Original Article

Identifying appropriate pre-pregnancy body mass index classification to improve pregnancy outcomes in women of childbearing age in Beijing, China: a retrospective cohort study

Rui-Fen Zhao MMed, Li Zhou MMed, Wei-Yuan Zhang MD

Department of Obstetrics, Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Chaoyang District, Beijing, China

Background and Objectives: This study explored the appropriate classification of pre-pregnancy body mass index (BMI) in women of childbearing age in Beijing, China. **Methods and Study Design:** Women with singleton pregnancies at more than 28 gestational weeks were retrospectively reviewed. Based on the pre-pregnancy BMI (kg/m^2), these patients were divided into 7 groups: <18.5, ≥18.5–22.9, ≥23–23.9, ≥24–24.9, ≥25–27.9, ≥28–29.9, and ≥30. Pregnancy adverse outcomes, including gestational hypertension with or without preeclampsia, gestational diabetes mellitus, initial cesarean section, postpartum hemorrhage, macrosomia, large-for-gestational age infant and so on were recorded. Binary logistic regression analysis was used to calculate the uncorrected and corrected odds ratios and 95% confidence intervals, with the ≥18.5–22.9 group serving as a reference. **Results:** A total of 11,136 pregnant women were analyzed. Incidences of above mentioned six adverse outcomes were greater in women with higher pre-pregnancy BMI. The risks of the abovementioned six adverse outcomes were increased significantly among the ≥23–23.9, ≥24–24.9, ≥25–27.9 groups and substantially higher in the ≥28–29.9, ≥30 groups after correction. <18.5 group showed an increased risk of small-for-gestational age infants. **Conclusions:** For women of childbearing age in Beijing, China, the optimal pre-pregnancy BMI range was ≥18.5–22.9 kg/m^2, with the cutoff value for overweight status being ≥23.0 kg/m^2 and the cutoff value for obesity being ≥28.0 kg/m^2.

Key Words: body mass index, pre-pregnancy, pregnancy outcomes

INTRODUCTION

Pre-pregnancy body mass index (BMI) has a substantial impact on the outcomes of pregnancy.[1-13] Several research studies have proposed optimal gestational weight gains based on different pre-pregnancy BMI classifications.[5,13-15] Pre-pregnancy BMI is considered an important parameter for pre-pregnancy counseling and weight management during pregnancy.

The anthropometric characteristics of women of childbearing age vary by ethnicity. In the developing countries of Asia, women of childbearing age tend to be somewhat smaller-bodied than those in developed European countries and the United States. The body shape of Chinese women of childbearing age is also different from that of women from other Asian countries. From 1999 to 2004, more than 85% of women of childbearing age in the United States had a BMI of ≥25.0 kg/m^2.[13] In 2011, more than 80% of women of childbearing age in mainland China had a BMI of ≤24.0 kg/m^2,[16] whereas the statistics from Erika Ota and colleagues showed that over 90% of pregnant women in Vietnam had a BMI of <23.0 kg/m^2 before pregnancy.[6]

Currently, there are three common BMI classification standards for weight management in clinical practice in China (Table 1). 1) According to the World Health Organization (WHO), BMI classification criteria are as follows: BMI (kg/m^2) <18.5 is underweight; 18.5 to 24.9 is normal weight; 25.0 to 29.9 is overweight; and ≥30.0 is obese.[17] 2) Chinese adult BMI classification criteria include the following: BMI (kg/m^2) <18.5 is underweight; 18.5 to 23.9 is normal weight; 24.0 to 27.9 is overweight; and ≥28.0 is obesity.[18] 3) WHO recommended BMI classification criteria for Asians: BMI (kg/m^2) <18.5 is underweight; 18.5 to 22.9 is normal weight; 23.0 to 24.9 is overweight; ≥25.0 is obese.[19-21] These three criteria agree on the definition of underweight individuals (all are BMI <18.5 kg/m^2), but their cutoff values for overweight and obese status are different from each other.

With China's increasing economic development, adult obesity has gradually become a major public health issue.

Corresponding Author: Dr Li Zhou, Beijing Obstetrics and Gynecology Hospital Capital Medical University, 251 Yaojiayuan Road, Chaoyang District, Beijing, China 100026.
Tel: +86-18611708929
Email: zhouli2699@163.com
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Table 1. Three common BMI classification standards

	WHO BMI classification criteria	Chinese adult BMI classification criteria	WHO recommended BMI classification criteria for Asians
Underweight	<18.5 (kg/m^2)	<18.5 (kg/m^2)	<18.5 (kg/m^2)
Normal weight	18.5–24.9 (kg/m^2)	18.5–23.9 (kg/m^2)	18.5–22.9 (kg/m^2)
Overweight	25.0–29.9 (kg/m^2)	24.0–27.9 (kg/m^2)	23.0–24.9 (kg/m^2)
Obese	≥30.0 (kg/m^2)	≥28.0 (kg/m^2)	≥25.0 (kg/m^2)

BMI: body mass index; WHO: World Health Organization.

Currently, the prevalence of obesity (≥28.0 kg/m^2) of Chinese urban residents is between 11.0% and 12.9%.[22] The prenatal care for these overweight or obese women of childbearing age poses a great challenge to obstetricians. The three weight classification standards with their inconsistent cutoff values for overweight and obese status also cause confusion for obstetricians. Therefore, we decided to perform this retrospective cohort study with the purpose of clarifying the appropriate classification of pre-pregnancy BMI in women of childbearing age in Beijing to guide the pre-pregnancy preparation and prenatal care. Our study aimed to investigate whether the cutoff values for overweight and obese status in pre-pregnancy BMI in childbearing age women of Beijing could be lower than in the WHO BMI classification criteria [overweight status (≥25.0 kg/m^2), obesity (≥30.0 kg/m^2)], but higher than in the WHO recommended Asian BMI classification criteria [overweight status (≥23.0 kg/m^2), obesity (≥25.0 kg/m^2)].

METHODS

Subjects

We retrospectively collected and established the cohort of all puerperae with a gestational age ≥28 weeks from 1 September 2014 to 31 August 2015 in the Beijing Obstetrics and Gynecology Hospital Capital Medical University. Systemic prenatal examination of selected cases were performed during the early pregnancy. Pregnant women with comorbid conditions such as severe heart, brain, lung, liver, and kidney disease, and chronic medical diseases were excluded. Also, women expecting twins or triplets, with incomplete data, or age under 18 years old during the pregnancy were ruled out (Figure 1).

Data collection

The following information was obtained by referring to the prenatal examination and inpatient medical records of pregnant women: medical record number, age of delivery, height, educational level, pre-pregnancy body mass, body mass at childbirth, gravida, para, gestational age period of pregnancy, gestational hypertension with or without preeclampsia, gestational diabetes mellitus (GDM), premature delivery, pregnancy anemia, initial cesarean section (CS), vaginal midwifery, postpartum hemorrhage, macrosomia, large-for-gestational age (LGA) or small-

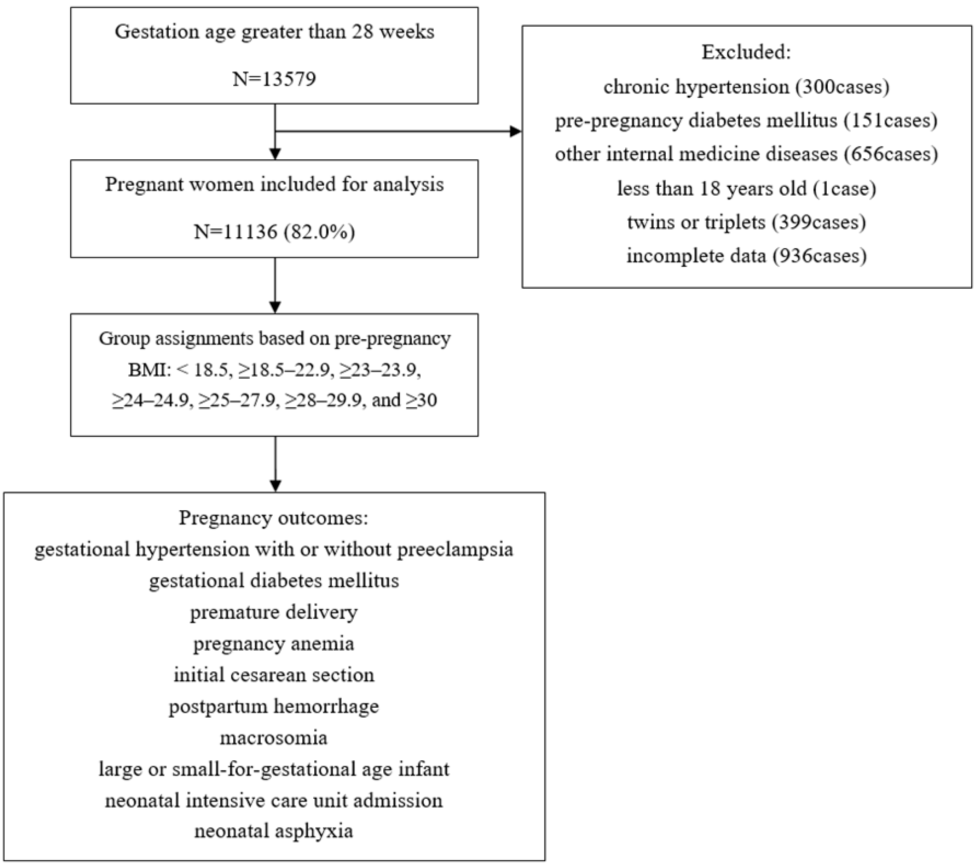

Figure 1. Patient enrollment flowchart. BMI: body mass index.

for-gestational age (SGA) infant, admission of infant to the neonatal intensive care unit (NICU), neonatal asphyxia and low birth weight (LBW) infants. The medical record number was the unique identification code for every pregnant woman. After data collection the medical record numbers were replaced by the digital serial numbers. The height of pregnant women was measured during the first prenatal examination during 7 to 12 weeks of pregnancy. The pre-pregnancy body weight was obtained as recalled by the pregnant women at this clinic visit. Body mass at childbirth was measured at the time of admission for delivery. Both the height and the body weight were measured using an RGZ-120 weight scale (Wujin City Balance Instrument Factory, China). The weight gain during pregnancy was calculated as the body weight at childbirth minus pre-pregnancy body mass. Gestational weeks was verified based on the last menstrual period of the pregnant woman and results of ultrasound examination during early pregnancy. The rate of weight gain during pregnancy was calculated by dividing the weight gain during pregnancy with the gestational weeks at the delivery. The neonatal body mass was the net body mass measured after omphalotomy at birth (ACS-20-YE electronic baby scale, weighing instrument factory in Wujin, China). This study was approved by the Medical Ethics Committee of Beijing Obstetrics and Gynecology Capital Medical University (approval letter No.:2017-KY-055-01).

Diagnostic criteria

1) GDM was diagnosed according to the criteria of the International Association of Diabetes and Pregnancy Study Group (IADPSG).[23] 2) Gestational hypertension was diagnosed by systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg that developed after 20 weeks and return to normal within 12 weeks after delivery. Preeclampsia: gestational hypertension accompanied by urinary protein ≥0.3 g/24 h, or other organ system involvement. 3) Premature delivery is defined as the delivery after 28 but before 37 gestational weeks. 4) Anemia during pregnancy was defined as hemoglobin <110 g/L and confirmed by the laboratory test when the pregnant women were admitted to the hospital for delivery. 5) Initial CS, also called primary CS in some works, refers to delivery by CS for the first time in women's life, whether she has had a previous vaginal delivery or not. Otherwise it is called repeated CS. 6) Postpartum hemorrhage was defined as the amount of bleeding >500 mL within 24 h after delivery of the fetus. 7) Macrosomia was defined as the birth weight of newborns greater than 4000 g; and LBW newborns were defined as the newborns with birth weight less than 2500 g. 8) LGA and SGA infants was defined as the neonatal body mass that was larger than the 90th percentile or less than the 10th percentile, respectively, adjusted for gestational age according to a Chinese reference curve.[24] 9) NICU admission of newborns: newborns sent to NICU within 24 h of birth. 10) Neonatal asphyxia: the Apgar score of newborns was ≤7 within 1 min of birth.

Quality control measures

Epidata were established based on the required variables and loaded to establish the database, and corresponding quality control files were also created. The data were added by the physicians or medical graduates who had clinical experience in the obstetrical department of Beijing Obstetrics and Gynecology Hospital. All staff were trained before data entry. The obtained data were checked and the missing items were supplemented by re-retrieving the medical records. The outliers were checked by re-retrieving the medical records and 10% of the cases were randomly selected for data checking.

Grouping

The three BMI classification criteria were the same for defining the BMI of underweight (all BMI <18.5 kg/m^2). The differences were the cutoff values for overweight status and obesity. The cut-off values of overweight status were 25.0, 24.0, and 23.0 (kg/m^2) and the cut-off values of obesity were 30.0, 28.0, and 25.0 (kg/m^2), respectively. All these BMI cut-off values were used to place the pregnant women in 7 groups: <18.5 group, ≥18.5–22.9 group, ≥23–23.9 group, ≥24–24.9 group, ≥25–27.9 group, ≥28–29.9 group, and ≥30 group.

Statistical analysis

Statistical analysis was performed using SPSS 20.0 software (IBM Corporation, Armonk, NY, US). Normality of distribution was evaluated using the Kolmogorov-Smirnov test. Variables with a normal distribution were compared using the variance analysis (one-way ANOVA), and values were presented as means ± standard deviation (SD). For variables with an abnormal distribution, the Kruskal Wallis test was used for comparisons, and values were presented as medians (interquartile range). Categorical variables were presented as frequencies (rate) and analyzed using chi-square. The pre-pregnancy BMI ≥18.5–22.9 group was used as the reference group to perform binary logistic regression analysis. The odds ratio (OR) and 95% confidence interval (CI) for risk of maternal and fetal adverse outcomes in other groups were calculated, and the confounding factors (including maternal age, educational level, parity, and rates of weight gain during pregnancy) were adjusted to further calculate the corrected OR and 95% CI for maternal and fetal adverse outcomes in other groups. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

1) General characteristics of study cohort: A total of 11,136 cases were enrolled in this study (Figure 1). The pre-pregnancy BMI ranged from 13.0 to 39.4 kg/m^2, with a mean±SD of 21.4±3.1 kg/m2 and median (P25, P75) of 20.9 kg/m^2 (19.2, 23.0). The proportion of pregnant women who were overweight or obese in the cohort was 25.9%, 17.6%, and 12.0% when the cut-off for being overweight was set at 23.0, 24.0, and 25.0 kg/m^2, respectively. The proportion of pregnant women with obesity in the cohort was 12%, 3.7%, and 1.6% when the cut-off for overweight status was set at 25.0, 28.0, and 30.0 kg/m^2, respectively. The minimum and maximum age of the women were 19 and 47 years old, respectively, and the mean±SD of age was 30.96±3.59 (years old). There were 1752 elderly pregnant women (≥35 years old), accounting for 15.7% of all the cases. The number of primiparas included was 9,164 (82.3%) and the number of multiparas

1972 (17.7%). A total of 10,672 cases (95.8%) belonged to the Han ethnicity and 464 cases (4.2%) to ethnic minorities. Educational levels included 2748 cases (24.7%) with education level of an associate's degree or below, 5840 cases (52.4%) with bachelor's degrees, and 2548 cases (22.9%) with master's degree or above. Pearson χ^2 test results of 7 groups showed that women with higher pre-pregnancy BMI were more likely to be older, to have lower education levels and higher rates of multipara ($p<0.001$) (Table 2). The gestational weeks in the 7 groups did not conform to the normal distribution. Median (P25, P75) of gestational weeks in the 7 groups were all 39.0 (38.0, 40.0), but nonparametric tests showed there to be significant differences between them ($p<0.001$).

2) The pre-pregnancy BMI was associated with six adverse outcomes, including gestational hypertension with or without preeclampsia, GDM, initial CS, postpartum hemorrhage, macrosomia and LGA infant. In the 7 groups, the occurrence of the above six adverse outcomes showed an upward trend with the increased pregnancy BMI ($p<0.001$) (Table 3). The pre-pregnancy BMI was related to the occurrence of premature delivery, SGA infant, and NICU admission ($p<0.05$). The occurrence of premature delivery and NICU admission of newborns had an increased trend with increased pre-pregnancy BMI in the 7 groups, while the occurrence of SGA infant was highest in the <18.5 group (3.7%) and was lowest in the ≥28–29.9 group (1.7%). The occurrence of anemia during pregnancy, vaginal midwifery, and neonatal asphyxia showed no correlation with pre-pregnancy BMI ($p>0.05$). When the analysis was limited to the full-term birth, the pre-pregnancy BMI had no correlation with LBW newborns ($p>0.05$). (Table 3)

3) The risks of adverse outcomes before and after correction in each pre-pregnancy BMI group were shown in Table 4. Compared to the reference group, the risks of gestational hypertension with or without preeclampsia, GDM, initial CS, postpartum hemorrhage, macrosomia, and LGA infant in pregnant women were increased in the pregnant women in each group with pre-pregnancy BMI ≥23.0 kg/m^2 before and after correcting the confounding factors (Table 4, Figure 2). The risks of the above six adverse outcomes were significantly lower in the <18.5 group compared to the reference group before and after the confounding factors were adjusted (Table 4, Figure 2). The risk of SGA infant was greater in the pregnant women in the <18.5 group than in the reference group, and the corrected OR (95% CI) was 1.62 (1.20–2.19) (Table 4, Figure 2). The risk of premature delivery in pregnant women in the ≥30 group was greater than in the reference group, and the corrected OR (95% CI) was 2.97 (1.91–4.60). In comparison with the reference group, the risk of NICU admission for pregnant women in ≥25–27.9 and ≥30 groups was greater, and the corrected ORs (95% CIs) were 1.72 (1.20–2.47) and 2.74 (1.47–5.12), respectively.

DISCUSSION

Pre-pregnancy BMI and adverse pregnancy outcomes

Several studies showed that adverse delivery outcomes increased with the increasing pre-pregnancy BMI. A prospective study conducted in Ireland by Jensen DM and colleagues showed that the risk of hypertensive complications, CS, labor induction, and macrosomia were significantly greater in pre-pregnancy overweight (BMI ≥25–29.9 kg/m^2) and obese (≥30 kg/m^2) pregnant women.[1] A prospective observational cohort study in Denmark conducted by Dennedy MC and colleagues showed that the risk of preeclampsia, gestational hypertension, CS, LGA infant, macrosomia, and neonatal congenital malformation were increased in pre-pregnancy overweight (BMI ≥25–29.9 kg/m^2) and obese (≥30 kg/m^2) pregnant women, and the effect of pre-pregnancy BMI was independent of the blood glucose.[2] Chinese scholars Liu X and colleagues showed that the risk of preeclampsia, GDM, premature rupture of membranes, placental abruption, CS, postpartum hemorrhage and LGA infant were significantly increased in pre-pregnancy overweight (BMI ≥24–27.9 kg/m^2) and obese (≥28 kg/m^2) pregnant women.[3] The research conducted by Li G et al showed that pre-pregnant BMI was one of the risk factors most strongly associated with macrosomia.[4] Several other Asian scholars also performed some investigations on this topic. The research conducted in Japan by Tanaka T (2014) et al showed the risk of gestational hypertension to be increased in pre-pregnancy BMI ≥25.0 kg/m^2 and 23–24.9 kg/m^2 pregnant women.[5] Research conducted in Vietnam by Erika Ota and colleagues showed the risk of LGA infant to be greater in pre-pregnancy BMI of ≥23.0 kg/m^2 pregnant women.[6] Nomura K et al also reported that women with pre-pregnancy BMI <18.5 kg/m^2 were more likely to have SGA infants, while women with pre-pregnancy BMI 25 kg/m^2 or larger were more likely to have LGA infants.[7] Our results were consistent with the reports from the previous studies that showed that the incidences of gestational hypertension with or without preeclampsia, GDM, initial CS, postpartum hemorrhage, macrosomia, and LGA infant were greater with greater pre-pregnancy BMI. According to the OR values level, the risk of the above adverse outcomes demonstrated a mild-to-moderate increase in the ≥23–23.9 group, the ≥24–24.9 group, and the ≥25–27.9 group pregnant women. In addition, the risk of the above adverse outcomes was increased steeply in the ≥28–29.9 and the ≥30 groups (Table 4, Figure 2).

Our study showed an increased risk of SGA infant in the pregnant women of <18.5 group, with a corrected OR value (95% CI) of 1.62 (1.20–2.19) (Table 4, Figure 2). Studies by Liu X et al, Tanaka T et al, and Erika Ota et al. have shown that pre-pregnancy underweight pregnant women (BMI <18.5 kg/m^2) had an increased risk of developing SGA infants.[3,5,6] Neggers Y et al also demonstrated that low pre-pregnancy weight was one of the strongest predictors of fetal growth restriction.[8]

Our study showed that pre-pregnancy BMI was unrelated to full-term LBW newborns. Studies conducted in Japan by Murai U et al showed that the risk of LBW newborns was increased in the pre-pregnancy BMI <18.5 kg/m^2 group compared with that of pre-pregnancy BMI of 18.5–22.9 kg/m^2 group.[25] Study conducted in China by Li Chunming et al also showed that the occurrence of full-term LBW newborns was significantly higher in pregnant women with pre-pregnancy BMI <18.5 kg/m^2 compared with that of pre-pregnancy BMI ≥18.5–23.9 kg/m^2 (3.2% vs 1.9%).[16] However, the occurrence of LBW newborns

Table 2. Study cohort characteristics by pre-pregnancy BMI categories [mean ± SD or n (%)]

Characteristics	BMI <18.5 n=1687	18.5 ≤–22.9 n=6575	≥23–23.9 n=919	≥24–24.9 n=629	≥25–27.9 n=919	≥28–29.9 n=230	BMI ≥ 30 n=177	F or χ^2	p
Maternal age (y)	29.7±3.37	31.0±3.55	31.6±3.60	31.8±3.74	31.6±3.57	31.8±3.84	31.3±3.55	56.02	<0.001
≥35 y	145 (8.6)	1015 (15.4)	174 (18.9)	145 (23.1)	185 (20.1)	56 (24.3)	32 (18.1)	124.80	<0.001
<35 y	1542 (91.4)	5560 (84.6)	745 (81.1)	484 (76.9)	734 (79.9)	174 (75.7)	145 (81.9)		
Han nationality	1625 (96.3)	6291 (95.7)	884 (96.2)	605 (96.2)	880 (95.8)	221 (96.1)	166 (93.8)	3.80	0.703
Minority	62 (3.7)	284 (4.3)	35 (3.8)	24 (3.8)	39 (4.2)	9 (3.9)	11 (6.2)		
Education level									
Associate's degree or below	431 (25.5)	1478 (22.5)	239 (26.0)	187 (29.7)	259 (28.2)	77 (33.5)	77 (43.5)	129.33	<0.001
Bachelor's degree	912 (54.1)	3428 (52.1)	471 (51.3)	316 (50.2)	499 (54.3)	128 (55.7)	86 (48.6)		
Master's degree or above	344 (20.4)	1669 (25.4)	209 (22.7)	126 (20.0)	161 (17.5)	25 (10.9)	14 (7.9)		
Parity									
Primiparity	1469 (87.1)	5445 (82.8)	734 (79.9)	486 (77.3)	718 (78.1)	177 (77.0)	135 (76.3)	62.18	<0.001
Multiparity	218 (12.9)	1130 (17.2)	185 (20.1)	143 (22.7)	201 (21.9)	53 (23.0)	42 (23.7)		
Rate of gestational weight gain (kg/w)	0.42±0.11	0.41±0.12	0.39±0.13	0.37±0.13	0.35±0.13	0.30±0.13	0.28±0.14	96.36	<0.001

BMI: body mass index; SD: standard deviation.

Table 3. Adverse pregnancy outcomes by pre-pregnancy BMI categories [n (%)]

Characteristics or pregnancy outcome	BMI <18.5 n=1687	18.5 ≤–22.9 n=6575	≥23–23.9 n=919	≥24–24.9 n=629	≥25–27.9 n=919	≥28–29.9 n=230	BMI ≥30 n=177	χ^2	p
Hypertensive disorder complicating pregnancy									
Yes	33 (2.0)	262 (4.0)	68 (7.4)	53 (8.4)	99 (10.8)	43 (18.7)	37 (20.9)	301.14	<0.001
No	1654 (98.0)	6313 (96.0)	851 (92.6)	576 (91.6)	820 (89.2)	187 (81.3)	140 (79.1)		
Gestational diabetes mellitus									
Yes	142 (8.4)	1051 (16.0)	196 (21.3)	159 (25.3)	278 (30.3)	94 (40.9)	74 (41.8)	396.98	<0.001
No	1545 (91.6)	5524 (84.0)	723 (78.7)	470 (74.7)	641 (69.7)	136 (59.1)	103 (58.2)		
Preterm birth									
Yes	74 (4.4)	329 (5.0)	53 (5.8)	34 (5.4)	64 (7.0)	20 (8.7)	27 (15.3)	48.62	<0.001
No	1613 (95.6)	6246 (95.0)	866 (94.2)	595 (94.6)	855 (93.0)	210 (91.3)	150 (84.7)		
Pregnancy anemia									
Yes	44 (2.6)	182 (2.8)	19 (2.1)	17 (2.7)	25 (2.7)	5 (2.2)	4 (2.3)	1.90	0.929
No	1643 (97.4)	6393 (97.2)	900 (97.9)	612 (97.3)	894 (97.3)	225 (97.8)	173 (97.7)		

BMI: body mass index; NICU: neonatal intensive care unit.
†Limited the analysis to full term pregnancies.

Table 3. Adverse pregnancy outcomes by pre-pregnancy BMI categories [n (%)]

Characteristics or pregnancy outcome	BMI <18.5 n=1687	18.5 ≤–22.9 n=6575	≥23–23.9 n=919	≥24–24.9 n=629	≥25–27.9 n=919	≥28–29.9 n=230	BMI ≥30 n=177	χ^2	p
Initial cesarean section									
Yes	276 (16.4)	1416 (21.5)	246 (26.8)	180 (28.6)	260 (28.3)	77 (33.5)	58 (32.8)	107.09	<0.001
No	1411 (83.6)	5159 (78.5)	673 (73.2)	449 (71.4)	659 (71.7)	153 (66.5)	119 (67.2)		
Vaginal midwifery									
Yes	96 (5.7)	375 (5.7)	42 (4.6)	31 (4.9)	43 (4.7)	8 (3.5)	7 (4.0)	6.291	0.391
No	1591 (94.3)	6200 (94.3)	877 (95.4)	598 (95.1)	876 (95.3)	222 (96.5)	170 (96.0)		
Postpartum hemorrhage									
Yes	223 (13.2)	1208 (18.4)	205 (22.3)	139 (22.1)	201 (21.9)	69 (30.0)	42 (23.7)	74.65	<0.001
No	1464 (86.8)	5367 (81.6)	714 (77.7)	490 (77.9)	718 (78.1)	161 (70.0)	135 (76.3)		
Macrosomia									
Yes	62 (3.7)	448 (6.8)	96 (10.4)	65 (10.3)	98 (10.7)	34 (14.8)	24 (13.6)	99.84	<0.001
No	1687 (96.3)	6127 (93.2)	823 (89.6)	564 (89.7)	821 (89.3)	196 (85.2)	153 (86.4)		
Large-for-gestational age infant									
Yes	277 (16.4)	1594 (24.2)	276 (30.0)	204 (32.4)	291 (31.7)	82 (35.7)	61 (34.5)	143.30	<0.001
No	1410 (83.6)	4981 (75.8)	643 (70.0)	425 (67.6)	628 (68.3)	148 (64.3)	116 (65.5)		
Small-for-gestational age infant									
Yes	63 (3.7)	159 (2.4)	17 (1.8)	14 (2.2)	18 (2.0)	4 (1.7)	5 (2.8)	14.15	0.028
No	1624 (96.3)	6416 (97.6)	902 (98.2)	615 (97.8)	901 (98.0)	226 (98.3)	172 (97.2)		
Neonatal asphyxia									
Yes	14 (0.8)	34 (0.5)	6 (0.7)	3 (0.5)	8 (0.9)	1 (0.4)	1 (0.6)	3.68	0.720
No	1673 (99.2)	6541 (99.5)	913 (99.3)	626 (99.5)	911 (99.1)	229 (99.6)	176 (99.4)		
Checking into NICU									
Yes	46 (2.7)	157 (2.4)	31 (3.4)	21 (3.3)	39 (4.2)	9 (3.9)	12 (6.8)	24.03	0.001
No	1641 (97.3)	6418 (97.6)	888 (96.6)	608 (96.7)	880 (95.8)	221 (96.1)	165 (93.2)		
Low birth weight infant †									
Yes	18 (1.1)	44 (0.7)	5 (0.6)	9 (1.5)	11 (1.3)	1 (0.5)	1 (0.7)	9.18	0.164
No	1595 (98.9)	6202 (99.3)	861 (99.4)	586 (98.5)	844 (98.7)	209 (99.5)	149 (99.3)		

BMI: body mass index; NICU: neonatal intensive care unit.
†Limited the analysis to full term pregnancies.

Table 4. The risks of adverse pregnancy outcomes before and after correction in each pre-pregnancy BMI group

	Unadjusted		Adjusted†	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Hypertensive disorder complicating pregnancy				
<18.5 (n=1687)	0.48 (0.33–0.69)	<0.001	0.49 (0.34–0.71)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.93 (1.46–2.54)	<0.001	1.98 (1.49–2.61)	<0.001
≥24–24.9 (n=629)	2.22 (1.63–3.02)	<0.001	2.37 (1.73–3.23)	<0.001
≥25–27.9 (n=919)	2.91 (2.28–3.71)	<0.001	3.40 (2.65–4.36)	<0.001
≥28–29.9 (n=230)	5.54 (3.89–7.89)	<0.001	7.66 (5.28–11.12)	<0.001
≥30 (n=177)	6.37 (4.34–9.34)	<0.001	9.77 (6.51–14.65)	<0.001
Gestational diabetes mellitus				
<18.5 (n=1687)	0.48 (0.40–0.58)	<0.001	0.53 (0.45–0.65)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.43 (1.20–1.69)	<0.001	1.30 (1.09–1.54)	0.003
≥24–24.9 (n=629)	1.78 (1.47–2.15)	<0.001	1.54 (1.26–1.87)	<0.001
≥25–27.9 (n=919)	2.28 (1.95–2.66)	<0.001	1.91 (1.63–2.24)	<0.001
≥28–29.9 (n=230)	3.63 (2.77–4.76)	<0.001	2.64 (1.99–3.50)	<0.001
≥30 (n=177)	3.78 (2.78–5.13)	<0.001	2.69 (1.95–3.69)	<0.001
Preterm birth				
<18.5 (n=1687)	0.87 (0.67–1.13)	0.294	0.96 (0.74–1.24)	0.734
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.16 (0.86–1.57)	0.325	1.09 (0.81–1.47)	0.568
≥24–24.9 (n=629)	1.09 (0.76–1.56)	0.660	0.98 (0.68–1.42)	0.920
≥25–27.9 (n=919)	1.42 (1.08–1.88)	0.013	1.29 (0.97–1.71)	0.079
≥28–29.9 (n=230)	1.81 (1.13–2.90)	0.014	1.53 (0.95–2.48)	0.083
≥30 (n=177)	3.42 (2.24–5.22)	<0.001	2.97 (1.91–4.60)	<0.001
Initial cesarean section				
<18.5 (n=1687)	0.71 (0.62–0.82)	<0.001	0.73 (0.63–0.85)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.33 (1.14–1.56)	<0.001	1.39 (1.17–1.65)	<0.001
≥24–24.9 (n=629)	1.46 (1.22–1.75)	<0.001	1.63 (1.33–2.00)	<0.001
≥25–27.9 (n=919)	1.44 (1.23–1.68)	<0.001	1.68 (1.42–2.00)	<0.001
≥28–29.9 (n=230)	1.83 (1.39–2.43)	<0.001	2.41 (1.75–3.32)	<0.001
≥30 (n=177)	1.78 (1.29–2.44)	<0.001	2.62 (1.83–3.77)	<0.001
Postpartum hemorrhage				
< 18.5 (n=1687)	0.68 (0.58–0.79)	<0.001	0.70 (0.60–0.82)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.28 (1.08–1.51)	0.004	1.26 (1.06–1.49)	0.007
≥24–24.9 (n=629)	1.26 (1.03–1.54)	0.022	1.24 (1.02–1.52)	0.035
≥25–27.9 (n=919)	1.24 (1.05–1.47)	0.011	1.26 (1.06 – 1.50)	0.008
≥28–29.9 (n=230)	1.90 (1.43–2.54)	<0.001	2.00 (1.48–2.67)	<0.001
≥30 (n=177)	1.38 (0.97–1.97)	0.071	1.48 (1.03–2.12)	0.032
Macrosomia				
<18.5 (n=1687)	0.52 (0.40–0.68)	<0.001	0.51 (0.39–0.67)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.60 (1.27–2.01)	<0.001	1.68 (1.33–2.12)	<0.001
≥24–24.9 (n=629)	1.58 (1.20–2.07)	0.001	1.73 (1.31–2.29)	<0.001
≥25–27.9 (n=919)	1.63 (1.30–2.06)	<0.001	1.93 (1.52–2.44)	<0.001
≥28–29.9 (n=230)	2.37 (1.63–3.46)	<0.001	3.41 (2.31–5.04)	<0.001
≥30 (n=177)	2.15 (1.38–3.33)	0.001	3.27 (2.07–5.15)	<0.001
Large for gestational age infant				
<18.5 (n=1687)	0.61 (0.53–0.71)	<0.001	0.60 (0.52–0.70)	<0.001
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.34 (1.15–1.56)	<0.001	1.39 (1.19–1.62)	<0.001
≥24–24.9 (n=629)	1.50 (1.26–1.79)	<0.001	1.60 (1.34–1.92)	<0.001
≥25–27.9 (n=919)	1.45 (1.25–1.68)	<0.001	1.66 (1.42–1.94)	<0.001
≥28–29.9 (n=230)	1.73 (1.31–2.28)	<0.001	2.32 (1.75–3.09)	<0.001
≥30 (n=177)	1.64 (1.20–2.25)	0.002	2.31 (1.66–3.20)	<0.001

BMI: body mass index; CI: confidence interval; NICU: neonatal intensive care unit; OR: odds ratio.
†Adjusted for maternal age, educational level, parity, and rates of weight gain during pregnancy.

Table 4. The risks of adverse pregnancy outcomes before and after correction in each pre-pregnancy BMI group

	Unadjusted		Adjusted†	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Small for gestational age infant				
<18.5 (n=1687)	1.57 (1.16–2.11)	0.003	1.62 (1.20–2.19)	0.002
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	0.76 (0.46–1.26)	0.288	0.73 (0.44–1.21)	0.227
≥24–24.9(n=629)	0.92 (0.53–1.60)	0.763	0.87 (0.50–1.51)	0.611
≥25–27.9(n=919)	0.81 (0.49–1.32)	0.391	0.72 (0.44–1.19)	0.202
≥28–29.9(n=230)	0.71 (0.26–1.94)	0.510	0.58 (0.21–1.60)	0.293
≥30 (n=177)	1.17 (0.48–2.89)	0.729	0.94 (0.37–2.35)	0.891
Checking into NICU				
<18.5 (n=1687)	1.15 (0.82–1.60)	0.423	1.19 (0.85–1.67)	0.305
≥18.5–22.9 (n=6575)	1.00		1.00	
≥23–23.9 (n=919)	1.43 (0.97–2.11)	0.075	1.39 (0.94–2.05)	0.103
≥24–24.9 (n=629)	1.41 (0.89–2.24)	0.144	1.35 (0.85–2.15)	0.208
≥25–27.9 (n=919)	1.81 (1.27–2.59)	0.001	1.72 (1.20–2.47)	0.003
≥28–29.9 (n=230)	1.67 (0.84–3.30)	0.145	1.52 (0.76–3.05)	0.238
≥30 (n=177)	2.97 (1.62–5.46)	<0.001	2.74 (1.47–5.12)	0.002

BMI: body mass index; CI: confidence interval; NICU: neonatal intensive care unit; OR: odds ratio.
†Adjusted for maternal age, educational level, parity, and rates of weight gain during pregnancy.

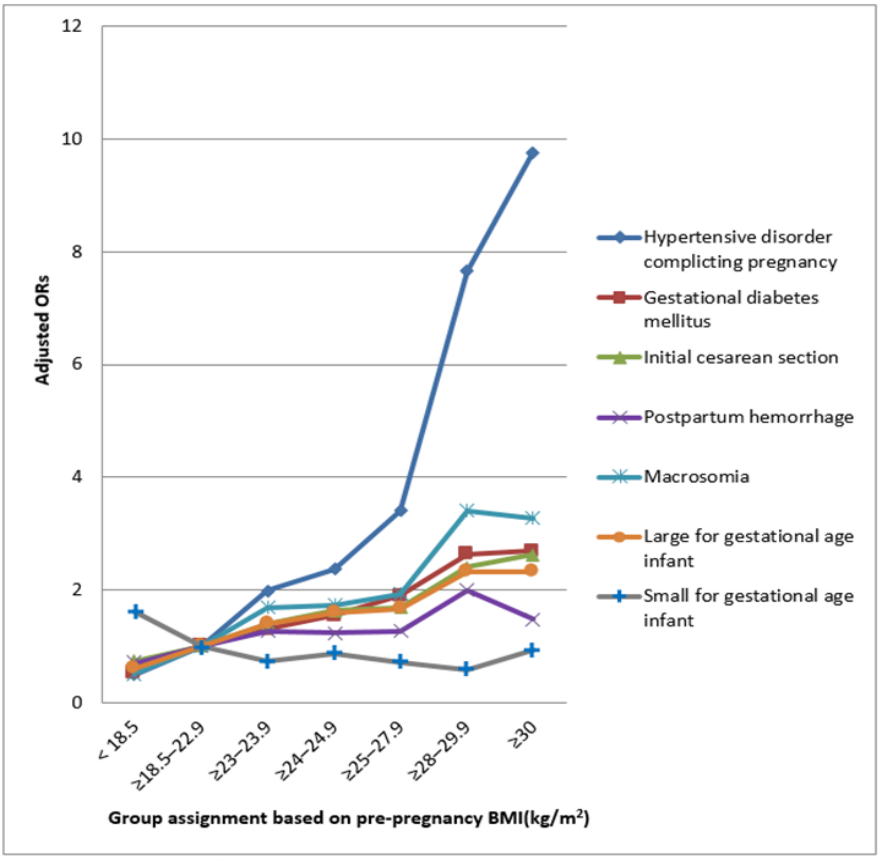

Figure 2. Different risks with different pre-pregnancy BMI values. BMI: body mass index; OR: odds ratio.

was not significantly lower in the overweight and obese groups (1.7% and 1.4%, respectively).[16] The overall occurrence of full-term LBW newborns in our study (0.8%) was significantly lower than in the two studies named above (4.2% in the study from Murai U et al and 2.0% in the study from Li Chunming et al).[25,16] Second, 75.1% of full-term pregnant women gained more than 12.5 kg during pregnancy in our study, while only 27.7% of full-term pregnant women gained more than 12.5 kg during pregnancy in the study performed by Murai U et al[25] In our study the average weight gain during pregnancy was 16.4 kg in the <18.5 group which was significantly higher than in the other six groups (15.9 kg, 15.1 kg, 14.7 kg, 13.6 kg, 11.8 kg, 10.7 kg for ≥18.5–22.9 group, ≥23–23.9 group, ≥24–24.9 group, ≥25–27.9 group, ≥28–29.9 group, and ≥30 group). These points may account for the differences between the results of our study and those reported in previous studies.

Our study also showed that the risk of preterm birth was increased in the pregnant women of ≥30 group, with the corrected OR value (95% CI) of 2.97 (1.91–4.60), while low pre-pregnancy weight (BMI <18.5 kg/m^2) did not increase the risk of preterm birth, with a corrected OR value (95% CI) of 0.96 (0.74–1.24). The results of various studies were inconsistent regarding the relationship between pre-pregnancy BMI and preterm birth.[1,3,8-11] Research reported by Hacini Afroukh N et al showed the risk of iatrogenic preterm birth to be greater in overweight pregnant women (pre-pregnancy BMI ≥25 kg/m^2) than in normal weight pregnant women (pre-pregnancy BMI ≥18.5–24.9 kg/m^2).[9] Research by Jensen DM et al. showed no association between overweight status (pre-pregnancy BMI ≥25 kg/m^2), obesity (pre-pregnancy BMI ≥30 kg/m^2) and preterm birth.[1] Research by Hacini Afroukh N et al, Neggers Y et al, and Khashan AS et al showed that the risk of preterm birth to be greater in pre-pregnant underweight (BMI <18.5 kg/m^2) pregnant women.[8-10] Research conducted by Chinese scholars Liu X et al and Ding XX et al showed that low pre-pregnancy weight did not increase the risk of preterm birth.[3,11]

Our research showed the risk of NICU admission for newborns to be higher in the ≥25–27.9 and ≥30 groups, with corrected OR values of 1.72 (1.20–2.47) and 2.74 (1.47–5.12), respectively. Research by Kall P et al. also showed an increased risk of NICU admission for newborns characterized by hypoglycemia in obese pregnant mothers.[12]

Appropriate pre-pregnancy BMI classification in women of childbearing age in Beijing, China

The risk of gestational hypertension with or without preeclampsia, GDM, initial CS, postpartum hemorrhage, LGA infant, and macrosomia increased with the increased pre-pregnancy BMI (Table 4, Figure 2). As the OR values showed, the risk of the above six adverse outcomes were increased significantly among the ≥23–23.9 and ≥24–24.9 groups after correction. When the overweight threshold of pre-pregnancy BMI was set at either 24.0 kg/m^2 or 25.0 kg/m^2, a significant number of high-risk pregnant women would be classified as normal pregnant women, which could lead to missed diagnosis and improper management. So the ≥23–23.9 and ≥24–24.9 groups could not be classified as normal weight. It is appropriate to set the pre-pregnant overweight threshold to ≥23.0 kg/m^2. Before pregnancy, women of childbearing age should be instructed to keep their BMI under 23.0 kg/m^2 to reduce the incidence of adverse pregnancy outcomes. For the pre-pregnancy BMI ≥23.0 kg/m^2, pregnant women should be included in the overweight range and provide maternal nutrition guidance and intensive pregnancy management.

Our study also showed that pregnant women in the ≥28–29.9 group had 7.66 times higher risk of gestational hypertension with or without pereclampsia, 2.64 times higher risk of GDM, 2.41 times higher risk of initial CS, 2.00 times higher risk of postpartum hemorrhage, 3.41 times higher risk of macrosomia, and 3.32 times higher risk of LGA infant over the reference group of pregnant women. There were no significant differences in the occurrence of the six adverse outcomes between the ≥28–29.9 group and the ≥30 group, using chi-square analysis. The risk of the six adverse outcomes in the ≥28–29.9 group was similar to those in the ≥30 group (Table 4, Figure 2). In Figure 2, when the pre-pregnancy BMI was ≥28.0 kg/m^2, the slope of the broken line of adjusted ORs increased. The threshold of obesity was too high when set at ≥30.0 kg/m^2 in pregnant women in our study. This is because some of the high-risk pregnant women with pre-pregnancy BMI ≥28–29.9 kg/m^2 would be excluded from key management. While compared to the reference group, the risk of the six adverse outcomes in ≥25–27.9 group pregnant women demonstrated a mild-to-moderate increase and was similar to those in the ≥23–23.9 and ≥24–24.9 groups (Table 4, Figure 2). Thus, the threshold of obesity was too low if it was set at ≥25.0 kg/m^2. It was reasonable to set the threshold of obesity to ≥28.0 kg/m^2 in women of childbearing age in Beijing, China.

Although the risk of the above-listed six adverse outcome indicators were reduced in the pre-pregnancy BMI <18.5 kg/m^2 pregnant women, our study and other studies including Liu X et al, Tanaka T et al, and Erika Ota et al. showed that the risk of SGA infant was greater in women with a pre-pregnancy BMI <18.5 kg/m^2 (Table 4, Figure 2).[3,5,6] The studies by Li Chunming et al and Murai U et al also showed that the risk of LBW infant to be greater in the women with a pre-pregnancy BMI <18.5 kg/m^2. In addition, adults with BMI <18.5 kg/m^2 had an increased risk of all-cause age-adjusted deaths.[26] All these serious adverse effects might offset and exceed the protective effect of pre-pregnancy BMI <18.5 kg/m^2 for six specific adverse pregnancy outcomes. Thus, it was appropriate to set the pre-pregnancy underweight cutoff value to <18.5 kg/m^2. Therefore, the appropriate pre-pregnancy BMI range for childbearing age women of Beijing, China was ≥18.5–22.9 kg/m^2.

Conclusion

Our study demonstrated that the pregnant women with inappropriately high or low pre-pregnancy BMI had increased risk of adverse pregnancy outcomes. Women of childbearing age should keep their BMI within the appropriate range while preparing for pregnancy. For women of childbearing age in Beijing, China, the optimal pre-pregnancy BMI range was ≥18.5–22.9 kg/m^2, with the cutoff value for overweight status being ≥23.0 kg/m^2 and the cutoff value for obesity being ≥28.0 kg/m^2.

Advantages and limitations

Sufficient planning was made before conducting this study. Statistics showed that our study had 90% power to calculate the corrected ORs (95% CIs) of the six adverse outcomes, which improved the reliability of our results and conclusions. Our study was a retrospective study. Data on lifestyle habits such as smoking, drinking, and activity are not available. These factors cannot be adjusted for the analyses. Data regarding pre-pregnancy weight were obtained by patient recall information, which could cause self-reporting and recall biases. One limitation of this study was that all pregnant women analyzed were from a single hospital in the downtown area of Beijing. They may have higher social status and may have been more affluent, healthy, and educated than the general population. Thus, the applicability of the data may be limited to pregnant women in large cities such as Beijing.

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AUTHOR DISCLOSURES

The authors have no competing financial interests.

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