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Association Between Prepregnancy Body Mass Index and Adverse Pregnancy Outcomes Among Women with Inadequate Gestational Weight Gain: A Retrospective Cohort Study

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Research Article

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Abstract

Background: Inadequate gestational weight gain (GWG) is a well-established risk factor for adverse maternal and neonatal outcomes. Although pre-pregnancy body mass index (BMI) informs clinical GWG recommendations, its role as an effect modifier—particularly in women with inadequate GWG—remains poorly characterized. This study aimed to evaluate how pre-pregnancy BMI modifies the risks of maternal and neonatal complications in this high-risk population.

Methods: We conducted a retrospective cohort study using data from 865 Chinese women with inadequate GWG, stratified by pre-pregnancy BMI into underweight (n = 233), normal-weight (n = 395), and overweight/obese (n = 237) groups. Multivariable logistic regression models were employed to estimate associations between BMI categories and pregnancy outcomes, adjusting for maternal age and total GWG.

Results: Compared with the normal-weight group, pre-pregnancy overweight/obesity was significantly associated with higher risks of cesarean delivery (adjusted odds ratio [aOR] = 2.23; 95% CI: 1.55–3.21) and hypertensive disorders of pregnancy (aOR = 4.22; 95% CI: 2.20–8.11). Pre-pregnancy underweight was independently associated with increased risk of neonatal low birth weight (aOR = 2.78; 95% CI: 1.56–4.95). The association between overweight/obesity and macrosomia was not statistically significant after adjustment. No significant associations were observed for preterm birth or other assessed outcomes.

Conclusion: Among women with inadequate GWG, pre-pregnancy BMI serves as a critical effect modifier of adverse pregnancy outcomes. Overweight/obesity predominantly elevates maternal morbidity, whereas underweight status confers substantial neonatal risk. These findings underscore the need for BMI-stratified clinical management in pregnant women with inadequate GWG to support targeted, evidence-based interventions.

1. Introduction

Gestational weight gain (GWG) serves as an important indicator of nutritional status during pregnancy, with both excessive and inadequate gain being associated with adverse maternal and neonatal outcomes[1, 2]. While excessive GWG has received substantial research attention, inadequate GWG remains a significant yet understudied public health concern[3, 4]. In China, approximately 24% of pregnant women experience inadequate GWG, which has been identified as an independent risk factor for low birth weight and small-for-gestational-age infants[5].

Current international guidelines recommend individualized GWG management based on pre-pregnancy body mass index (BMI)[6, 7]. However, a critical knowledge gap exists regarding how pre-pregnancy BMI modifies health outcomes specifically among women with inadequate GWG. Previous studies have generally treated inadequate GWG as a homogeneous condition without accounting for potential effect

modification by pre-pregnancy nutritional status[8]. This limitation stems from both methodological constraints in subgroup analyses and a predominant research focus on obesity-related complications.

The complex interaction between GWG patterns and pre-pregnancy BMI suggests that inadequate GWG may have differential health implications across various BMI categories[9, 10]. For instance, the metabolic consequences of insufficient weight gain likely differ substantially between underweight versus overweight women[11]. Understanding these distinctions is essential for developing targeted interventions and personalized clinical management strategies.

This retrospective cohort study utilized clinical data from 865 pregnant women with inadequate GWG to examine how pre-pregnancy BMI influences maternal and neonatal outcomes. The study population demonstrated substantial heterogeneity in pre-pregnancy BMI distribution, with approximately 27% underweight, 46% normal weight, and 27% overweight or obese. This distribution reflects the diverse nutritional profiles within the inadequate GWG population and provides an optimal foundation for investigating BMI-dependent outcome variations.

The primary objective was to systematically compare pregnancy outcomes across different pre-pregnancy BMI categories among women with inadequate GWG, with the goal of identifying high-risk subgroups that may benefit from tailored clinical management. The findings aim to contribute to more precise perinatal care strategies that account for both gestational weight patterns and pre-pregnancy nutritional status.

2. Methods

2.1 Study population

This study was a retrospective cohort study. The study population consisted of pregnant women who received regular prenatal care and delivered at Wenzhou Maternal and Child Health Care Hospital and The Second Affiliated Hospital of Wenzhou Medical University between January 1, 2022, and December 31, 2024. During the 2022-2024 period, the total number of deliveries in the two hospitals was 24,600 and 21,080, respectively, summing to 45,680.

The inclusion criteria were: singleton pregnancy; gestational age at delivery ≥ 28 weeks and ≤ 42 weeks; availability of complete and accurate records of pre-pregnancy weight, height, and pre-delivery weight; and complete data on key maternal and neonatal outcomes in the clinical records. The exclusion criteria were: multiple gestation; gestational age at delivery < 28 weeks or > 42 weeks; presence of diseases severely affecting weight metabolism (e.g., uncontrolled hyperthyroidism, chronic kidney disease, cancer); and fetus with known major congenital malformations or chromosomal abnormalities. Based on the above criteria, a total of 865 pregnant women with inadequate gestational weight gain were ultimately included as the study subjects (**Figure 1**). The sample size met the power requirements for statistical testing of the primary outcomes. Using cesarean delivery rate as a key outcome for estimation: assuming a cesarean rate of 50% in the overweight/obese group and 35% in the normal

weight group, with α=0.05 (two-sided) and β=0.2 (power=80%), the calculated minimum sample size per group was approximately 180. The sample sizes of the three groups in this study (underweight group: n=233; normal weight group: n=395; overweight/obese group: n=237) all exceeded this threshold, ensuring sufficient power to detect intergroup differences.

2.2 Study variables

Pre-pregnancy BMI (kg/m²) was calculated using weight and height obtained from premarital examinations. On average, the interval between the premarital examination and the first prenatal visit was 8.5 months. Women were categorized as underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), or obese (≥30.0 kg/m²) according to World Health Organization (WHO) criteria. Gestational age at birth was calculated as the completed weeks of gestation from the first day of the last menstrual period to the date of delivery.

GWG was defined as the difference in kilograms between the weight at the last prenatal visit and the weight at the first prenatal visit. Two different classification methods for GWG were used. First, GWG was categorized as below, within, or above the recommendations of the Institute of Medicine (IOM, 2009). The IOM-recommended weight gain ranges were 12.5–18 kg for underweight women, 11.5–16 kg for normal weight women, 7–11.5 kg for overweight women, and 5–9 kg for obese women. Second, GWG was divided into four groups: low (<10 kg), medium (10–15 kg), high (16–19 kg), or very high (≥20 kg).

2.3 Maternal outcomes

All data regarding maternal complications and pregnancy outcomes were collected from medical records, including prenatal visits and delivery records. Hypertensive disorders of pregnancy were recorded based on the most severe condition identified at each prenatal visit. Cesarean delivery included cesarean sections performed either before or during labor. This study excluded cesarean sections performed solely on maternal request without clinical indications; only cesarean deliveries with clear medical indications were included.

2.4 Neonatal outcomes

Neonatal outcome measures included birth weight and gestational age at birth. Based on birth weight, infants were categorized as low birth weight (LBW, <2500 g), macrosomia (≥4000 g), small-for-gestational-age (SGA, <10th percentile), or large-for-gestational-age (LGA, >90th percentile).

2.5 Statistical analysis

The chi-square test was used to assess differences in proportions. In multiple logistic regression models, categories of GWG and pre-pregnancy BMI were mutually adjusted to estimate their independent associations with various pregnancy outcomes and neonatal complications. These models were also adjusted for several maternal characteristics (including maternal age, parity, height, education

level, occupation, and region of residence) and gestational age at birth. Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. The interaction between GWG and pre-pregnancy BMI was assessed separately for all outcome measures. The statistical significance level for interactions was set at $P < 0.01$. Data analysis was performed using SPSS version 11.5 software (SPSS Inc., Chicago, USA).

3. Results

A total of 865 pregnant women with inadequate gestational weight gain (GWG) were included in this study. Based on pre-pregnancy body mass index (BMI), the participants were categorized into three groups: underweight (n=233), normal weight (n=395), and overweight or obese (n=237).

3.1 Gestational weight gain

As shown in Table 1, the median gestational weight gain (GWG) differed among the three groups. The underweight group demonstrated the highest median GWG (10.00 kg; interquartile range [IQR]: 8.00-10.00 kg), followed by the normal weight group (6.50 kg; IQR: 5.00-7.50 kg), while the overweight/obese group showed the lowest median GWG (4.00 kg; IQR: 2.00-5.75 kg). When compared to the lower limits of the Institute of Medicine (IOM) recommendations, all groups exhibited varying degrees of inadequate weight gain. The median GWG values were 2.50 kg, 5.00 kg, and 3.00 kg below the IOM recommendations for the underweight, normal weight, and overweight/obese groups, respectively.

3.2 Maternal baseline characteristics and pregnancy outcomes

Table 2 compares the baseline characteristics and pregnancy complications among the three groups. Significant differences were observed in maternal age ($P < 0.001$), mode of delivery ($P < 0.001$), and hypertensive disorders of pregnancy ($P < 0.001$) across the groups. Specifically, the overweight/obese group exhibited higher rates of both cesarean delivery (33.7%) and hypertensive disorders of pregnancy (56.7%) compared to the other two groups. The incidence of precipitate labor also differed significantly among the groups ($P = 0.017$), with the underweight group showing the lowest incidence (9.5%). Neonatal birth weight distribution demonstrated significant differences ($P = 0.02$), with the overweight/obese group having the highest incidence of macrosomia (60.0%), while the underweight group had the highest incidence of low birth weight (36.1%). No statistically significant differences were found for other indicators, including maternal height, preterm birth, anemia, or premature rupture of membranes.

3.3 Analysis of the association between pre-pregnancy BMI and pregnancy outcomes

Table 3 presents the results of the logistic regression analysis examining the associations between pre-pregnancy BMI status and pregnancy outcomes, using the normal weight group as the reference. The analysis includes both unadjusted odds ratios (ORs) and ORs adjusted for maternal age and total gestational weight gain (GWG).

The analysis revealed that pre-pregnancy overweight or obesity was a significant risk factor for cesarean delivery, with the association remaining statistically significant after adjustment for confounders (adjusted OR = 2.231, 95% CI: 1.553-3.206, P < 0.001). In contrast, no significant association was observed between pre-pregnancy underweight and cesarean delivery risk. For hypertensive disorders of pregnancy, the strongest association was found with overweight or obesity, yielding a substantially elevated risk after adjustment (adjusted OR = 4.221, 95% CI: 2.196-8.111, P < 0.001), while underweight showed no significant association.

Regarding precipitate labor, the unadjusted analysis suggested a potential protective effect of underweight (OR = 0.205, P < 0.05); however, this association was attenuated and lost statistical significance after adjustment. Conversely, adjusted analysis indicated that overweight or obesity was significantly associated with a reduced risk of precipitate labor (adjusted OR = 0.224, 95% CI: 0.061-0.822, P < 0.05).

In neonatal outcomes, pre-pregnancy underweight was identified as an independent risk factor for low birth weight, demonstrating a significant association after adjustment (adjusted OR = 2.779, 95% CI: 1.560-4.950, P < 0.001). Overweight or obesity showed no significant association with low birth weight. For macrosomia, the unadjusted analysis indicated an increased risk associated with overweight or obesity (OR = 3.255, P < 0.05), but this relationship was not statistically significant in the adjusted model. No significant association was found between underweight and macrosomia. For other outcomes, including preterm birth and dystocia, no significant associations were observed for either underweight or overweight/obesity compared to the normal weight group.

In summary, among women with inadequate GWG, pre-pregnancy BMI status demonstrates significant associations with specific maternal and neonatal outcomes. Overweight or obesity primarily elevates the risk of adverse maternal outcomes, including cesarean delivery and hypertensive disorders of pregnancy, along with a trend toward neonatal macrosomia. Conversely, underweight status is predominantly associated with an increased risk of neonatal low birth weight.

Discussion

This study, analyzing clinical data from 865 pregnant women with inadequate GWG, confirms that pre-pregnancy BMI is a key effect modifier influencing maternal and neonatal outcomes. Under the uniform condition of inadequate GWG, distinct pre-pregnancy BMI subgroups exhibited significantly heterogeneous risk profiles. Specifically, pre-pregnancy overweight/obesity significantly increased the risks of cesarean delivery (adjusted OR=2.231) and hypertensive disorders of pregnancy (adjusted OR=4.221), while pre-pregnancy underweight was an independent risk factor for neonatal low birth weight (adjusted OR=2.779). These findings indicate that inadequate GWG does not represent a homogeneous clinical condition; its health impacts are highly dependent on pre-pregnancy nutritional status. This challenges the existing GWG management paradigm and underscores the necessity of precise risk stratification based on pre-pregnancy BMI.

Previous studies have often treated inadequate GWG as a single risk factor or focused primarily on the synergistic effects of excessive GWG and obesity, failing to systematically uncover the risk differentials within the inadequate GWG population[2, 12]. The innovation of this study lies in its stratification by pre-pregnancy BMI, revealing unique risk patterns specific to the context of inadequate GWG. Importantly, we found that even with inadequate GWG, the maternal complication risks associated with pre-pregnancy overweight/obesity persisted significantly, and the risk impact of pre-pregnancy underweight on neonatal low birth weight was not mitigated. These findings highlight the central role of baseline pre-pregnancy status in GWG management, advancing the understanding of the complex relationship between GWG and pregnancy outcomes from a "holistic view" to a "stratified view."

The underlying mechanisms for these associations likely involve distinct physiological pathways. For individuals with pre-pregnancy overweight/obesity, inadequate GWG may fail to effectively reverse their inherent metabolic abnormalities, such as insulin resistance and chronic inflammation, which collectively form the pathological basis for the increased risks of hypertensive disorders and cesarean delivery[13, 14]. For those with pre-pregnancy underweight, inadequate GWG likely compounds maternal nutritional reserve deficiencies, impacting placental function and nutrient transport efficiency, thereby leading to fetal growth restriction[3]. Notably, the adjusted analysis showed a significantly reduced risk of precipitate labor in the overweight/obese group (adjusted OR=0.224). This phenomenon suggests that pre-pregnancy BMI might influence uterine contractility by affecting endocrine homeostasis (e.g., leptin levels), although the precise mechanisms require further investigation[15, 16].

The results of this study offer clear clinical guidance. They indicate that managing inadequate GWG requires a precision stratification strategy: for underweight pregnant women, clinical interventions should focus on nutritional reinforcement and preventing low birth weight; for overweight/obese pregnant women, emphasis should be placed on monitoring and managing hypertensive disorders and preparing for potential cesarean delivery. As a retrospective study unable to fully control for potential confounders like lifestyle during pregnancy, future prospective research incorporating detailed biomarker data is needed for validation. Based on this, designing and evaluating individualized intervention plans for different subgroups will be a key direction for advancing the development of a precise perinatal healthcare model.

Abbreviations

GWG: Gestational Weight Gain; ***BMI***: Body Mass Index; ***aOR***: adjusted Odds Ratio; ***CI***: Confidence Interval; ***LBW***: Low Birth Weight; ***WHO***: World Health Organization; ***IOM***: Institute of Medicine; ***SGA***: Small-for-Gestational-Age; ***LGA***: Large-for-Gestational-Age; ***OR***: Odds Ratio; ***IQR***: Interquartile Range; ***SPSS***: Statistical Product and Service Solutions.

Declarations

Ethics approval and consent to participate:In the current retrospective study, all participants provided written informed consent for the use of their data, while the study was approved by the ethics committee of the Wenzhou People's Hospital, according to the Declaration of Helsinki (approval no. KY-202602-009).

Consent for publication:Not applicable

Availability of data and materials: The datasets generated and/or analysed during the current study are not publicly available due to ethical and privacy restrictions, but are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: Zhu S participated in the concept and design. Chen B, HU X, and Lin M provided administrative support. Chen B, HU X, Lin M and Yuan W collected research materials. Chen B and Zhu S were responsible for collecting and organizing data, and working together with Zheng J to analyze and interpret the data. All authors participated in writing and proofreading the manuscript. Zheng J acted as guarantor.

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Tables

Table 1. Comparison of Gestational Weight Gain among Pregnant Women with Inadequate GWG by Pre-pregnancy BMI.

	Underweight (n=233)	Normal (n=395)	Overweight or obese (n=237)
GWG median (IQR) (kg)	10.00(8.00,10.00)	6.50(5.00,7.50)	4.00(2.00,5.75)
IOM-recommended lower limit (kg)	12.50	11.50	7.00
GWG deficit from IOM lower limit, median (kg)	2.50	5.00	3.00

Table 2. Cross-tabulation of BMI (Underweight / Normal / Overweight or Obese) with Maternal Baseline Characteristics, Obstetric Complications, Delivery Method, and Neonatal Weight.

	Underweight n(%)	Normal n(%)	Overweight or obese n(%)	P-value
Age(years)				<0.001
20	0(00.0)	2(50.0)	2(50.0)	
20-30	112(35.1)	143(44.8)	64(20.1)	
30-40	119(23.4)	229(45.0)	161(31.6)	
40	2(06.1)	21(63.6)	10(30.3)	
Height(cm)				0.159
150-159	99(24.9)	179(45.1)	119(30.0)	
160-169	126(28.6)	199(45.2)	115(26.1)	
170-179	8(28.6)	17(60.7)	3(10.7)	
Preterm Birth				0.096
Yes	27(22.9)	49(41.5)	42(35.6)	
No	206(27.6)	346(46.3)	195(26.1)	
Dystocia				0.797
Yes	13(27.1)	20(41.7)	15(31.3)	
No	220(26.9)	375(45.9)	222(27.2)	
Delivery method				<0.001
Vaginal delivery	117(30.5)	192(50.0)	75(19.5)	
Cesarean section	116(24.1)	203(42.2)	162(33.7)	
Hypertensive Disorders of Pregnancy				<0.001
Yes	9(15.0)	17(28.3)	34(56.7)	
No	224(27.8)	378(47.0)	203(25.2)	
Anemia				0.951
Yes	40(28.0)	64(44.8)	39(27.3)	
No	193(26.7)	331(45.8)	198(27.4)	
Premature Rupture of Membranes				0.664

Yes	37(24.2)	74(48.4)	42(27.5)	
No	196(27.5)	321(45.1)	195(27.4)	
Retained Products of Conception				0.189
Yes	26(28.3)	48(52.2)	18(19.6)	
No	207(26.8)	347(44.9)	219(28.3)	
Precipitate Labor				0.017
Yes	2(09.5)	16(76.2)	3(14.3)	
No	231(27.4)	379(44.9)	234(27.7)	
Gestational Diabetes Mellitus				0.691
Yes	27(25.2)	53(49.5)	27(25.2)	
No	206(27.2)	342(45.1)	210(27.7)	
Fetal Distress				0.145
Yes	25(36.2)	25(36.2)	19(27.5)	
No	208(26.1)	370(46.5)	218(27.4)	
Birth weight				0.02
Low Birth Weight Infant (LBW)	35(36.1)	32(33.0)	30(30.9)	
Normal Birth Weight Infant	197(26.2)	358(47.5)	198(26.3)	
Macrosomia	1(06.7)	5(33.3)	9(60.0)	

Note: Values are presented as the number of patients (composition ratio).

Table 3. Logistic regression analysis of pregnancy outcomes by pre-pregnancy BMI among women with inadequate gestational weight gain.

	Underweight		Overweight or obese	
	Unadjusted OR (95%CI)	**Adjusted OR (95%CI)**	**Unadjusted OR (95%CI)**	**Adjusted OR (95%CI)**
Cesarean section	0.938 (0.678,1.296)	0.863 (0.598,1.274)	2.043 (1.458,2.863)***	2.231 (1.553,3.206)***
Preterm Birth	0.926 (0.561,1.527)	1.134 (0.652,1.974)	1.521 (0.972,2.380)	1.343 (0.834,2.161)
Dystocia	1.108 (0.540,2.271)	0.963 (0.433,2.144)	1.267 (0.636,2.525)	1.383 (0.659,2.903)
Hypertensive Disorders of Pregnancy	0.893 (0.392,2.038)	0.771 (0.316,1.882)	3.724 (2.030,6.831)***	4.221 (2.196,8.111)***
Precipitate Labor	0.205 (0.047,0.900)*	0.307 (0.065,1.450)	0.304 (0.088,1.053)	0.224 (0.061,0.822)*
Birth weight				
LBW vs Normal	1.988 (1.194,3.310)**	2.779 (1.560,4.950)***	1.695 (1.000,2.873)	1.360 (0.782,2.366)
Macrosomia vs Normal	0.363 (0.042,3.133)	0.751 (0.080,7.049)	3.255 (1.076,9.845)*	2.051 (0.641,6.564)

Note: All analyses were conducted within the subgroup of pregnant women with inadequate gestational weight gain (n=865). Data are presented as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Binary logistic regression was used for the analysis. The adjusted model controlled for (was adjusted for) maternal age, and total gestational weight gain. The reference category is the normal pre-pregnancy BMI group. *p < 0.05, **p < 0.01, ***p < 0.001

Figures

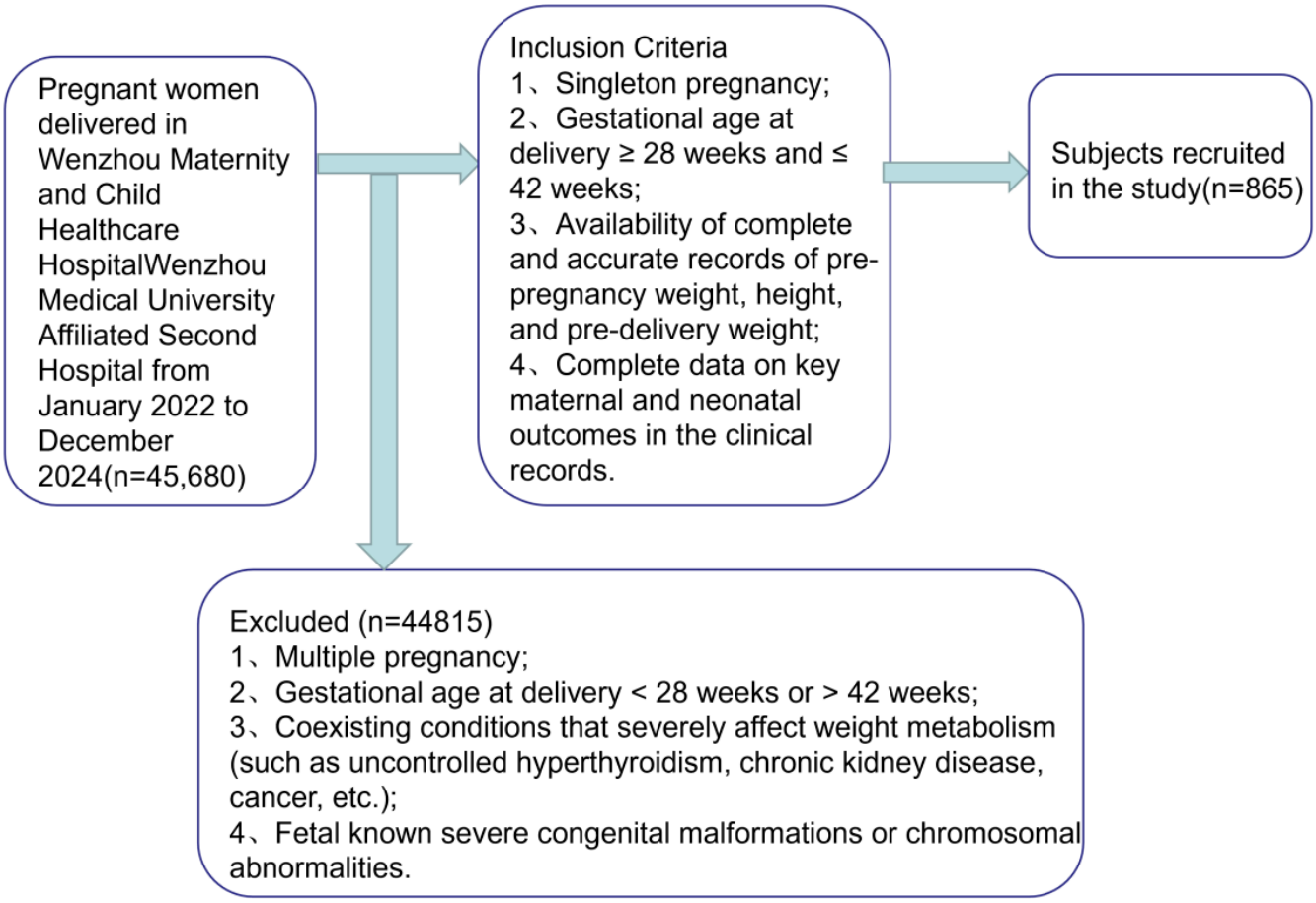


Figure 1

Flowchart showing enrollment in the study.