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Delivery mode and maternal-infant outcomes in women with class III obesity (BMI ≥ 40 kg/m²): a retrospective cohort study with propensity score matching

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Research Article

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Abstract

Background

Obesity has become a major global public health challenge, and class III obesity (BMI ≥ 40 kg/m²) during pregnancy poses exceptional clinical risks. The optimal mode of delivery for this population remains controversial. This study aimed to compare maternal and neonatal outcomes between vaginal delivery and cesarean section in women with class III obesity at delivery using propensity score matching (PSM).

Methods

This single-center retrospective cohort study included 177 singleton pregnant women with delivery BMI ≥ 40 kg/m² at Xuzhou Maternal and Child Health Hospital from January 2024 to June 2026. Participants were divided into vaginal delivery (n = 29) and cesarean section (n = 148) groups. PSM was performed using 1:2 nearest-neighbor matching without replacement, incorporating 14 baseline covariates with a caliper of 0.2 × SD. The primary outcome was postpartum hemorrhage (PPH) rate. Secondary outcomes included maternal hospital stay, MICU admission, neonatal birth weight, macrosomia, Apgar scores, neonatal asphyxia, and NICU admission. Sensitivity analysis (SA) used multivariable regression adjusting for residual imbalances in gravidity, parity, premature rupture of membranes, and hypertensive disorders.

Results

PSM successfully matched 87 cases (29 vaginal, 58 cesarean). After matching, most covariates achieved SMD < 0.10. The PPH rate was higher in the vaginal delivery group than in the cesarean group (44.8% vs. 1.7%; OR 46.31, 95% CI 5.63–381.30, P < 0.001), and the 5-min Apgar score was lower in the vaginal delivery group (β = −0.40, 95% CI − 0.66 to − 0.14, P = 0.003). Sensitivity analysis confirmed the robustness of these findings. No significant differences were observed in hospital stay, MICU admission, birth weight, macrosomia, neonatal asphyxia, or NICU admission.

Conclusions

In women with class III obesity (BMI ≥ 40 kg/m²), vaginal delivery was associated with a substantially increased risk of postpartum hemorrhage. After carefully weighing maternal and neonatal benefits and risks, planned cesarean delivery may be considered one of several clinical options; multicenter validation is warranted.

Background

Obesity has become a severe global public health challenge with a continuing upward trend [1]. The prevalence of obesity among women of reproductive age is rising in parallel, exerting significant impacts

on reproductive health and perinatal outcomes. Multiple studies have demonstrated a close association between obesity and adverse pregnancy outcomes, including hypertensive disorders of pregnancy, gestational diabetes mellitus (GDM), venous thromboembolism, increased cesarean delivery rates, and elevated risk of postpartum hemorrhage [2–5]. Body mass index (BMI), as a core indicator for assessing the degree of fat accumulation, has been widely used in clinical practice and epidemiological research; BMI ≥ 40 kg/m² is defined as class III obesity, also termed severe or morbid obesity [6].

This population faces particularly prominent clinical challenges during pregnancy and childbirth. On one hand, the excessively thickened abdominal fat layer can interfere with the accuracy of electronic fetal monitoring signal acquisition, increasing the difficulty of labor monitoring. On the other hand, abnormal accumulation of adipose tissue in the pelvic and perineal regions may lead to relative narrowing of the birth canal, obstruction of fetal head descent, prolonged labor, and increased need for operative delivery [6–8]. Furthermore, obese pregnant women are prone to fatty infiltration of the uterine myometrium, resulting in diminished physiological function of uterine smooth muscle cells and an increased incidence of uterine atony-related postpartum hemorrhage [8].

Regarding evidence-based decision-making for the optimal mode of delivery in obese women, no consensus has been reached. Some scholars advocate elective cesarean section as an effective strategy to reduce perinatal complications, arguing that it can effectively avoid birth canal trauma during vaginal delivery and reduce adverse maternal-fetal events associated with delayed emergency cesarean conversion and prolonged labor [9–10]. However, opponents emphasize the inherent surgical risks of cesarean delivery, including increased intraoperative blood loss, poor wound healing, postoperative ileus, thromboembolism, and transient tachypnea of the newborn [11–14]. Most previous studies have focused on pre-pregnancy BMI or early pregnancy BMI, with few dedicated studies on the specific population with delivery BMI ≥ 40 kg/m², and existing literature generally suffers from methodological limitations such as small sample sizes and inadequate confounding control.

In recent years, propensity score matching (PSM), an advanced statistical method for controlling selection bias and confounding bias in observational studies, has been widely applied in clinical epidemiology [15]. PSM constructs a multivariable logistic regression model to estimate the conditional probability (i.e., propensity score) of each study subject receiving the "treatment" (in this study, a specific mode of delivery), and pairs or stratifies subjects with similar propensity scores, thereby achieving an approximately randomized balance in the distribution of baseline covariates between the treatment and control groups [16]. This method can effectively simulate the design advantages of randomized controlled trials, improve the credibility of causal inference, and is particularly suitable for clinical scenarios where random allocation is not feasible [15–16].

Based on the above background, this study aimed to compare the differences in maternal and neonatal outcomes between vaginal delivery and cesarean section in women with severe obesity (delivery BMI ≥ 40 kg/m²), with a focus on the distribution of key outcome indicators such as postpartum hemorrhage

and neonatal asphyxia, in order to provide evidence-based medical evidence for clinical decision-making in this special population.

Methods

Study design and setting

This study adopted a single-center retrospective cohort study design, and its research protocol was approved by the Ethics Committee of our hospital (Approval No.: XZFY2026-08-005K-01(J)). Given the retrospective nature of data collection, the requirement for informed consent was waived. Singleton pregnant women with delivery BMI ≥ 40 kg/m² who delivered at Xuzhou Maternal and Child Health Hospital from January 1, 2024 to June 30, 2026 were included. Delivery BMI was calculated using the measured height (cm) and weight (kg) at the time of admission for labor (or before cesarean section), using the formula BMI = weight/height². Inclusion criteria were: (1) singleton pregnancy; (2) delivery BMI ≥ 40 kg/m²; (3) gestational age ≥ 28 weeks; (4) complete and traceable clinical records. Exclusion criteria were: (1) multiple pregnancy; (2) stillbirth or known major fetal structural anomalies/chromosomal abnormalities; (3) severe medical or surgical comorbidities (e.g., uncontrolled heart failure, end-stage renal disease, acute liver failure) precluding any mode of delivery; (4) transfer to another hospital or severely missing delivery records.

A total of 177 eligible women were included and divided into the vaginal delivery group (29 cases, including spontaneous and instrumental delivery) and the cesarean section group (148 cases, including elective and emergency cesarean delivery).

Propensity score matching strategy

To minimize the interference of selection bias on causal inference, PSM was employed to balance baseline confounders. First, a multivariable unconditional logistic regression model was used to construct the propensity score estimation model, with mode of delivery (vaginal delivery = 1, cesarean section = 0) as the dependent variable and the following 14 baseline covariates as independent variables: age, height, pre-pregnancy BMI, gestational weight gain, gestational age, gravidity, parity, pregestational diabetes mellitus (PGDM), GDM, premature rupture of membranes, preeclampsia, hypothyroidism, scarred uterus, and hypertensive disorders (including chronic hypertension and/or gestational hypertension). The univariate associations of each covariate with mode of delivery are presented in Supplementary Table S1.

The matching algorithm used 1:2 nearest-neighbor matching without replacement (vaginal delivery: cesarean section), with a caliper width set at 0.2 times the standard deviation of the logit-transformed propensity score; all 58 cesarean controls were independent individuals and no control was reused. Matching quality was evaluated using the standardized mean difference (SMD) for each covariate, with

|SMD| < 0.1 considered as good balance, and Love plot visualization showing the change in SMD before and after matching.

Outcome measures

Primary outcome: incidence of postpartum hemorrhage (PPH). According to the definitions of the World Health Organization (WHO) and the Chinese Society of Obstetrics and Gynecology, PPH was defined as vaginal bleeding ≥ 500 mL within 24 hours after vaginal delivery, or blood loss ≥ 1000 mL during cesarean section.

Secondary outcomes included: (1) postpartum hospital stay (days); (2) maternal intensive care unit (MICU) admission rate (%); (3) neonatal birth weight (g); (4) macrosomia rate (birth weight ≥ 4000 g); (5) Apgar scores at 1 and 5 minutes; (6) neonatal asphyxia rate (Apgar score ≤ 7 at 1 minute or ≤ 7 at 5 minutes); (7) neonatal intensive care unit (NICU) admission rate (%).

Statistical analysis

All statistical analyses were performed using Python 3.13 (Python Software Foundation), primarily utilizing the statsmodels 0.14.6 and SciPy 1.18.0 packages. Statistical inference was based primarily on the clinical significance of effect estimates and their 95% CIs rather than on P values alone: P values only reflect the probability that a difference arises from sampling error, whereas effect estimates and CIs provide quantitative information on the strength and precision of associations, serving as the principal basis for assessing clinical relevance. A two-sided $P < 0.05$ was used only as an auxiliary reference for statistical significance. Continuous variables were assessed for normality using the Shapiro-Wilk test: normally distributed data were expressed as Mean ± SD and compared using independent t-test (equal variance) or Welch t-test (unequal variance); non-normally distributed data were expressed as Median (IQR) and compared using the Mann-Whitney U test. Categorical variables were expressed as n (%) and compared using the chi-square test or Fisher exact test, depending on expected frequencies.

Propensity score matching (PSM): Mode of delivery (vaginal delivery = 1, cesarean section = 0) was used as the dependent variable, and a multivariable unconditional logistic regression model was used to estimate propensity scores, incorporating 14 baseline covariates: age, height, pre-pregnancy BMI, gestational weight gain, gestational age, gravidity, parity, PGDM, GDM, premature rupture of membranes, preeclampsia, hypothyroidism, scarred uterus, and hypertensive disorders. The matching algorithm used 1:2 nearest-neighbor matching without replacement, with a caliper of 0.2 × SD(logit PS). Each cesarean control was an independent individual and no control was reused; all 29 vaginal delivery cases were matched to 58 independent cesarean controls. Matching quality was assessed primarily by SMD: $|SMD| < 0.10$ indicated good balance, $0.10 \leq |SMD| < 0.20$ indicated mild residual imbalance (acceptable), and $|SMD| > 0.20$ indicated significant residual imbalance requiring adjustment in sensitivity analysis.

Outcome effect estimation was performed in the matched cohort. Binary outcomes were reported as odds ratios (OR) with 95% confidence intervals (CI), and continuous variables as mean differences (β) with 95% CI. Multiple comparisons were corrected using the Benjamini-Hochberg false discovery rate (FDR) method. As this was an exploratory retrospective study, no a priori sample size calculation was performed. Given the rarity of the delivery BMI ≥ 40 kg/m² population, all eligible cases during the study period were included. In the matched cohort, 87 independent individuals (29 vaginal delivery and 58 cesarean) were included in the outcome analyses. Missing data: all variables had < 5% missing rates, and complete-case analysis was used without imputation.

Sensitivity analysis (SA): To control for notable residual imbalance after matching (|SMD| > 0.20), multivariable regression models were fitted in the matched cohort with the outcome variable as the dependent variable and gravidity, parity, premature rupture of membranes, and hypertensive disorders as covariates (logistic regression for binary outcomes; linear regression for continuous outcomes). Both the unadjusted model (main analysis, with the group variable only) and the SA-adjusted model (with the group variable and the four covariates) were reported with effect estimates and 95% CI. If the adjusted effect estimates were consistent with the main analysis in direction, significance, and magnitude, the conclusions were considered robust.

Results

Study population and baseline characteristics

During the study period, 221 women with delivery BMI ≥ 40 kg/m² delivered at our hospital. After strict application of the inclusion and exclusion criteria, 177 eligible subjects were included in the analysis cohort. Among them, 29 (16.4%) were in the vaginal delivery group and 148 (83.6%) were in the cesarean section group. Before PSM, the two groups were unbalanced across age, gestational age, premature rupture of membranes, preeclampsia, hypertensive disorders, and scarred uterus (Table 1); after FDR adjustment, differences in gestational age, premature rupture of membranes, hypertensive disorders, and scarred uterus remained statistically significant, indicating selection bias in the original cohort (Fig. 1).

Table 1
Baseline characteristics before PSM (N = 177)

Variable	Cesarean (n = 148)	Vaginal delivery (n = 29)	Mean diff/OR (95% CI)	P value	P_adj (FDR)
Age (years)	30.50 (26.75 ~ 35.00)	29.00 (24.00 ~ 31.00)	2.43 (0.43, 4.42)	0.029*	0.090
Height (cm)	163.00 (159.50 ~ 166.00)	163.00 (160.00 ~ 168.00)	-1.26 (-3.23, 0.71)	0.269	0.524
Pre-pregnancy weight (kg)	93.94 ± 11.40	95.28 ± 12.97	-1.33 (-5.98, 3.31)	0.574	0.855
Pre-pregnancy BMI	35.46 ± 3.82	35.39 ± 4.25	0.07 (-1.48, 1.62)	0.517	0.855
Delivery weight (kg)	114.02 ± 9.67	116.09 ± 10.73	-2.07 (-5.98, 1.85)	0.277	0.524
Delivery BMI	42.17 (41.04 ~ 44.44)	42.19 (41.02 ~ 44.47)	-0.11 (-1.23, 1.02)	0.973	0.973
Gestational weight gain (kg)	20.08 ± 8.48	20.81 ± 7.73	-0.73 (-4.06, 2.60)	0.667	0.855
Gravidity	2.00 (1.00 ~ 3.00)	2.00 (1.00 ~ 3.00)	0.23 (-0.36, 0.81)	0.727	0.855
Parity	0.00 (0.00 ~ 1.00)	1.00 (0.00 ~ 1.00)	-0.02 (-0.40, 0.36)	0.649	0.855
Gestational age	38.86 (37.86 ~ 39.43)	39.57 (39.00 ~ 40.00)	-0.92 (-1.52, -0.32)	< 0.001*	0.003*
Comorbidities					
PGDM	17 (11.5)	4 (13.8)	OR = 0.81	0.754	0.855
GDM	60 (40.5)	16 (55.2)	OR = 0.55	0.145	0.353
PROM	20 (13.5)	11 (37.9)	OR = 0.26	0.002*	0.009*
Preeclampsia	29 (19.6)	1 (3.4)	OR = 6.82	0.032*	0.090
Hypothyroidism	28 (18.9)	5 (17.2)	OR = 1.12	0.832	0.884
Hypertensive disorders	47 (31.8)	2 (6.9)	OR = 6.28	0.006*	0.026*
Scarred uterus	58 (39.2)	2 (6.9)	OR = 8.70	< 0.001*	0.007*

*Data are presented as Mean ± SD, Median (IQR), or n (%). Continuous variables: independent t-test (equal variance) or Welch t-test (unequal variance) for normal distribution; Mann-Whitney U test for non-normal distribution. Categorical variables: chi-square test or Fisher exact test. P_adj: Benjamini-Hochberg FDR-adjusted P value. Hypertensive disorders = chronic hypertension and/or gestational hypertension; Scarred uterus = previous cesarean section or myomectomy. *P < 0.05. PSM = propensity score matching; SMD = standardized mean difference; PGDM = pregestational diabetes mellitus; GDM = gestational diabetes mellitus.*

High cesarean rate and influencing factors before matching

Among the 177 women with class III obesity (delivery BMI ≥ 40 kg/m²), the cesarean delivery rate was 83.6% (148/177), far exceeding the overall cesarean rate at our institution during the same period. Pre-PSM baseline comparison (Table 1) showed that scarred uterus had the strongest association with cesarean delivery (39.2% vs 6.9%, OR = 8.70, P_adj = 0.007). Preeclampsia and hypertensive disorders, as relative medical indications for cesarean delivery, reduced the probability of trial of labor, whereas premature rupture of membranes (P_adj = 0.009) promoted spontaneous labor and vaginal delivery. These factors constituted typical "confounding by indication," which was the core rationale for using PSM to balance baseline characteristics.

After 1:2 nearest-neighbor matching, all 29 vaginal delivery cases were successfully matched to 58 cesarean delivery cases. After matching, the balance of most covariates improved significantly (Table 2, Fig. 2); gravidity, parity, premature rupture of membranes, and hypertensive disorders still showed residual imbalance (|SMD| > 0.20), which was addressed through multivariable regression adjustment in the sensitivity analysis. The SMD values for all covariates before and after matching are detailed in Supplementary Table 2.

Table 2
Baseline characteristics after PSM (N = 87)

Variable	Cesarean (n = 58)	Vaginal delivery (n = 29)	SMD	P value
Age (years)	27.69 ± 4.39	27.90 ± 4.74	-0.045	0.841
Height (cm)	164.13 ± 5.15	163.97 ± 4.95	0.032	0.888
Pre-pregnancy weight (kg)	94.44 ± 12.38	95.28 ± 12.97	-0.066	0.771
Pre-pregnancy BMI (kg/m²)	35.00 ± 3.93	35.39 ± 4.25	-0.095	0.975
Delivery weight (kg)	114.82 ± 10.39	116.09 ± 10.72	-0.121	0.468
Delivery BMI (kg/m²)	41.81 (40.63–42.93)	42.19 (41.02–44.47)	-0.189	0.280
Gestational weight gain (kg)	20.38 ± 8.67	20.81 ± 7.73	-0.053	0.819
Gravidity	1.50 (1.00–2.00)	2.00 (1.00–3.00)	-0.323	0.043
Parity	0.00 (0.00–0.00)	1.00 (0.00–1.00)	-0.380	0.004
Gestational age (weeks)	39.29 (38.75–40.00)	39.57 (39.00–40.00)	-0.149	0.479
Comorbidities				
PGDM	6 (10.3)	4 (13.8)	-0.105	0.725
GDM	27 (46.6)	16 (55.2)	-0.171	0.448
PROM	15 (25.9)	11 (37.9)	-0.258	0.246
Preeclampsia	2 (3.4)	1 (3.4)	0.000	1.000
Hypothyroidism	9 (15.5)	5 (17.2)	-0.046	1.000
Hypertensive disorders	8 (13.8)	2 (6.9)	0.225	0.485
Scarred uterus	3 (5.2)	2 (6.9)	-0.072	1.000

PSM = propensity score matching; SMD = standardized mean difference. Matching method: 1:2 nearest-neighbor matching without replacement, caliper = 0.2 × SD(logit PS); all 58 cesarean controls were independent individuals. Continuous variables presented as Mean ± SD or Median (IQR); categorical variables as n (%). Continuous variables compared by t-test or Mann-Whitney U test; categorical variables by χ^2 test or Fisher exact test. |SMD| < 0.10 indicates good balance.

Maternal outcomes

Table 3 presents the comparison of pregnancy outcomes after matching. In the matched cohort, the PPH rate in the vaginal delivery group was approximately 26-fold higher than that in the cesarean group

(44.8% vs 1.7%; OR 46.31, 95% CI 5.63–381.30): a total of 14 PPH events occurred (16.1%), including 13 (44.8%) in the vaginal delivery group and 1 (1.7%) in the cesarean group. There were no significant differences in hospital stay or MICU admission rate between the two groups (FDR-adjusted P > 0.05) (Fig. 3).

Neonatal outcomes

No significant differences were observed in neonatal birth weight or macrosomia rate between the two groups. Apgar 5-minute scores were significantly lower in the vaginal delivery group (β = -0.40, 95% CI -0.66 to -0.14, P = 0.003). Apgar 1-minute scores did not differ significantly between groups (β = -0.21, 95% CI -0.43 to 0.02, P = 0.075) and remained non-significant after sensitivity-analysis adjustment (β = -0.22, 95% CI -0.46 to 0.02, P = 0.074). Neonatal asphyxia rate and NICU admission rate also showed no significant differences between groups.

Table 3
Comparison of pregnancy outcomes after PSM

Outcome	Cesarean (n = 58)	Vaginal delivery (n = 29)	OR/Mean diff (95% CI)	P value	P_adj (FDR)
Binary outcomes					
Postpartum hemorrhage	1 (1.7)	13 (44.8)	46.31 (5.63, 381.30)	< 0.001*	0.004*
Macrosomia	17 (29.3)	5 (17.2)	0.50 (0.16, 1.54)	0.227	0.372
Asphyxia	1 (1.7)	2 (6.9)	4.22 (0.37, 48.62)	0.248	0.372
MICU admission	1 (1.7)	1 (3.4)	2.04 (0.12, 33.76)	0.620	0.636
NICU admission	6 (10.3)	4 (13.8)	1.39 (0.36, 5.36)	0.636	0.636
Continuous outcomes					
Birth weight	3669.31 ± 567.27	3598.28 ± 429.82	-71.03 (-308.88, 166.81)	0.554	0.636
Apgar 1 min	9.00 (9.00 ~ 9.00)	9.00 (9.00 ~ 9.00)	-0.21 (-0.43, 0.02)	0.075	0.225
Apgar 5 min	10.00 (9.00 ~ 10.00)	9.00 (9.00 ~ 10.00)	-0.40 (-0.66, -0.14)	0.003*	0.014*
Hospital stay (days)	7.00 (6.00 ~ 8.00)	5.00 (4.00 ~ 8.00)	-1.07 (-2.78, 0.65)	0.218	0.372

Cesarean group n = 58; vaginal delivery group n = 29 (independent matched samples). Continuous variables are presented as Mean ± SD or Median (IQR). Binary outcomes were analyzed by logistic regression and continuous outcomes by linear regression, reporting OR or mean difference β (95% CI). P_adj: Benjamini-Hochberg FDR-adjusted P value. OR = odds ratio; CI = confidence interval; MICU = maternal intensive care unit; NICU = neonatal intensive care unit; FDR = false discovery rate.

Sensitivity analysis

In the sensitivity analysis, gravidity, parity, premature rupture of membranes, and hypertensive disorders were included as covariates in multivariable regression models (Table 4). The OR for PPH increased further after adjustment (46.31 → 51.66), and the between-group difference in Apgar 5-minute scores remained significant after adjustment (β = -0.40 → -0.43, both $P < 0.01$). Apgar 1-minute scores, hospital stay, macrosomia, birth weight, neonatal asphyxia, MICU admission, and NICU admission showed no statistically significant between-group differences after adjustment. The direction, significance, and magnitude of the effect estimates were consistent between the main and sensitivity analyses, indicating that the conclusions were robust.

Table 4
Effect estimates for pregnancy outcomes: main analysis and sensitivity analysis (SA)

Outcome variable	Cesarean (n = 58)	Vaginal delivery (n = 29)	Unadjusted model (main analysis)	Unadjusted model (main analysis)	SA adjusted model	SA adjusted model
			Effect size (95% CI)	P value	Effect size (95% CI)	P value
PPH (OR, 95% CI)	1/58 (1.7)	13/29 (44.8)	46.31 (5.63, 381.30)	< 0.001	51.66 (5.77, 462.66)	< 0.001
MICU admission (OR, 95% CI)	1/58 (1.7)	1/29 (3.4)	2.04 (0.12, 33.76)	0.620	3.29 (0.18, 61.18)	0.425
PPH volume, mL (β, 95% CI)	534.8 ± 111.8	609.0 ± 274.9	74.14 (-8.35, 156.63)	0.078	74.98 (-11.47, 161.43)	0.088
Hospital stay, d (β, 95% CI)	7.8 ± 3.8	6.7 ± 3.7	-1.07 (-2.78, 0.65)	0.218	-1.17 (-2.84, 0.49)	0.165
Macrosomia (OR, 95% CI)	17/58 (29.3)	5/29 (17.2)	0.50 (0.16, 1.54)	0.227	0.54 (0.17, 1.72)	0.298
Neonatal asphyxia (OR, 95% CI)	1/58 (1.7)	2/29 (6.9)	4.22 (0.37, 48.62)	0.248	8.03 (0.64, 100.69)	0.106
NICU admission (OR, 95% CI)	6/58 (10.3)	4/29 (13.8)	1.39 (0.36, 5.36)	0.636	1.63 (0.39, 6.81)	0.500
Birth weight, g (β, 95% CI)	3669.3 ± 567.3	3598.3 ± 429.8	-71.03 (-308.88, 166.81)	0.554	-28.06 (-272.58, 216.45)	0.820
Apgar 1 min (β, 95% CI)	8.9 ± 0.4	8.7 ± 0.7	-0.21 (-0.43, 0.02)	0.075	-0.22 (-0.46, 0.02)	0.074
Apgar 5 min (β, 95% CI)	9.7 ± 0.5	9.3 ± 0.7	-0.40 (-0.66, -0.14)	0.003	-0.43 (-0.70, -0.15)	0.003

SA = sensitivity analysis. The SA-adjusted model included gravidity, parity, premature rupture of membranes, and hypertensive disorders as covariates (logistic regression for binary outcomes; linear regression for continuous outcomes). Cesarean group, n = 58. Vaginal delivery group, n = 29.

Discussion

This study used PSM to compare maternal and neonatal outcomes of different delivery modes in women with class III obesity (delivery BMI ≥ 40 kg/m²) and found that the PPH rate in the vaginal delivery group was approximately 26-fold higher than that in the cesarean group (44.8% vs 1.7%; OR 46.31, 95% CI 5.63–381.30) and that the 5-min Apgar score was lower (β = −0.40, 95% CI − 0.66 to − 0.14), with the core findings confirmed as robust by sensitivity analysis. These findings have important implications for clinical practice. Postpartum hemorrhage is the leading cause of maternal mortality, and obesity is an independent risk factor [5]. In this study, the PPH rate in the vaginal delivery group was 44.8%, far exceeding the general population level [17–18]. This effect was further strengthened after adjusting for gravidity, parity, premature rupture of membranes, and hypertensive disorders, suggesting that it was not driven by residual confounding but was closely related to the interaction between vaginal delivery itself and obesity.

Common causes of postpartum hemorrhage include uterine atony, genital tract trauma, retained placenta, and coagulopathy [19]. The mechanisms of PPH in obese pregnant women include: long-term obesity can lead to dysregulation of adipokine secretion, which in turn downregulates the expression of oxytocin receptors on uterine smooth muscle cells and interferes with calcium-dependent excitation-contraction coupling, impairing effective uterine contractility [20]; overweight or obese pregnant women have significantly increased risks of GDM and hypertensive disorders of pregnancy, which can induce systemic vascular endothelial damage, platelet dysfunction, and coagulation-fibrinolysis system imbalance, increasing susceptibility to PPH [21–22]; abdominal fat accumulation can lead to unclear uterine fundal palpation and reduced effectiveness of uterine massage, increasing the difficulty of hemostatic interventions [23]. In this study, the PPH rate in the cesarean group was only 1.7%, not because cesarean delivery itself prevents hemorrhage, but because it allows direct visualization of uterine contraction and immediate intervention, a technical advantage that is particularly critical in obese women.

Apgar 5-minute scores were significantly lower in the vaginal delivery group, and the between-group difference remained significant after sensitivity-analysis adjustment (β = −0.40 → −0.43, both $P < 0.01$), indicating robust findings. Apgar 1-minute scores showed no statistically significant difference in either the unadjusted (β = −0.21, 95% CI − 0.43 to 0.02, $P = 0.075$) or the adjusted model (β = −0.22, 95% CI − 0.46 to 0.02, $P = 0.074$). The lower Apgar scores in the vaginal delivery group may be related to birth canal compression and intermittent hypoxic stress during vaginal delivery; however, the absence of significant differences in neonatal asphyxia and NICU admission rates suggests that the clinical significance of this score difference is limited. Given the small sample size, statistical power for low-event outcomes such as MICU admission, NICU admission, and neonatal asphyxia was insufficient, warranting validation in larger samples.

This study used 1:2 nearest-neighbor PSM without replacement to balance baseline confounders, achieving overall good balance across the 14 covariates (most |SMD| < 0.10), and supplemented it with

multivariable regression in the sensitivity analysis to control residual confounding—a design well suited to small-sample observational studies. Although PSM balanced the measured covariates, matching can only control measured confounders; unmeasured confounders (e.g., analgesic modality, intrapartum medication, and clinicians' decision preferences) may still exist, and the results should be interpreted as strong associations rather than causal evidence. In addition, the vaginal delivery group comprised only 29 cases, yielding limited statistical power for some outcomes, and the 95% CI of the OR for PPH was wide (5.63–381.30); the single-center design also limits generalizability. These conclusions warrant validation in multicenter, large-sample prospective studies.

Conclusions

This study demonstrated that in women with class III obesity (delivery BMI ≥ 40 kg/m²), vaginal delivery was associated with a significantly increased risk of postpartum hemorrhage (44.8% vs 1.7%; OR 46.31, 95% CI 5.63–381.30). After carefully weighing maternal and neonatal benefits and risks, planned cesarean delivery may be considered one of several clinical options, especially for women with high-risk comorbidities such as preeclampsia or diabetes. Clinical decision-making should follow the principle of individualization, with delivery plans jointly developed by a multidisciplinary team and the parturient; multicenter validation is warranted.

Abbreviations

BMI
Body Mass Index
PSM
Propensity Score Matching
SA
Sensitivity Analysis
SMD
Standardized Mean Difference
PPH
Postpartum Hemorrhage
PGDM
Pregestational Diabetes Mellitus
GDM
Gestational Diabetes Mellitus
MICU
Maternal Intensive Care Unit
NICU
Neonatal Intensive Care Unit
OR
Odds Ratio

CI
Confidence Interval
FDR
False Discovery Rate
IQR
Interquartile Range
SD
Standard Deviation
WHO
World Health Organization
ACOG
American College of Obstetricians and Gynecologists

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Xuzhou Maternal and Child Health Hospital (Approval No.: XZFY2026-08-005K-01(J)). Given the retrospective nature of data collection, the requirement for informed consent was waived.

Consent for publication

Not applicable.

STROBE statement

This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational cohort studies. A completed STROBE checklist is provided as Supplementary Material (Additional file 2).

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. Supplementary materials (Supplementary Table S1: propensity score model coefficients; Supplementary Table S2: SMD summary before and after matching) are provided as Additional file 1.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YYC designed the study, collected and analyzed the data, and drafted the manuscript. ML participated in clinical interpretation, and contributed to study design as well as critical revision of the manuscript. All authors have read and approved the final version of the manuscript.

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YYC and ML are obstetricians at the Department of Obstetrics, Xuzhou Maternal and Child Health Hospital, with clinical and research interests in high-risk pregnancy management, particularly obesity-related peripartum care.

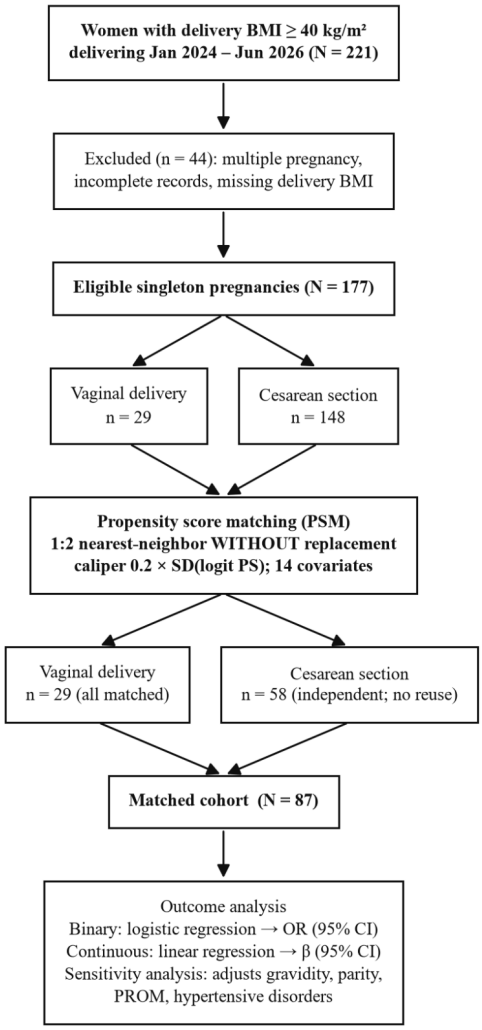
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Figures



PSM = propensity score matching; SD = standard deviation; OR = odds ratio; CI = confidence interval; PROM = premature rupture of membranes.

Figure 1

Study flow diagram. From 221 women with delivery BMI ≥ 40 kg/m² screened, 44 were excluded (multiple pregnancy, incomplete records, or BMI not recorded at delivery). Of the 177 eligible participants, 29 underwent vaginal delivery and 148 underwent cesarean section. Propensity score matching (1:2 nearest-neighbor without replacement, 14 covariates, caliper = 0.2 × SD) yielded a matched cohort of 87 (29 vaginal, 58 cesarean).

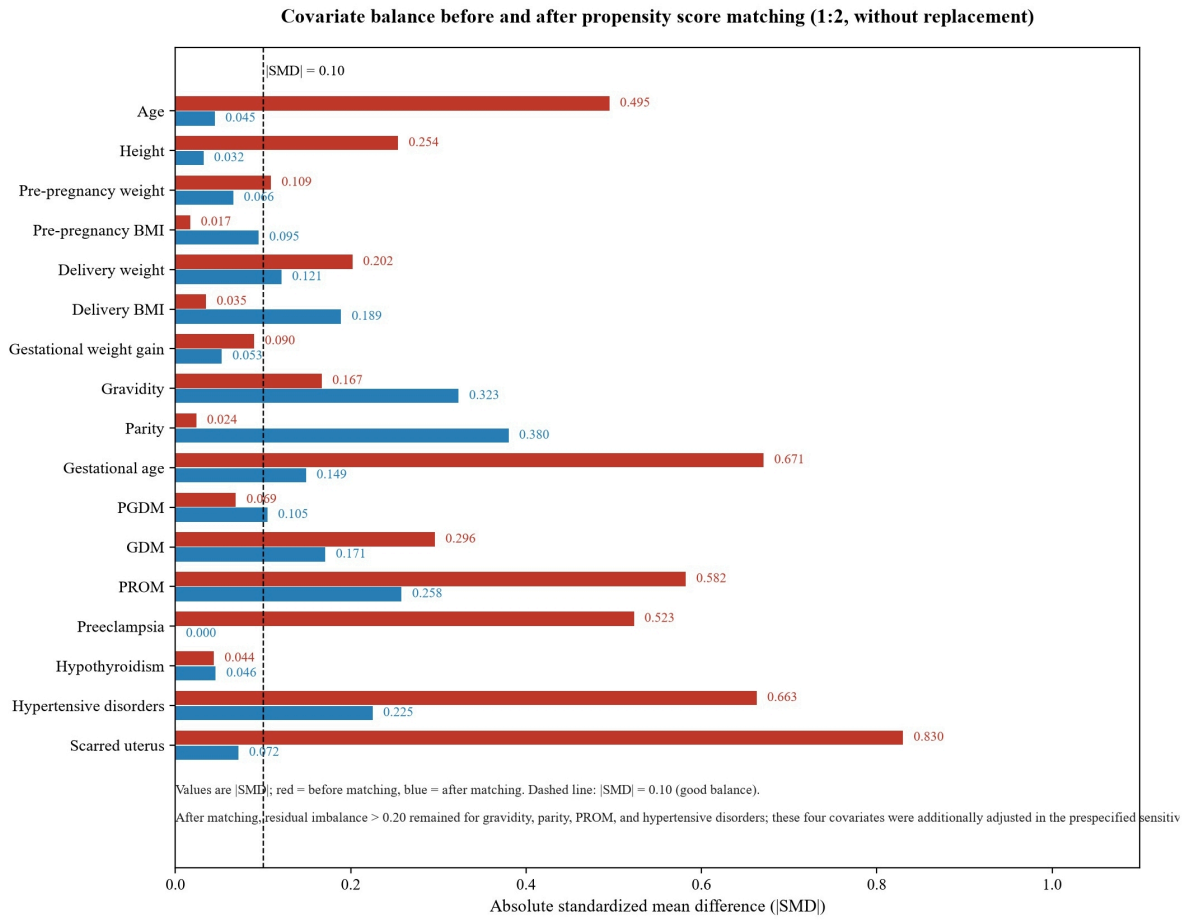
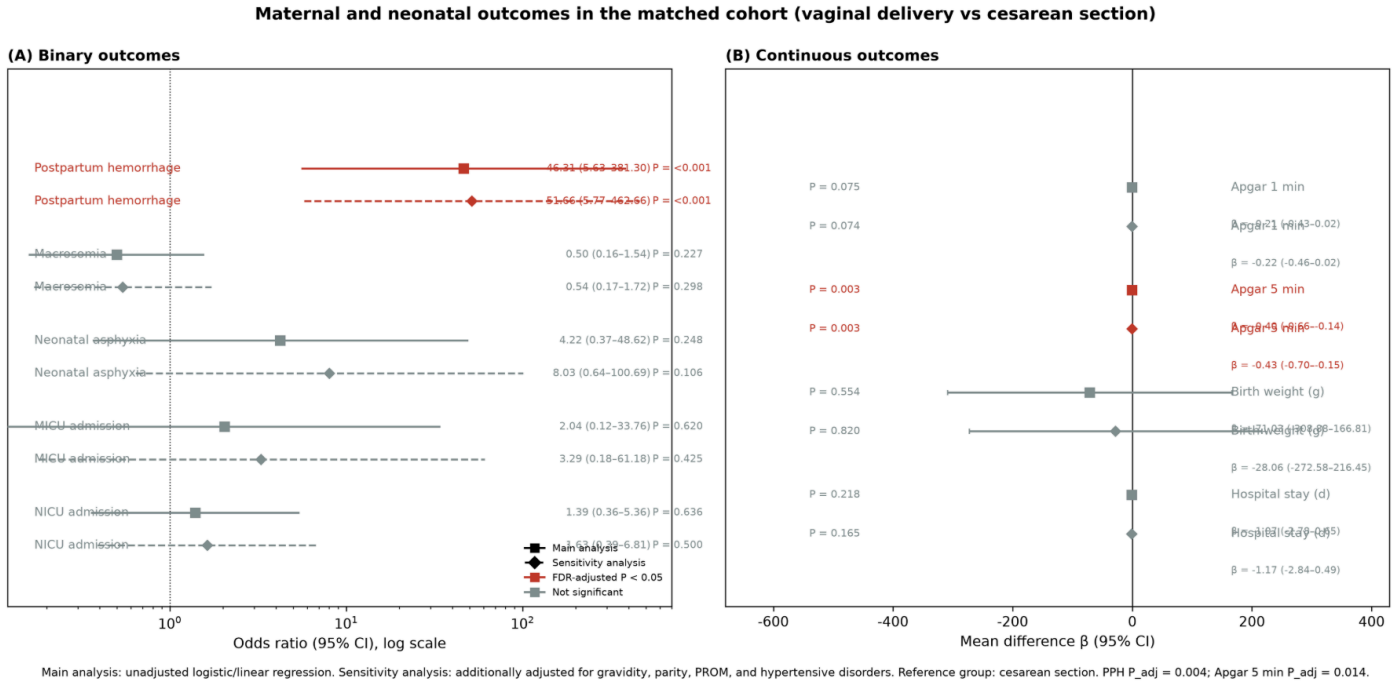


Figure 2

Covariate balance diagnostics (Love plot) before and after propensity score matching. Red bars represent absolute standardized mean differences (|SMD|) before matching; blue bars represent |SMD| after matching. The dashed vertical line at |SMD| = 0.1 indicates the threshold for acceptable balance. Before matching, multiple covariates (scarred uterus, hypertensive disorders, preeclampsia, PROM, gestational age) showed substantial imbalance (|SMD| > 0.1). After matching, most covariates achieved |SMD| < 0.1, although residual imbalance remained for gravidity, parity, PROM, and hypertensive disorders, which were addressed in the sensitivity analysis.



Main analysis: unadjusted logistic/linear regression. Sensitivity analysis: additionally adjusted for gravidity, parity, PROM, and hypertensive disorders. Reference group: cesarean section. PPH P_adj = 0.004; Apgar 5 min P_adj = 0.014.

Figure 3

Forest plot of maternal and neonatal outcomes after propensity score matching. (A) Binary outcomes presented as odds ratios (OR) with 95% confidence intervals on a log scale. (B) Continuous outcomes presented as mean differences (β) with 95% confidence intervals. Squares represent the main analysis (unadjusted logistic/linear regression); diamonds represent the sensitivity analysis (multivariable regression). Red markers indicate statistical significance (FDR-adjusted P < 0.05); grey markers indicate non-significance. The reference group is cesarean section; vaginal delivery is the index group. PPH = postpartum hemorrhage; MICU = maternal intensive care unit; NICU = neonatal intensive care unit.