0.913
Height,cm	160.0(158.0, 165.0)	160.0(158.0, 164.0)	160.0(158.0, 165.0)	162.0(160.0, 165.0)	<0.001
First trimester weight,kg	53.0(49.0, 59.0)	51.0(46.5, 56.0)	53.0 (49.5, 58.0)	59.6(52.0, 65.0)	<0.001
First trimester BMI (kg/m²)	20.50 (18.9, 22.5)	19.80(18.1,21.7)	20.40(19.1,22.1)	22.40 (19.9,24.9)	<0.001
BMI<18.5	17,459 (19.8)	10,648(33.1)	5,449(14.0)	1,362(7.9)	
18.5≤BMI<24	63351 (71.7)	20537(63.8)	31244(80.2)	11570(67.5)	
24≤BMI<28	5580 (6.3)	762(2.4)	1735(4.5)	3083(18.0)	
BMI≥28	1907 (2.2)	263(0.8)	507(1.3)	1137(6.6)	
Total GWG, kg	15.00 (12.00, 18.00)]	12.00(10.0,13.0)	16.00(15.0,18.0)	20.00(18.0,24.0)	<0.001
GWG per week, kg/week	0.38 (0.31, 0.46)	0.30(0.25,0.33)	0.41(0.37,0.46)	0.53(0.46,0.61)	<0.001
In vitro fertilization	1,780 (2.0)	691(2.1)	704(1.8)	385(2.2)	<0.001
Nulliparas	51,428 (58.2)	19,355(60.1)	22,308(57.3)	9,765(56.9)	<0.001
GA at delivery, d	272.8 (13.0)	272.5(13.5)	273.7(11.9)	271.3(14.4)	<0.001
Pre-existing diabetes	385 (0.4)	181(0.6)	114(0.3)	90(0.5)	<0.001
Chronic hypertension	372 (0.4)	99(0.3)	125(0.3)	148(0.9)	<0.001

Cesarean section history	16511 (18.7)	5548(17.2)	7289(18.7)	3674(21.4)	<0.001
Gestational diabetes	11,196 (12.7)	4,232(13.1)	4,514(11.6)	2,450(14.3)	<0.001
Cesarean section	38,181 (43.2)	12,297(38.2)	16,757(43.0)	9,127(53.2)	<0.001
Repeat Cesarean section	15,780 (95.6%)	5,212 (93.9)	7,013(96.2)	3,555(96.8)	<0.001

Abbreviations: GA gestational age

Data are presented as either number and percentage (%) for categorical variables, median and inter-quartile range for continuous non normal variables, mean and standard deviation (SD) for continuous normal variables.

Effects of GWG on maternal outcomes

For maternal outcomes, compared to GWG within recommendation, GWG above was associated with higher risk in cesarean birth, both in nulliparas (45.0% vs 34.3%, aOR 1.55, 95%CI 1.47–1.63) and multiparas with no prior cesarean section (31.7% vs 22.4%, aOR 1.51, 95%CI 1.38–1.65), PIH (9.0% vs 3.7%, aOR 2.41, 95%CI 2.16-2.69) and severe postpartum hemorrhage (4.8% vs 4.1%, aOR 1.15, 95%CI 1.06-1.26). While inadequate GWG was linked with higher risk in PROM (16% vs 14%, aOR 1.15, 95%CI 1.11-1.20), and placenta abruption (0.86% vs 0.56%, aOR 1.54, 95%CI 1.29-1.85) (listed in Table 3 ,Figure 2a and Figure3a)

Table 3. Maternal Outcomes According to the IOM GWG Categories

Outcomes	GWG						
	Below			Within	Above		
	N (%)	Unadjusted OR,p-value	Adjusted OR,p-value	N (%)	N (%)	Unadjusted OR,p-value	Adjusted OR,p-value
Intensive levels of anxiety*	784 (2.4%)	0.65(0.59,0.71) p<0.001	0.63(0.57,0.68) p<0.001	1,445 (3.7%)	1,544 (9.0%)	2.57(2.38,2.76) p<0.001	2.44(2.26,2.64) p<0.001
DM†	4,232(13.14%)	1.15(1.10,1.21)p<0.001	1.16(1.11,1.22) p<0.001	4,514(11.6%)	2,450(14.3%)	1.27(1.20,1.34) p<0.001	1.24(1.17,1.31) p<0.001
DM*	5,159(16.0%)	1.17(1.12, 1.22) p<0.001	1.15(1.11,1.20) p<0.001	5,456(14.0%)	2,226(13.0%)	0.92(0.87,0.96) p=0.001	0.92(0.87,0.97) p=0.001
Area under curve††	5,679 (29.3%)	0.80(0.76,0.83) p<0.001	0.76(0.73,0.80) p<0.001	7,649 (34.3%)	4,395 (45.0%)	1.57(1.49,1.65) p<0.001	1.55(1.47,1.63) p<0.001
Area under curve for diabetes but CS free††	1,406 (19.2%)	0.82(0.76,0.89) p<0.001	0.82(0.76,0.89) p<0.001	7,243(22.4%)	2,536 (31.7%)	1.61(1.47,1.75) p<0.001	1.51(1.38,1.65) p<0.001
Area under curve on external test*	3,099 (9.6%)	1.11(1.06,1.17) p<0.001	1.08(1.02,1.14) p<0.001	3,398 (8.7%)	2,031 (11.8%)	1.40(1.32,1.49) p<0.001	1.37(1.29,1.45) p<0.001
Myocardial infarction§	1,276 (4.0%)	0.96(0.89,1.04) p=0.32	0.96(0.89,1.04) p=0.32	1,600 (4.1%)	817 (4.8%)	1.17(1.07,1.27) p<0.001	1.15(1.06,1.26) p=0.002
Death prior to CS	259(4.7%)	1.10(0.92,1.30) p=0.29	1.12(0.94,1.32) p=0.21	312(4.3%)	194(5.3%)	1.25(1.04,1.50) p=0.019	1.27(1.05,1.52) p=0.012
Death prior CS	1,017(3.8%)	0.94(0.86,1.02) p=0.12	0.92(0.85,1.01) p=0.070	1,288(4.1%)	623(4.6%)	1.14(1.04,1.26) p=0.008	1.12(1.01,1.24) p=0.025
Stroke	277(0.86%)	1.55(1.30,1.85) p<0.001	1.54(1.30, 1.85) p<0.001	217(0.56%)	121(0.71%)	1.27 (1.01, 1.61) p<0.001	1.21(0.96, 1.54) p<0.001

ption*	<0.001		p<0.001			1.58) 1.51) p=0.098	
						p=0.037	
ational	725(3.6%)	1.09(0.98, 1.21) p= 0.10	1.03(0.93, 1.14) p=0.59	743(3.4%)	219(2.7%)	0.81(0.69,	0.79(0.68,
final						0.94) p=0.007	0.92) p=0.004
th§							

Abbreviations: OR, odds ratio; CI, Confidence interval; GDM, gestational diabetes; PROM, premature rupture of membrane; CS, Cesarean section

*The analysis was adjusted for maternal age, conception method, parity, chronic hypertension, pre-gestational diabetes, and gestational diabetes.

†The analysis was adjusted for maternal age, conception method, parity, chronic hypertension, previous cesarean section history and pre-gestational diabetes.

‡The analysis was adjusted for maternal age, conception method, chronic hypertension, pre-gestational diabetes, and gestational diabetes.

§The analysis was adjusted for maternal age, conception method, parity, chronic hypertension, prior cesarean section, pre-gestational diabetes.

The bolded values indicate statistical significance.

Effects of GWG on neonatal outcomes

For the neonatal outcomes, GWG outside the IOM guidelines was associated with overall PTB (10.0% for above, aOR 1.48, 95%CI 1.38-1.58, 8.1% for below, aOR 1.22, 95% CI 1.15-1.29), both in indicated (3.6% for above, aOR 2.04, 95%CI 1.82-2.29, 2.1% for below, aOR 1.27, 95%CI 1.14-1.42) and spontaneous PTB (6.4% for above, aOR 1.25, 95%CI 1.16-1.35, 6.0% for below, aOR 1.19, 95%CI 1.11-1.27) compared with GWG within the IOM guidelines (6.7% for overall, 1.7% for medically-indicated PTB and 5.0% for spontaneous PTB), it was also associated with newborn asphyxia (2.81% for above, aOR 2.28, 95%CI 2.00-2.61, 1.73% for below, aOR 1.42, 95%CI 1.25-1.61, 1.22% for within). GWG above the guidelines was associated with large for gestational age neonates (36.6% for above, 16.9% for within, aOR 1.76, 95%CI 1.69-1.85) and macrosomia (11.0% for above, 6.3% for within, aOR 1.83, 95%CI 1.72-1.96). While GWG below the guidelines was associated with fetal distress (8.5% for below, 7.1% for within, aOR 1.19, 95%CI 1.12-1.26) and small for gestational neonates (8.5% for below, 5.8% for within, aOR 1.50, 95%CI 1.41-1.60). (listed in Table 4, Figure 2b and Figure 3b)

Table 4. Neonatal Outcomes According to the IOM GWG Categories

Outcomes	GWG						
	Below			Within	Above		
	N (%)	Unadjusted OR, p-value	Adjusted OR, p-value	N (%)	N (%)	Unadjusted OR, p-value	Adjusted OR, p-value
Preterm birth	2,601(8.1%)	1.22(1.15,1.28) p<0.001	1.22(1.15,1.29) p<0.001	2,626(6.7%)	1,712(10.0%)	1.53(1.44,1.63) p<0.001	1.48(1.38,1.58) p<0.001
0-28W	90(0.28%)	3.15(2.13,4.66) p<0.001	3.28(2.19,4.90) p<0.001	35(0.09%)	36(0.21%)	2.42(1.52,3.85) p<0.001	2.41(1.50,3.87) p<0.001
28-32W	447(1.4%)	1.52(1.32,1.75) p<0.001	1.54(1.34,1.78) p<0.001	361(0.93%)	336(2.0%)	2.19(1.88,2.54) p<0.001	2.07(1.78,2.42) p<0.001
32-34W	339(1.0%)	1.15(0.99,1.34) p=0.063	1.15(0.99,1.34) p=0.070	361(0.93%)	285(1.7%)	1.86(1.59,2.17) p<0.001	1.78(1.52,2.09) p<0.001
34-37W	1,725(5.4%)	1.13(1.06,1.21) p<0.001	1.13(1.06,1.21) p<0.001	1,869(4.8%)	1,055(6.2%)	1.33(1.23,1.44) p<0.001	1.28(1.19,1.39) p<0.001
Indicated preterm birth	670(2.1%)	1.24(1.11,1.38) p<0.001	1.27(1.14,1.42) p<0.001	658(1.7%)	616(3.6%)	2.17(1.94,2.42) p<0.001	2.04(1.82,2.29) p<0.001
Spontaneous preterm birth	1,931(6.0%)	1.20(1.12,1.28) p<0.001	1.19(1.11,1.27) p<0.001	1,968(5.0%)	1,096(6.4%)	1.28(1.19,1.38) p<0.001	1.25(1.16,1.35) p<0.001
a.with PROM	711(2.2%)	1.39(1.24,1.54) p<0.001	1.35(1.21,1.50) p<0.001	624(1.6%)	377(2.2%)	1.38(1.21,1.57) p<0.001	1.35(1.18,1.53) p<0.001
b.without PROM	1,220(3.8%)	1.10(1.02,1.19) p=0.017	1.10(1.02,1.20) p=0.016	1,344(3.4%)	719(4.2%)	1.22(1.11,1.34) p<0.001	1.19(1.09,1.31) p<0.001
LGA	3,461(11.2%)	0.62(0.59,0.65) p<0.001	0.61(0.59,0.64) p<0.001	6,249(16.9%)	4,322(36.6%)	1.78(1.71,1.87) p<0.001	1.76(1.69,1.85) p<0.001
Macrosomia	1066(3.5%)	0.54(0.50,0.58) p<0.001	0.53(0.49,0.57) p<0.001	2316(6.3%)	1782(11.0%)	1.85(1.73,1.97) p<0.001	1.83(1.72,1.96) p<0.001
SGA	2,619(8.5%)	1.52(1.43,1.61) p<0.001	1.50(1.41,1.60) p<0.001	2,128(5.8%)	748(4.6%)	0.79(0.73,0.86) p<0.001	0.78(0.72,0.86) p<0.001

	p<0.001				p<0.001		
Fetal distress	2,739(8.5%)	1.22(1.16, 1.29) p<0.001	1.19 (1.12, 1.26) p<0.001	2,749(7.1%)	995(5.8%)	0.81 (0.75, 0.87) p<0.001	0.80 (0.74, 0.86) p<0.001
Newborn asphyxia	530(1.73%)	1.42(1.25,1.61) p<0.001	1.42(1.25,1.61) p<0.001	451(1.22%)	454(2.81%)	2.33(2.04,2.66) p<0.001	2.28(2.00,2.61) p<0.001

Abbreviations: OR, odds ratio; CI, Confidence interval; PROM, Premature rupture of membrane; LGA, large for gestational age; SGA, small for gestational age.

The analysis was adjusted for maternal age, parity, conception method, chronic hypertension, prior cesarean section, pre-gestational diabetes, and gestational diabetes.

The bolded values indicate statistical significance.

Discussion

In this analysis of 88,297 singleton pregnancies, we found associations between not achieving gestational weight gain goals recommended by IOM and several adverse maternal and neonatal outcomes including cesarean birth, PROM, PIH, postpartum hemorrhage, PTB, LGA, SGA, macrosomia, fetal distress and newborn asphyxia.

Our findings corresponds to other studies including a recent meta analysis of GWG and pregnancy outcomes that included 1,309,136 women.¹ Specifically, the study showed that insufficient GWG was related to SGA (OR 1.53, 95%CI 1.44-1.64) and preterm birth (OR 1.70, 95%CI 1.32-2.20), whereas excessive GWG was associated with LGA (OR 1.85, 95%CI 1.76-1.95), macrosomia (OR 1.95, 95%CI 1.79-2.11), and cesarean birth (OR 1.30, 95%CI 1.25-1.35). A similar study from the US including 29,861 pregnancies also evaluated the relationship between excessive GWG and PIH (aOR 1.84, 95%CI 1.66-2.04), the prevalence of GDM in the total population was 6.2%.¹⁶ However, we found in our study that the impact of excessive GWG on the risk of PIH in Chinese seems to be larger than in the Westerners (aOR 2.44, 95%CI 2.26-2.64), and the prevalence of GDM was 12.7%. Although it is not possible to perform statistical comparison based on these figures. As it is well known that body fat percentage in Chinese is higher than that in Caucasian at the same GWG category, the metabolic mechanism leading to PIH and GDM may manifest that a lower cutoff at 24 kg/m² for defining overweight and 28 kg/m² for defining obese in Chinese would be more applicable for risk assessment.

In addition to common perinatal outcomes associated with poor GWG control and well described in previous studies, we also explored the possible relationship with premature rupture of membrane (PROM) and placenta abruption. In particular, inadequate GWG was associated with higher risk in PROM (aOR 1.15, 95%CI 1.11-1.20) and placenta abruption (aOR 1.54, 95%CI 1.29-1.85), indicating that nutritional factors or underlying social economic factors may play a role in the pathogenesis of these conditions.³⁰ Considerably fewer

studies have evaluated the specific correlation between GWG and preterm birth subgroup (medically-indicated PTB, PPRM and sPTB without PROM) and gestational week distribution.^{31,32,33} In our study, we found that excessive GWG had greater influence on total PTB than insufficient GWG (aOR 1.48, 95%CI 1.38-1.58 vs aOR 1.22, 95%CI 1.15-1.29), with highest odds ratio in medically-indicated PTB subgroup (aOR 2.04, 95%CI 1.82-2.29), while insufficient GWG had highest odds ratio in PPRM subgroup (aOR 1.35, 95%CI 1.21-1.50), and among gestational weeks between 24 and 28 (aOR 3.28, 95%CI 2.19-4.90). Such findings is different from similar population based studies from developed countries but supports study from middle income countries.^{1,5,34}

Studies testifying IOM recommendations among Chinese have reached inconclusive results,^{23,35,36} Single site study including 4,736 term pregnancies using the WHO BMI cut-off points, concluded that IOM GWG recommendations are appropriate for Chinese women.²³ While study carried out in Hong Kong including 754 pregnancies with complete anthropometry data,³⁵ found that the IOM recommended weight gain ranges are narrower than observed. However, larger cohort study encompassing 13,717 pregnancies with optimal outcomes conducted in a Middle-South city of China revealed that the IOM recommended GWG ranges are still within the middle 70% of Chinese GWG distributions.³⁶ In a recently published follow-up study including 34,288 pregnancies,³⁷ the author managed to develop GWG charts of Chinese women based on the same BMI classification system in our study, and found that the IOM recommended ranges fell within the 25th and 75th percentiles for underweight and normal weight women but fell below the 50th percentile for overweight and obese women. Neither aforementioned studies included data relating to postpartum outcomes. Elevating the upper limit of the GWG ranges may lead to long-term adverse outcomes, including postpartum weight retention childhood obesity, and adolescent cardiometabolic risk.^{38,39,40,41} Nonetheless, a meta-analysis of Westerners from 25 pooled cohort studies including 196,670 participants revealed that GWG ranges associated with the lowest risks for any adverse outcome were roughly comparable with the IOM ranges for underweight, normal weight, and overweight, and were lower for all obesity grades.⁴²

A cohort study, the INTERGROWTH-21st Project,⁴³ reported that the weight gain pattern in normal weight women who came from eight geographically diverse urban areas, including China, was strikingly similar, indicates that separate GWG charts for women from different racial groups are not necessary. The researchers speculating that the racial differences reported are more likely caused by social economical or lifestyle factors than true biological differences in nutrient absorption among uncomplicated women.^{44,45,46} Until now, the IOM recommendations was well-accepted in China, Our data showed that GWG within IOM recommendations may help prevent various adverse perinatal outcomes. Given the risks of a GWG outside of the IOM recommendations, as documented in this population based study whereby only 44.1% of women achieved a optimal GWG targets. Appropriate management of GWG, by way of lifestyle instructions in diet, exercise and other health behaviours,⁴⁷ will assists in promoting maternal and neonatal health.

This study has several limitations. First, the analyses did not account for potential confounding factors, such as medical insurance type or hospital type. Second, first trimester pregnancy BMI, instead of pre-pregnancy BMI, was used to classify women. This introduces the possibility of mis-classification bias. We did not assume that women gained a standard weight during first trimester which ignored individual difference.

However, it is not feasible to measure the pre-pregnancy weight in clinical practise and self-reported pre-pregnancy weight is generally unreliable. Noted strengths included prospectively designed and well defined net-work based data acquisition system with detailed information on perinatal outcomes. The sample size was the largest concerning Chinese ethics before submission and spanned the four main economic zones of China and is representative. With rigorous ascertainment of outcomes and calculation of GWG to account for the duration of pregnancy. The results presented as incidence rates and adjusted odds ratio is readily for clinical counseling.

Conclusion

Inadequate and excessive GWG both remained to be a big issue in Chinese pregnant population, IOM guidelines is applicable in predicting adverse outcomes and maintaining appropriate GWG is essential in preventing adverse maternal and neonatal outcomes.

Declarations

Acknowledgements

We thank the following hospitals, including Beijing Haidian maternal and child health hospital, Sichuan University West China Second Hospital, Southern Medical University Nanfang Hospital, Northwest women and children's hospital, Ruijin maternal and child health hospital, Hunan maternal and child health care hospital, and Shengjing Hospital affiliated to China Medical University, where the register work was conducted for this program.

Details of ethics approval

Our study was performed in compliance with the Declaration of Helsinki (as revised in 2013). The retrospective birth registry study protocol was approved by the Ethics Committee of Peking Union Medical College Hospital (reference number PUMCH-JS-1151) under a waiver of informed consent from individual patients.

Contributions

JS Gao conceived the study design which was advised by JT Liu; XT Wang, J He, JX Sun, XW Liu and SX Liao helped to collect data and supervise the collection process; Hu J wrote statistical program and Liu S analyzed the data; Dong J was responsible for designing the network based system with manuscripts contrived by JS Gao and JT Liu; Hu J edited the draft and had primary responsibility for the final content. Gao JS and Liu JT critically reviewed the draft and provided important intellectual content to the interpretation of the results. All the authors read and approved the final manuscript.

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Funding information

This study was supported by the 13th Five-Year National Science and Technology Support Program (number [no.] 2015BAI13B04) and CAMS Innovation Fund for Medical Science (no. 2017-I2M-3-007).

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Figures

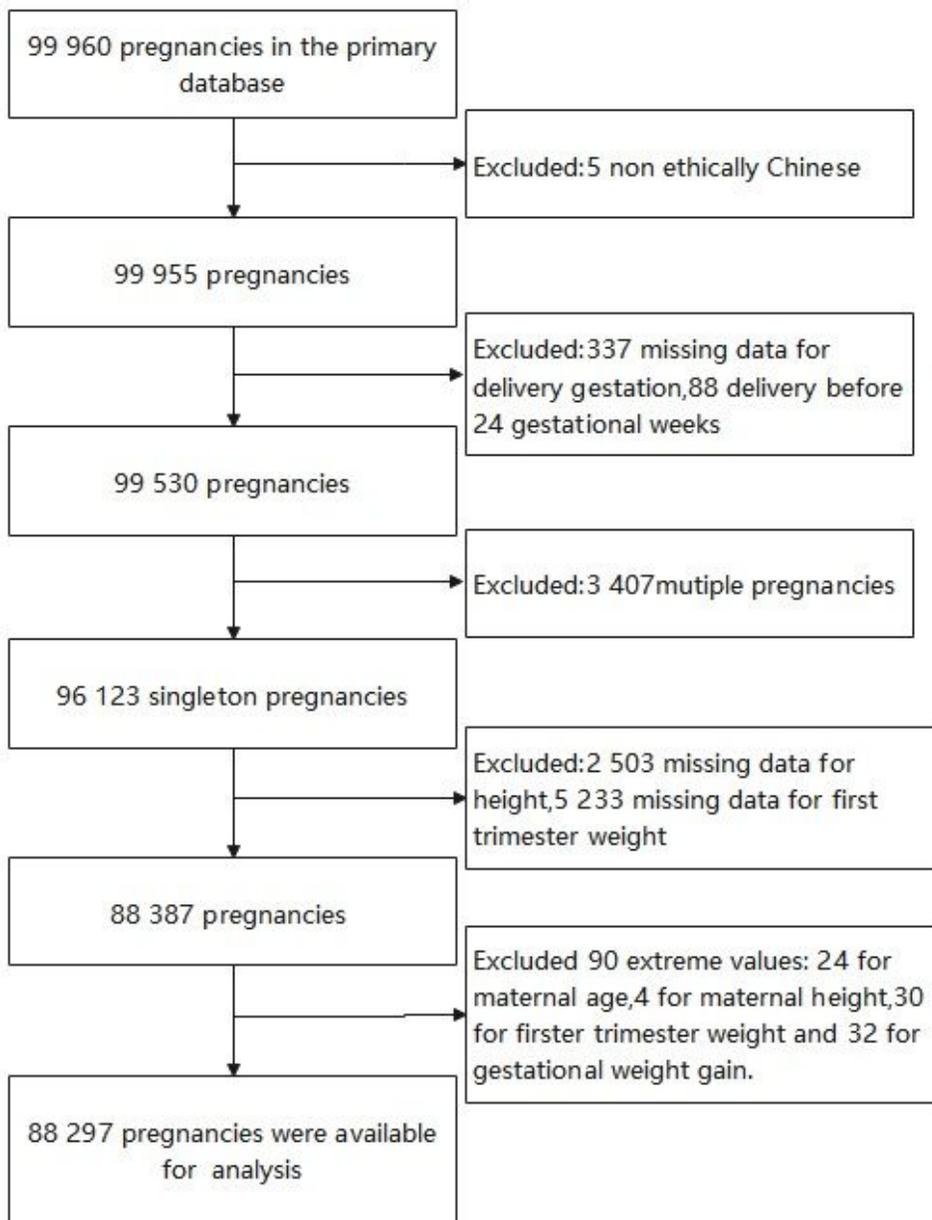
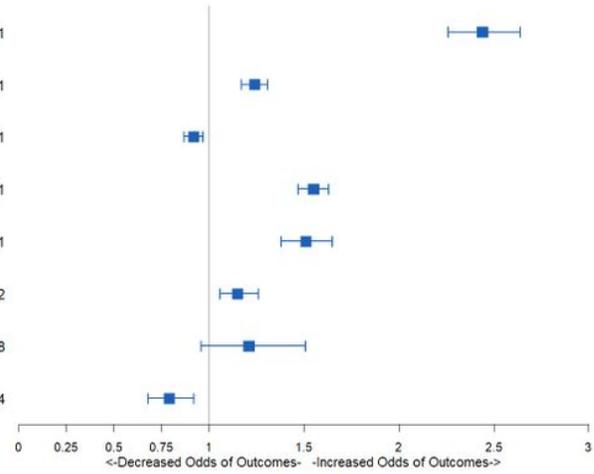


Figure 1

Flow chart for data selection process

pregnancy induced hypertensive disorders	1544(9.00%)	2.57(2.38,2.76) p<0.001	2.44(2.26,2.64) p<0.001
Gestational Diabetes	2450(14.28%)	1.27(1.20,1.34) p<0.001	1.24(1.17,1.31) p<0.001
Premature rupture of membrane	2226(12.98%)	0.92(0.87,0.96) p=0.001	0.92(0.87,0.97) p=0.001
Cesarean section for nulliparas	4395(45.01%)	1.57(1.49,1.65) p<0.001	1.55(1.47,1.63) p<0.001
Cesarean section for multiparas without CS history	2536(31.70%)	1.61(1.47,1.75) p<0.001	1.51(1.38,1.65) p<0.001
Postpartum hemorrhage	817(4.76%)	1.17(1.07,1.27) p<0.001	1.15(1.06,1.26) p=0.002
Placenta abruption	121(0.71%)	1.27(1.01,1.58) p=0.037	1.21(0.96,1.51) p=0.098
Operational vaginal birth	219(2.73%)	0.81(0.69,0.94) p=0.007	0.79(0.68,0.92) p=0.004



Preterm birth	1712(9.98%)	1.53(1.44,1.63) p<0.001	1.48(1.38,1.58) p<0.001
Indicated preterm birth	616(3.59%)	2.17(1.94,2.42) p<0.001	2.04(1.82,2.29) p<0.001
Spontaneous preterm birth	1096(6.39%)	1.28(1.19,1.38) p<0.001	1.25(1.16,1.35) p<0.001
a.with PROM	377(2.20%)	1.38(1.21,1.57) p<0.001	1.35(1.18,1.53) p<0.001
b.without PROM	719(4.19%)	1.22(1.11,1.34) p<0.001	1.19(1.09,1.31) p<0.001
LGA	4322(36.65%)	1.78(1.71,1.87) p<0.001	1.76(1.69,1.85) p<0.001
SGA	748(4.61%)	0.79(0.73,0.86) p<0.001	0.78(0.72,0.86) p<0.001
Macrosomia(birth weight ≥4000g)	1782(10.99%)	1.85(1.73,1.97) p<0.001	1.83(1.72,1.96) p<0.001
fetal distress	995(5.8%)	0.81(0.75,0.87) p<0.001	0.80(0.74,0.86) p<0.001
neonatal asphyxia	454(2.81%)	2.33(2.04,2.66) p<0.001	2.28(2.00,2.61) p<0.001

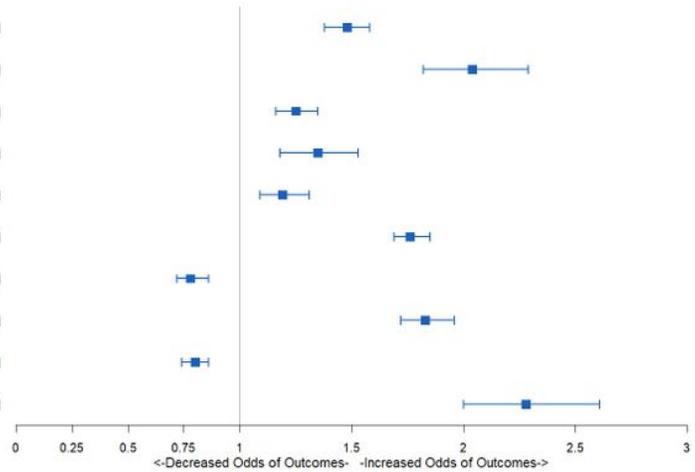


Figure 2

a. Forest plot for adjusted OR of GWG above recommendations and maternal outcomes. Abbreviations: CS, cesarean section. Reference group: GWG within recommendations. b. Forest plot for adjusted OR of GWG above recommendations and neonatal outcomes. Abbreviations: PROM, premature rupture of fetal membrane; LGA, large for gestational age; SGA, small for gestational age. Reference group: GWG within recommendations.

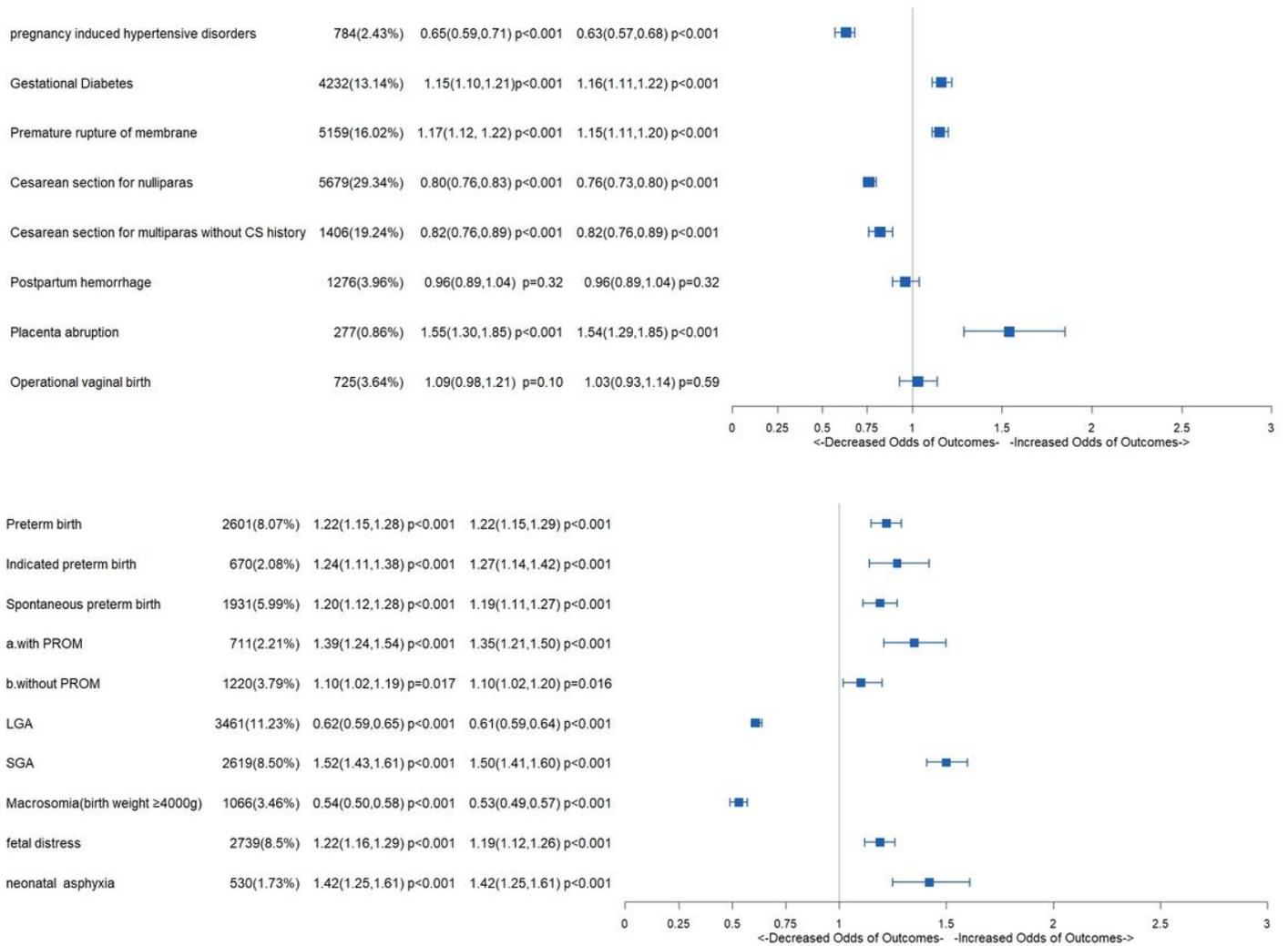


Figure 3

a. Forest plot for adjusted OR of GWG below recommendations and maternal outcomes. Abbreviations: CS, cesarean section. Reference group: GWG within recommendations. b. Forest plot for adjusted OR of GWG below recommendations and neonatal. Abbreviations: PROM, premature rupture of fetal membrane; LGA, large for gestational age; SGA, small for gestational age Reference group: GWG within recommendations.