Clinical Research Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2019, Vol. 47(9) 4397–4412

DOI: 10.1177/0300060519861463
journals.sagepub.com/home/imr
SAGE

Effect of maternal weight gain according to the Institute of Medicine recommendations on pregnancy outcomes in a Chinese population

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Abstract

Objective: This study aimed to analyze the effects of maternal weight on adverse pregnancy outcomes.

Methods: Data were retrospectively collected from a hospital in Wuhan, China. A total of 1593 pregnant women with singletons were included. Adverse outcomes during pregnancy, such as small for gestational age (SGA), large for gestational age (LGA), and hypertensive disorders in pregnancy (HDP) were analyzed.

Results: The risks of low birth weight, SGA, and preterm birth were significantly higher in the inadequate gestational weight gain (GWG) group compared with the adequate GWG group. GWG over the guidelines was related to a higher risk of macrosomia, LGA, cesarean section, and HDP than GWG within the guidelines. The risks of low birth weight (OR = 5.082), SGA (OR = 3.959), preterm birth (OR = 3.422), and gestational diabetes mellitus (OR = 1.784) were significantly higher in women with a normal pre-pregnancy body mass index (BMI) and inadequate GWG compared with women with a normal pre-pregnancy BMI and adequate GWG. The risks of macrosomia (OR = 3.654) and HDP (OR = 1.992) were increased in women with normal pre-pregnancy BMI and excessive GWG.

Conclusion: Women with an abnormal BMI and inappropriate GWG have an increased risk of adverse maternal and infant outcomes. Weight management during the perinatal period is required.

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Keywords

Pregnancy, complications, weight gain, birth weight, adverse outcome, body mass index, macrosomia, hypertensive disorder

Date received: 29 March 2019; accepted: 13 June 2019

Background

A peculiar phenomenon that two separate individuals (mother and fetus) have a mutually interactive dependency concerning their respective weight has been reported and intensively investigated.[1] Many researchers have concluded that appropriate pre-pregnancy body mass index (BMI) and weight gain during pregnancy are important for pregnant women and their offspring.[2–4] Increased pre-pregnancy maternal insulin resistance and accompanying hyperinsulinemia, inflammation, and oxidative stress appear to account for early placental and fetal dysfunction.[5] Unfortunately, accurate mechanisms of adverse perinatal outcomes affected by pre-pregnancy BMI and weight gain are unclear. Notably, the BMI is increasing in developed countries, as well as in some developing countries, and is increasingly becoming a worldwide health problem.[6,7] Some researchers have suggested that the incidence of overweight/obesity in pregnant women is as high as 30%. Approximately 40% of women gain excessive weight during pregnancy in Western countries.[8] However, gestational weight gain (GWG) is also increasing globally.[9,10] Maternal pre-pregnancy weight and GWG are major contributors to pregnancy and fetal health.[11] Excessive and insufficient maternal pre-pregnancy weight or GWG have a profound effect on pregnancy outcomes, such as macrosomia, cesarean delivery, gestational diabetes (GDM), small for gestational age (SGA), and large for gestational age (LGA).[12,13] Therefore, how to predict and effectively control the pre-pregnancy BMI and GWG have important clinical significance and social value, and they are the focus of maternal and child health work.

The Institute of Medicine (IOM) updated the GWG guidelines in 2009 to effectively manage maternal weight and weight gain.[9] Although the undated guidelines verified the relationships between perinatal outcomes and maternal weight, these results were based on a lower general population BMI with limited ethnic diversity.[14] Notably, Asian women often have a lower BMI and smaller GWG than do European and American women.[6,7,15] Chinese women may be the leanest population. However, the prevalence of overweight and obesity in China is quickly increasing with its opening-up policy for promoting cultural exchange and economic development.[15,16] An increasing amount of women are enjoying the Westernized diet and lifestyle.[16,17] The prevalence of obesity increased from 3.1% to 6.1% from 1992 to 2002 in China.[18] However, there is still no official recommendation of GWG for Chinese pregnant women, and recent data on maternal pre-pregnancy BMI and GWG are rare.[19] Therefore, in the present study, we collected current data of maternal weight to analyze the effects of maternal weight on the incidence of pregnancy outcomes in Wuhan, China.

Material and methods

Study population

In this study, we retrospectively analyzed medical records in the Department of

Table 1. Definitions of the pre-pregnancy BMI and GWG groups.

Groups	Pre-pregnancy BMI (kg/m^2)	GWG groups		
		Inadequate (kg)	Adequate (kg)	Excessive (kg)
Underweight	$<$18.5	$<$12.5	12.5–18.0	$>$18.0
Normal weight	18.5–23.9	$<$11.5	11.5–16.0	$>$16.0
Overweight	24.0–27.9	$<$7.0	7.0–11.5	$>$11.5
Obese	$\geq$28.0	$<$5.0	5.0–9.0	$>$9.0

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

Obstetrics, Maternal and Child Health Hospital of Hubei Province, Wuhan, China. Eligibility criteria included the following: singleton pregnancy, primipara, older than 18 years old, spontaneous conception, no pre-existing diabetes mellitus or HIV infection, and no illicit drug use. From 1 January 2016 to 31 March 2016, 1593 women met the eligibility criteria. The research protocol for this study was approved by the Medical Ethics Committee of the Maternal and Child Health Hospital of Hubei Province. We only retrospectively extracted data on the patients' weight and other basic information. We did not affect treatment decisions and the patients were not adversely affected. Therefore, we did not obtain written consent from each patient.

Data collection and evaluation

All useful information was retracted from the clinical records. Women included in this study were categorized by the recently developed Chinese BMI standard as follows: underweight (BMI $<$18.5 kg/m^2), normal weight (BMI $\geq$18.5 kg/m^2 and $<$24.0 kg/m^2), overweight (BMI $\geq$24 kg/m^2 and $<$28.0 kg/m^2), obese (BMI $\geq$28.0 kg/m^2). Maternal GWG was recorded as the weight gain from pre-pregnancy to the time just before delivery. Three categories of inadequate, adequate, and excessive GWG were defined according to the updated IOM guidelines.[20] Details of these categories are shown in Table 1. Because there were only 18 women with obesity, we integrated overweight and obese into one group (BMI $\geq$24.0 kg/m^2).

Assessment of outcome

The primary outcome of this study was to assess the factors that affect pre-pregnancy BMI and GWG, and their effects on maternal and neonatal outcomes. A prenatal examination was defined as when pregnant women visited the hospital regularly for a maternity examination. The pregnancy outcomes included low birth weight ([LBW] $<$2500 g), macrosomia ($\geq$4000 g), SGA, LGA, the characteristic of amniotic fluid, hypertensive disorders in pregnancy (HDP), preterm birth, GDM, and cesarean section. SGA and LGA were defined as those newborns whose birth weight was $<$10th percentile and $>$90th percentile for gestational age, respectively. SGA and LGA were determined by the Chinese criterion.[21]

Statistical analysis

Descriptive characteristics of variables are expressed as means and frequencies. Categorical variables were analyzed using the chi-square test. Logistic regression models were used to assess the risk of adverse pregnancy outcomes by calculating odds ratios (ORs) and 95% confidence intervals (CIs). Statistical analyses were carried out using SPSS software 19.0 (IBM, Armonk, NY, USA). Statistical significance was considered as $P < 0.05$ or if the 95% CI of OR did not include 1.

Results

Baseline characteristics of the study population

The sociodemographic characteristics of women who were included in this study are shown in Table 2. The mean pre-pregnancy BMI of 1593 pregnant women was $20.3 \pm 2.5\,kg/m^2$. There were 405 (25.4%) underweight women, 1054 (66.2%) normal weight women, and 134 (8.4%) women with overweight/obesity. The mean age of the women was 27.88 ± 3.41 years (range: 18–42 years), and the majority of pregnant women (74.6%) were aged between 25 and 34 years.

Differences in maternal age and gestational age among pre-pregnancy BMI groups were significant (all $P < 0.05$). The proportion of mothers who were older than 30 years in the overweight group was significantly higher than that in the other groups ($P < 0.001$). Women with a high education were more likely to have a normal pregnancy weight than those in the other groups ($P = 0.02$). Differences in birth weight and fetal growth among the pre-pregnancy BMI groups were significant (all $P < 0.05$). Additionally, the incidence of GDM among the pre-pregnancy BMI groups was significant, with the highest incidence in the overweight/obese group ($P < 0.001$). As expected, the rate of cesarean section among the pre-pregnancy BMI groups was significant, with the highest rate in the overweight/obese group ($P < 0.001$). Maternal pre-pregnancy BMI had no significant effects on prenatal examinations, preterm birth, HDP, and amniotic fluid.

The mean GWG was 17.2 ± 4.9 kg. Women with an advanced maternal age were more likely to gain inadequate weight ($P = 0.032$). Gestational age at delivery was significantly different among the GWG groups in which maternal GWG was significantly associated with a shorter gestational age ($P < 0.001$). The proportion of pregnant women with a low education in the inadequate GWG group was higher than that in those in the adequate and excessive GWG groups ($P < 0.01$). The incidence of preterm birth (<37 weeks) significantly decreased from the inadequate GWG group to the excessive GWG group ($P < 0.05$). Furthermore, differences in LBW, SGA, GDM, and HDP were significantly different among the groups (all $P < 0.05$).

Effects of pre-pregnancy BMI and GWG on pregnancy outcomes

Variables with significant differences among the pre-pregnancy BMI and GWG groups were included in further analysis. The relationships between abnormal pre-pregnancy BMI and adverse pregnancy outcomes are shown in Table 3. The risks of macrosomia (OR = 0.387, 95% CI: 0.209–0.720), LGA (OR = 0.511, 95% CI: 0.349–0.747), GDM (OR = 0.57, 95% CI: 0.363–0.895), and cesarean section (OR = 0.66, 95% CI: 0.523–0.831) were significantly lower in the underweight group compared with the normal weight group (all $P < 0.05$). The risks of GDM (OR = 2.229, 95% CI: 1.444–3.632) and cesarean section (OR = 1.617, 95% CI: 1.113–2.349) were significantly higher in the overweight/obese group compared with the normal weight group (both $P < 0.05$).

The risks of LBW (OR = 4.428, 95% CI: 2.410–8.134) and SGA (OR = 3.543, 95% CI: 1.986–6.320) were significantly higher in the inadequate GWG group compared

Table 2. Maternal and fetal characteristics by pre-pregnancy BMI and GWG categories.

Variables	Number (n = 1593)	Pre-pregnancy BMI categories (%) Underweight (n = 405, 25.4%)	Normal weight (n = 1054, 66.2%)	Overweight/obese (n = 134, 8.4%)	*P* value	GWG categories (%) Inadequate (n = 171, 10.7%)	adequate (n = 565, 35.5%)	Excessive (n = 857, 53.8%)	*P* value
Gestational age (weeks)	37.97 ± 1.28	38.0 ± 1.26	37.99 ± 1.27	37.68 ± 1.32	0.021	37.42 ± 1.50	37.98 ± 1.27	38.08 ± 1.20	<0.001
Age (years)	27.88 ± 3.41	26.83 ± 3.22	28.12 ± 3.38	29.17 ± 3.42	<0.001	27.78 ± 4.09	27.75 ± 3.28	27.98 ± 3.34	0.435
Age groups (years)									
≤25	348 (21.8)	141 (34.8)	194 (18.4)	13 (9.7)	<0.001	49 (28.7)	125 (22.1)	174 (20.3)	0.116
25–29	811 (50.9)	197 (48.6)	546 (51.8)	68 (50.7)		73 (42.6)	289 (51.2)	449 (52.4)	
≥30	434 (27.3)	67 (16.5)	314 (29.8)	53 (39.6)		49 (28.7)	151 (26.7)	234 (27.3)	
Advanced maternal age (≥35 years)									
No	1536 (96.4)	396 (97.8)	1016 (96.4)	124 (92.5%)	0.018	159 (93.0)	549 (97.2)	828 (96.6)	0.032
Yes	57 (3.6)	9 (2.2)	38 (3.6)	10 (7.5%)		12 (7.0)	16 (2.8)	29 (3.4)	
Education (years)[#]									
>13	1223 (76.8)	292 (72.1)	831 (78.8)	100 (74.6)	0.02	110 (64.3)	443 (78.4)	670 (78.2)	<0.001
≤12	370 (23.2)	113 (27.9)	223 (21.2)	34 (25.4)		61 (35.7)	122 (21.6)	187 (21.8)	
Prenatal examination									
No	770 (48.3)	187(46.2)	520 (49.3)	63 (47.0)	0.529	118 (69.0)	267 (47.3)	385 (44.7)	<0.001
Yes	823 (51.7)	218 (53.8)	534 (50.7)	71 (53.0)		53 (31.0)	298 (52.7)	472 (55.3)	
Preterm birth (gestational weeks)									
<37	60 (3.8)	16 (4.0)	37 (3.5)	7 (5.2)	0.602	19 (11.1)	22 (3.9)	18 (1.8)	<0.001
≥37	1533 (96.2)	389 (96.0)	1017 (96.5)	127 (94.8)		152 (88.9)	543 (96.1)	838 (98.2)	
Birth weight (g)									
<2500	70 (4.4)	23 (5.7)	40 (3.8)	7 (5.2)	0.018	25 (14.6)	22 (3.9)	23 (2.7)	<0.001
2500–4000	1426 (89.5)	370 (91.4)	937 (88.9)	119 (88.8)		141 (82.5)	528 (93.4)	757 (88.3)	
≥4000	97 (6.1)	12 (3.0)	77 (7.3)	8 (6.0)		5 (2.9)	15 (2.7)	77 (9.0)	
Fetal growth									
SGA	77 (4.8)	27 (6.7)	45 (4.3)	5 (3.7)	0.001	25 (14.6)	26 (4.6)	26 (3.0)	<0.001
AGA	1285 (80.7)	342 (84.4)	840 (79.7)	103 (76.9)		133 (77.8)	485 (85.8)	667 (77.9)	
LGA	231 (14.5)	36 (8.9)	169 (16.0)	26 (11.3)		13 (7.6)	54 (9.6)	164 (19.1)	

(continued)

Table 2. Continued.

Variables	Number (n = 1593)	Pre-pregnancy BMI categories (%) Underweight (n = 405, 25.4%)	Normal weight (n = 1054, 66.2%)	Overweight/obese (n = 134, 8.4%)	*P* value	GWG categories (%) Inadequate (n = 171, 10.7%)	adequate (n = 565, 35.5%)	Excessive (n = 857, 53.8%)	*P* value
GDM									
No	1431 (89.8)	380 (93.8)	945 (89.7)	106 (79.1)	<0.001	143 (83.6)	500 (88.5)	788 (92.0)	0.002
Yes	162 (10.2)	25 (6.2)	109 (10.3)	28 (20.9)		28 (16.4)	65 (11.5)	69 (8.0)	
Hypertensive disorders in pregnancy									
No	1517 (95.2)	391 (96.5)	999 (94.8)	127 (94.8)	0.356	164 (95.9)	550 (97.3)	803 (93.7)	0.006
Yes	76 (4.8)	14 (3.5)	55 (5.2)	7 (5.2)		7 (4.1)	15 (2.7)	54 (6.3)	
Characteristic of amniotic fluid									
Clear	1276 (80.1)	333 (82.2)	830 (78.7)	113 (84.3)	0.145	137 (80.0)	459 (81.2)	680 (79.3)	0.682
Abnormal	317 (19.9)	72 (17.8)	224 (21.3)	21 (15.7)		34 (20.0)	106 (18.8)	177 (20.7)	
Cesarean section									
No	782 (49.1)	234 (57.8)	500 (47.4)	48 (35.8)	<0.001	96 (56.1)	301 (53.3)	385 (44.9)	0.001
Yes	811 (50.9)	171 (42.2)	554 (52.6)	86 (64.2)		75 (43.9)	264 (46.7)	472 (55.1)	

Values are mean±standard deviation or number (%).
P values in bold indicate that the difference was significant.
[#]After 12 years of study, women graduated from high school in China.
BMI: body mass index; GWG: gestational weight gain; SGA: small for gestational age; AGA: average for gestational age; LGA: large for gestational age; GDM: gestational diabetes mellitus; HDP: hypertensive disorders in pregnancy.

Table 3. Effects of pre-pregnancy BMI and GWG on maternal and fetal outcomes (n = 1593).

	Pre-pregnancy BMI categories[#]				GWG categories*			
	Underweight		Overweight/obese		Inadequate		Excessive	
Outcomes	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
LBW	1.526 (0.902–2.583)	0.115	1.397 (0.613–3.185)	0.426	4.428 (2.410–8.134)	**<0.001**	0.681 (0.376–1.233)	0.205
Macrosomia	0.387 (0.209–0.720)	**0.003**	0.806 (0.380–1.708)	0.573	1.102 (0.395–3.078)	0.852	3.62 (2.060–6.361)	**<0.001**
SGA	0.624 (0.382–1.021)	0.06	1.151 (0.449–2.951)	0.07	3.543 (1.986–6.320)	**<0.001**	0.649 (0.373–1.129)	0.126
LGA	0.511 (0.349–0.747)	**0.001**	1.261 (0.797–1.994)	0.322	0.779 (0.414–1.464)	0.437	2.239 (1.613–3.109)	**<0.001**
Preterm birth	0.885 (0.486–1.608)	0.688	0.660 (0.288–1.512)	0.326	3.085 (1.627–5.849)	**0.001**	0.560 (0.300–1.044)	0.068
HDP	0.65 (0.358–1.183)	0.159	1.001 (0.446–2.246)	0.998	1.565 (0.627–3.903)	0.337	2.466 (1.377–4.414)	**0.002**
GDM	0.57 (0.363–0.895)	**0.015**	2.229 (1.444–3.632)	**<0.001**	1.506 (0.932–2.435)	0.095	0.674 (0.471–0.962)	**0.03**
Cesarean section	0.66 (0.523–0.831)	**<0.001**	1.617 (1.113–2.349)	**0.012**	0.891 (0.631–1.257)	0.51	1.398 (1.129–1.730)	**0.002**

[#]The normal weight group was the reference group.
*The adequate GWG group was the reference group.
P values in bold indicate that the difference was significant.
BMI: body mass index; GWG: gestational weight gain; OR: odds ratio; CI: confidence interval; LBW: low birth weight; SGA: small for gestational age; LGA: large for gestational age; GDM: gestational diabetes mellitus; HDP: hypertensive disorders in pregnancy.

Table 4. Gestational weight gain according to pre-pregnancy body mass index category.

Variable	Total (n = 1593), n (%)	Underweight (n = 405), n (%)	Normal (n = 1054), n (%)	Overweight/obese (n = 134), n (%)	*P* value
Inadequate	171 (10.7)	43 (10.6)	121 (11.5)	7 (5.2)	0.001
Adequate	565 (35.5)	191 (47.2)	353 (33.5)	21 (15.7)	<0.001
Excessive	857 (53.8)	171 (42.2)	580 (55.0)	106 (79.1)	<0.001

with the adequate GWG group (both $P < 0.05$). The risk of preterm birth was also significantly higher in the inadequate GWG group compared with the adequate GWG group (OR = 3.085, 95% CI: 1.627–5.849, $P = 0.001$). GWG over the guidelines was related to a higher risk of macrosomia (OR = 3.620, 95% CI: 2.060–6.361), LGA (OR = 2.239, 95% CI: 1.613–3.109), cesarean section (OR = 1.398, 95% CI: 1.129–1.730), and HDP (OR = 2.466, 95% CI: 1.377–4.414) than GWG within the guidelines (all $P < 0.05$). However, the risk of GDM (OR = 0.674, 95% CI: 0.471–0.962) was significantly lower in the excessive GWG group compared with the adequate GWG group ($P = 0.03$).

Distribution and heterogeneity of the study population (GWG according to pre-pregnancy BMI category)

In this study, more than 50% of women had excessive weight during the pregnancy period. The percentages of women with adequate GWG and inadequate GWG were 35.5% and 10.7%, respectively. The rate of women who gained optimal weight significantly varied by pre-pregnancy BMI, with the highest percentage in the underweight group and the lowest in the overweight/obese group ($P = 0.001$). Most women in the normal weight and overweight/obese groups had excessive GWG (Table 4).

The distribution of the study population is shown in Table 5. A synergistic reaction between pre-pregnancy BMI and GWG was observed. Women in the underweight group who had inadequate GWG showed the highest incidence of LBW, SGA, and preterm birth among the groups (all $P < 0.01$). The incidence of LBW, SGA, and preterm birth in the whole study population was 4.4%, 4.8%, and 3.8%, respectively. Women in the overweight group who gained excessive GWG showed the highest incidence of LGA and cesarean section among the groups. The incidence of LGA and cesarean section in the whole study population was 14.5% and 50.9%, respectively. However, even for women who had adequate GWG, the prevalence of adverse pregnancy outcomes was significantly different among the pre-pregnancy BMI groups, including LBW, macrosomia, LGA, SGA, GDM, and preterm birth (all $P < 0.001$). Therefore, the study population showed heterogeneity either by pre-pregnancy BMI or GWG categories. Additionally, an antagonistic effect was observed. The incidence of preterm birth was 11.1% in women with inadequate GWG in the underweight group, and was lower with adequate (4.7%) and excessive (1.2%) GWG in the underweight group. This trend was similar for macrosomia, LGA, SGA, and preterm birth. Therefore, weight gain during pregnancy can balance the risk of abnormal pre-pregnancy BMI.

Combined effects of pre-pregnancy BMI and GWG on adverse pregnancy outcomes

In underweight pregnant women, inadequate GWG was significantly associated

Table 5. Distribution of the study population.

Outcomes	Underweight (n = 405), n (%)				Normal weight (n = 1054), n (%)				Overweight (n = 134), n (%)			
	Inadequate (n = 43)	Adequate (n = 191)	Excessive (n = 171)	*P*	Inadequate (n = 121)	Adequate (n = 353)	Excessive (n = 580)	*P*	Inadequate (n = 7)	Adequate (n = 21)	Excessive (n = 106)	*P*
LBW												
No	35 (81.4)	180 (94.2)	167 (97.7)	<0.001	104 (86.0)	342 (96.9)	568 (97.9)	<0.001	7 (100)	21 (100)	99 (93.4)	0.377
Yes	8 (18.6)	11 (5.8)	4 (2.3)		17 (14.0)	11 (3.1)	12 (2.1)		0 (0)	0 (0)	7 (6.6)	
Macrosomia												
No	43 (100)	187 (97.9)	163 (100)	0.158	116 (95.9)	342 (96.9)	519 (89.5)	<0.001	7 (100)	21 (100)	98 (92.5)	0.325
Yes	0 (0)	4 (2.1)	0 (0)		5 (4.1)	11 (3.1)	61 (10.5)		0 (0)	0 (0)	8 (7.5)	
SGA												
No	34 (79.1)	179 (93.7)	165 (96.5)	0.001	105 (86.8)	340 (96.3)	564 (97.2)	<0.001	7 (100)	20 (95.2)	102 (96.2)	0.846
Yes	9 (20.9)	12 (6.3)	6 (3.5)		16 (13.2)	13 (3.7)	16 (2.8)		0 (0)	1 (4.8)	4 (3.8)	
LGA												
No	43 (100)	175 (91.6)	151 (88.3)	0.51	109 (90.1)	317 (89.8)	459 (79.1)	<0.001	6 (85.7)	19 (90.5)	83 (78.3)	0.41
Yes	0 (0)	16 (8.4)	20 (11.7)		12 (9.9)	36 (10.2)	121 (20.9)		1 (14.3)	2 (9.5)	23 (21.7)	
Preterm birth												
No	38 (88.3)	182 (95.3)	169 (98.8)	0.005	107 (88.4)	340 (96.3)	570 (98.3)	<0.001	7 (100)	21 (100)	99 (93.4)	0.377
Yes	5 (11.6)	9 (4.7)	2 (1.2)		14 (11.6)	13 (3.7)	10 (1.7)		0 (0)	0 (0)	7 (6.6)	
HDP												
No	41 (95.3)	188 (98.4)	162 (94.7)	0.143	116 (95.9)	341 (96.6)	542 (93.4)	0.094	7 (100)	21 (100)	99 (93.4)	0.377
Yes	2 (4.7)	3 (1.6)	39 (5.3)		5 (4.1)	12 (3.4)	38 (6.6)		0 (0)	0 (0)	7 (6.6)	
GDM												
No	41 (95.3)	179 (93.7)	160 (93.6)	0.907	97 (80.2)	310 (87.8)	538 (92.8)	<0.001	5 (71.4)	11 (52.4)	90 (84.9)	0.003
Yes	2 (4.7)	12 (6.3)	11 (6.4)		24 (19.8)	43 (12.2)	42 (7.2)		2 (28.6)	10 (47.6)	16 (15.1)	
Cesarean section												
No	28 (65.1)	114 (59.7)	92 (53.8)	0.31	64 (52.9)	176 (49.9)	260 (44.8)	0.145	4 (57.1)	11 (52.4)	33 (31.1)	0.086
Yes	15 (34.9)	77 (40.3)	79 (46.2)		57 (47.1)	177 (50.1)	320 (55.2)		3 (42.9)	10 (47.6)	73 (68.9)	
Prenatal examination												
No	25 (58.1)	95 (49.7)	67 (39.2)	0.033	87 (71.9)	163 (46.2)	270 (46.6)	<0.001	6 (85.7)	9 (42.9)	48 (45.3)	0.106
Yes	18 (41.9)	96 (50.3)	104 (60.8)		34 (28.1)	190 (53.8)	310 (53.4)		1 (14.3)	12 (57.1)	58 (54.7)	

(continued)

Table 5. Continued.

Outcomes	Underweight (n = 405), n (%)				Normal weight (n = 1054), n (%)				Overweight (n = 134), n (%)			
	Inadequate (n = 43)	Adequate (n = 191)	Excessive (n = 171)	*P*	Inadequate (n = 121)	Adequate (n = 353)	Excessive (n = 580)	*P*	Inadequate (n = 7)	Adequate (n = 21)	Excessive (n = 106)	*P*
Education (years)												
No	16 (37.2)	50 (26.2)	47 (27.5)	0.342	42 (34.7)	63 (17.8)	118 (20.3)	<0.001	3 (42.9)	9 (42.9)	22 (20.8)	0.057
Yes	27 (62.8)	141 (73.8)	124 (72.5)		79 (65.3)	290 (82.2)	462 (79.7)		4 (57.1)	12 (57.1)	84 (79.2)	
Advanced maternal age (≥35 years)												
<35	41 (95.3)	187 (97.9)	168 (98.2)	0.508	111 (91.7)	343 (97.2)	562 (96.9)	0.014	7 (100)	19 (90.5)	98 (92.5)	0.707
≥35	2 (4.7)	4 (2.1)	3 (1.8)		10 (8.3)	10 (2.8)	18 (3.1)		0 (0)	2 (9.5)	8 (7.5)	

P values in bold indicate that the difference was significant.
LBW: low birth weight; SGA: small for gestational age; LGA: large for gestational age; GDM: gestational diabetes mellitus; HDP: hypertensive disorders in pregnancy.

with LBW (OR = 3.740, 95% CI: 1.404–9.966), SGA (OR = 3.949, 95% CI: 1.544–10.096), and the characteristic of amniotic fluid (OR = 2.326, 95% CI: 1.089–4.966) (all $P < 0.05$), whereas excessive GWG had no significant association with adverse outcomes compared with optimal GWG (Table 6). These results are slightly different from those in Table 3, which showed that excessive GWG was significantly associated with adverse outcomes.

The risks of LBW (OR = 5.082, 95% CI: 2.308–11.193), SGA (OR = 3.985, 95% CI: 1.857–8.555), and GDM (OR = 1.784, 95% CI: 1.030–3.089) were significantly higher in women with normal weight and inadequate GWG compared with those with normal weight and adequate GWG (all $P < 0.05$). Furthermore, the risk of preterm birth (OR = 3.422, 95 CI%: 1.560–7.507) was significantly higher in women with normal weight and inadequate GWG compared with those with normal weight and adequate GWG ($P = 0.002$). The risks of macrosomia (OR = 3.654, 95% CI: 1.896–7.045), LGA (OR = 2.231, 95% CI: 1.558–3.458), and HDP (OR = 1.992, 95 CI%: 1.027–3.866) were significantly higher in women with normal weight and excessive GWG compared with women with normal weight and adequate GWG (all $P < 0.05$). However, the risk of GDM (OR = 0.563, 95% CI: 0.360–0.881) was significantly decreased with normal weight and excessive GWG ($P = 0.012$). Because some subgroups in the overweight/obese group had no adverse pregnancy outcomes, we were unable to evaluate the combined effects in overweight women. For overweight women, excessive GWG was significantly negatively associated with GDM (OR = 0.196; 95% CI: 0.071–0.536).

Discussion

The IOM recommendations regarding GWG were developed in 1990. To be

Table 6. ORs for the associations between GWG and adverse pregnancy outcomes in the normal weight and underweight groups.

	Underweight group (n = 405)				Normal weight group (n = 1054)			
	Inadequate		Excessive		Inadequate		Excessive	
Outcomes	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
LBW	3.740 (1.404–9.966)	**0.008**	0.392 (0.122–1.255)	0.392	5.082 (2.308–11.193)	**<0.001**	0.657 (0.287–1.505)	0.32
Macrosomia	Unavailable		2.294 (0.678–7.760)	0.182	1.34 (0.456–3.938)	0.594	3.654 (1.896–7.045)	**<0.001**
SGA	3.949 (1.544–10.096)	**0.004**	0.542 (0.199–1.478)	0.232	3.985 (1.857–8.555)	**<0.001**	0.742 (0.353–1.561)	0.432
LGA	Unavailable		1.449 (0.725–2.895)	0.294	0.969 (0.487–1.930)	0.93	2.231 (1.558–3.458)	**<0.001**
Preterm birth	2.661 (0.844–8.384)	0.095	0.239 (0.051–1.123)	0.07	3.422 (1.56–7.507)	**0.002**	0.459 (0.199–1.058)	0.068
Characteristic of amniotic fluid	2.326 (1.089–4.966)	**0.029**	1.096 (0.627–1.915)	0.747	0.76 (0.441–1.309)	0.322	1.119 (0.810–1.545)	0.495
HDP	3.057 (0.495–18.882)	0.229	3.481 (0.927–13.077)	0.065	1.225 (0.423–3.551)	0.709	1.992 (1.027–3.866)	**0.042**
GDM	0.728 (0.157–3.377)	0.685	1.026 (0.440–2.389)	0.953	1.784 (1.030–3.089)	**0.039**	0.563 (0.360–0.881)	**0.012**
Cesarean section	0.793 (0.398–1.582)	0.511	1.271 (0.838–1.929)	0.259	0.886 (0.586–1.339)	0.565	1.224 (0.939–1.595)	0.135

P values in bold indicate that the difference was significant.
OR: odds ratio; CI: confidence interval; SGA: small for gestational age; LGA: large for gestational age; GDM: gestational diabetes mellitus; HDP: hypertensive disorders in pregnancy.

more effective, the updated IOM guidelines in 2009 incorporated information on BMI and recommended GWG for different women.[20] Although many studies have evaluated the clinical applicability of IOM recommendations during the previous 10 years, the relationship between GWG that is consistent with the IOM guidelines and pregnancy outcomes is unclear.[22] Many of the findings vary by countries and ethnic diversity.[22,23] This study was performed to examine the relationships among pre-pregnancy BMI, GWG, and pregnancy outcomes for Chinese pregnant women.

IOM weight gain recommendations have been criticized by Asian scholars (Chinese, Koreans, and Japanese) as being ill-adapted for Asian women.[14,22] However, we wanted to test these recommendations in our population. Notably, we performed this testing with an "adapted Asian IOM recommendation" because our definitions of overweight and obesity are different from the original definition (i.e., obesity: $\geq$28 kg/m^2, overweight: 24.0–27.9 kg/m^2). Furthermore, the mean BMI of our population was 20.3 kg/m^2. Therefore, for 20 kg/m^2, the IOM recommendation is a weight gain of 11.5–16 kg. In our population, the mean GWG was 17.8 kg. Therefore, there appears to be a mismatch at low BMIs. However, we were able to analyze our results using this tool.

In the current study, 66.2% of Chinese women had a normal weight, and only 25.4% of women were underweight before pregnancy. Because the criterion of overweight and obesity for Chinese women is lower than World Health Organization recommendations, pregnant women with obesity in China are relatively uncommon. Our results are optimistic because a normal BMI is the primary factor in achieving good pregnancy outcomes. However, the rate of adequate GWG is too low (35.5%). Excessive GWG was observed in most normal weight women (55.0%) and in those who were overweight/obese (79.1%). These findings indicate that weight management during the perinatal period is required in China.

Neonatal birth weight is not only an important indicator of nutrition during pregnancy, but also reflects the intrauterine environment exposed by the fetus.[24] This predictive factor includes four primary variables: LBW, macrosomia, LGA, and SGA.[25] This study showed that mothers with a low BMI appeared to have a lower risk of delivering a neonate who was LGA and had macrosomia than mothers with a normal BMI. Additionally, mothers who had an inadequate weight had a higher risk of delivering a neonate with LBW and SGA, even if the pre-pregnancy BMI was normal. A study from Japan that included 1336 women also showed that pregnant women who were underweight before pregnancy were independently associated with delivery of LBW infants.[26] A systematic review showed that pregnant patients who obtain inadequate weight compared with the IOM recommendations have a higher odds of SGA and lower odds of LGA than GWG within the guidelines.[13] Macri and her colleagues highlighted pre-pregnant BMI and excessive GWG as independent risk factors for LGA and macrosomia.[27] However, their study was performed in women with gestational diabetes, not in the general population, as in the present study. When combined with an inadequate pre-pregnant BMI, excessive GWG is a synergistic risk factor for poor outcome. Many studies have shown that when obesity occurs, an optimal GWG can guarantee a better pregnancy outcome.[10]

Apart from neonatal birth weight, other adverse pregnancy outcomes are commonly evaluated, including HDP, GDM, preterm birth, and cesarean section.[12,28] Several epidemiological studies have shown that BMI, GWG, anemia, and lower education are convertible risk factors for these adverse outcomes.[29] In this study, the prevalence of HDP, preterm birth, and cesarean section was 4.8%, 3.8%, and 50.9%, respectively. Additionally, mothers in the overweight/obese group or excessive GWG group were more likely to have HDP and cesarean section. Mothers in the inadequate GWG group had a higher risk of having preterm birth. The mechanism for this finding could be that inadequate weight gain induces secretion of epinephrine and cortisol, which then results in an elevation in corticosterone-releasing-hormone and prostaglandin production. These are all key factors for premature delivery. Furthermore, impaired immunity and potential uterine infection may result from inadequate maternal nutrition.[30,31] Another common complication during pregnancy is GDM, which is diagnosed in >8.3% of pregnancies worldwide. The rate of GDM in this study was 10.2%. Increasing BMI appears to account for an increased prevalence of GDM in the USA.[32] Interestingly, we found that mothers with a high pre-pregnancy BMI were more likely to have GDM, and the risk of GDM was significantly lower in the excessive GWG group compared with the adequate GWG group. Additionally, the effect of GWG on GDM was stronger than that of pre-pregnancy BMI. Previous studies on the role of GWG in GDM are contradictory.[33,34] These contradictory results may be attributed to dietary regulation and exercise of pregnant women after being diagnosed with GDM.[35–37]

In this study, many pregnant women gained more weight than that recommended by the IOM guidelines, especially for women who were overweight and obese. The effects of GWG on adverse pregnancy outcomes were stronger than those of pre-pregnancy BMI. We urgently need to improve management of GWG of pregnant women in China, especially to prevent excessive GWG. However, the combined effect of pre-pregnancy BMI and GWG on birth weight of newborns should also be considered. Guiding individualized GWG when the pregnancy weight is known would be helpful. We also identified some controllable risk factors of pre-pregnancy and GWG, such as conception age, education, and prenatal examinations. Conception age is a risk factor of abnormal GWG.[38,39] More women with a high education appeared to have a normal pregnancy weight than women with a low education. This finding could have resulted from better economic factors in women with a high education.[17] Although patients with advanced maternal age are notable, more attention should be paid to women older than 30 years or younger than 25 years in terms of weight control. The dietary schedule should be evidence-based and pluralistic.[31]

In conclusion, this study shows that abnormal maternal weight and inappropriate GWG are related to an increased risk of adverse perinatal outcomes. Distinguishing pregnant women at risk of adverse pregnancy outcomes by using current BMI and GWG classifications is of clinical value. GWG should be the top priority in gestational weight management. Furthermore, more research should focus on the requirement for GWG standards suited to Chinese characteristics. There are specific Chinese birthweight curves for neonates.[21] Therefore, with knowledge of the 10th percentile (SGA) and the 90th percentile (LGA) of newborns, we could test the proposed "maternal-fetal-corpulence symbiosis", which was recently proposed by Robillard et al.,[1] in the future.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

This work was supported by Scientific Research Projects of Hubei Provincial Maternity and Children's Hospital (no. 20927006) and Epidemiological study of hypertensive disease in pregnancy and pregnancy outcome of mother and child in Hubei province (WJ2018H0147).

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