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Development and external validation of clinical predictive model for stress urinary incontinence in Chinese women : a multicenter retrospective study

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Abstract

Background Stress urinary incontinence (SUI), the prevalent form of urinary incontinence, significantly impairs women's quality of life. This study aims to create a visual nomogram to estimate the risk of SUI within one year postpartum for early intervention in high-risk Chinese women.

Methods We recruited 1,531 postpartum women who gave birth at two hospitals in Kunshan City from 2021 to 2022. Delivery details were meticulously extracted from the hospitals' medical records system, while one-year postpartum follow-ups were conducted via phone surveys specifically designed to ascertain SUI status. Utilizing data from one hospital as the training set, logistic regression analysis was performed to pinpoint significant factors and subsequently construct the nomogram. To ensure robustness, an independent dataset sourced from the second hospital served as the external validation cohort. The model's performance was rigorously evaluated using calibration plots, ROC curves, AUC values, and DCA curves.

Results The study population was 1,125 women. The SUI incidence within one year postpartum was 26% (293/1125). According to the regression analysis, height, pre-pregnancy BMI, method of induction, mode of delivery, perineal condition, neonatal weight, SUI during pregnancy, and SUI during the first pregnancy were incorporated into the nomogram. The AUC of the nomogram was 0.829 (95% CI 0.790–0.867), and the external validation set was 0.746 (95% CI 0.689–0.804). Subgroup analysis based on parity showed good discrimination. The calibration curve indicated concordance. The DCA curve showed a significant net benefit.

Conclusion Drawing from real-world data, we have successfully developed an SUI predictive model tailored for postpartum Chinese women. Upon successful external validation, this model holds immense potential as an effective screening tool for SUI, enabling timely interventions and ultimately may improve women's quality of life.

Keywords Stress urinary incontinence, Prediction model, External validation

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Introduction

Stress Urinary Incontinence (SUI) involves the involuntary leakage of urine from the urethral opening during periods of increased abdominal pressure, such as coughing or laughing. The prevalence of SUI is 5–72% worldwide [1]. It is the most common form of urinary incontinence (UI). The etiology of the disease is primarily linked to risk factors such as age, childbirth, obesity, and constipation, which affect the anatomy of the urethra, surrounding structures, and pelvic nerves. Notably, pregnancy and childbirth are well-known high-risk factors [2]. Previous studies report the incidence of postpartum UI ranging from 11.4 to 43.6% [1, 3], primarily attributed to SUI, with the prevalence of SUI within one year postpartum varying between 6.9% and 41.7% [4–7]. Many pregnant and postpartum women suffer from persistent SUI, significantly increasing the risk of long-term recurrence [8]. Continuous UI can be desruptive to social activities, sexual life as well as mental and physical health, severely diminishing quality of life. In the United States, the annual medical cost for treating UI is estimated to reach $19.5 billion, In China, although these data have not been released, the average cost of a single surgery is 20,000 yuan, imposing a substantial burden on families, society, and the economy [9]. Thus, proactive prevention or early detection of postpartum SUI is essential for timely implementation of appropriate treatment plans.

Advanced statistical methods, such as artificial intelligence and predictive modeling, have become increasingly used in the medical field [10]. Nomograms have emerged as reliable and user-friendly visual tools for quantitative risk prediction, providing individual risk scores through numerical estimation of event probability. These accurate risk predictions guide clinicians in stratifying patient groups based on risk and aid in clinical decision-making [11]. Currently, there is extensive research which primarily focuses on analyzing the risk factors of postpartum SUI [4–6, 8], Although some studies have begun to explore the specific roles of each risk factor in the occurrence of postpartum SUI and have developed predictive models for postpartum SUI [9, 12], they are limited by small sample sizes and short-term follow, variations in the number and mode of deliveries, and lack of external validation, thus restricting their applicability in real-world settings. To address these limitations, our study utilized a sufficient sample size and real-world clinical scenarios, expanding the selection of variables and conducting a one-year postpartum follow-up to develop the prediction model.More importantly, as a multicenter study, we prioritized external validation methods, which will be more helpful in evaluating the effectiveness and generalization ability of the model. Our objective is to utilize real-world clinical data to develop a predictive model that identifies key risk factors associated with SUI in postpartum Chinese women. This will contribute significantly to the management and early intervention of postpartum SUI, possessing crucial clinical value. We hypothesize that a nomogram based on clinical features can quantify the risk of developing SUI.

Methods

Study population

The study cohort consisted of parturients from two community hospitals, Dianshan Lake People's Hospital and Bacheng People's Hospital, located in Kunshan City, Jiangsu Province. A total of 1,531 parturients who received perinatal care cards and antenatal examinations at these hospitals were included for statistical analysis of relevant clinical information. Protocols were approved by the Human Research Ethics Committee of the medical institution (Approval No. FK2024001). All participants provided informed consent. Additionally, this study was conducted in accordance with the principles of the Helsinki Declaration.

We included women who met the following criteria: (a) full-term singleton pregnancies with gestational weeks between 37 and 42; (b) age at delivery between 18 and 45 years; (c) not pregnant within one year postpartum; and (d) complete case information. The exclusion criteria were: (a) urinary incontinence prior to pregnancy; (b) preterm delivery, overdue delivery, or dystocia; (c) history of diabetes; (d) previous history of pelvic surgery; and (e) severe urinary and renal diseases.

Study design and variables

General information on the recruited parturients was collected through the case system. We conducted home visits within 6 weeks postpartum for all recruited women to explain the main content of the study, obtain informed consent. A postpartum SUI follow-up questionnaire was developed, and participants were contacted via telephone one year after delivery. Those who failed home visits and did not answer three consecutive phone calls at different times were considered lost to follow-up and excluded from the study.A flow diagram of the study design is shown in Fig. 1.

The follow-up questionnaire covered the following aspects:

(a) Delivery information: painless delivery, non-painless delivery, emergency cesarean section, elective cesarean section; (b) Presence of uncontrollable urine leakage before, during, and after pregnancy. If present, further inquiries were made about the type of urinary incontinence, the timing of the first occurrence, the frequency and resolution time of urinary incontinence, and the current weight of those with persistent urinary incontinence during the follow-up period; (c) Presence of constipation during pregnancy and postpartum,

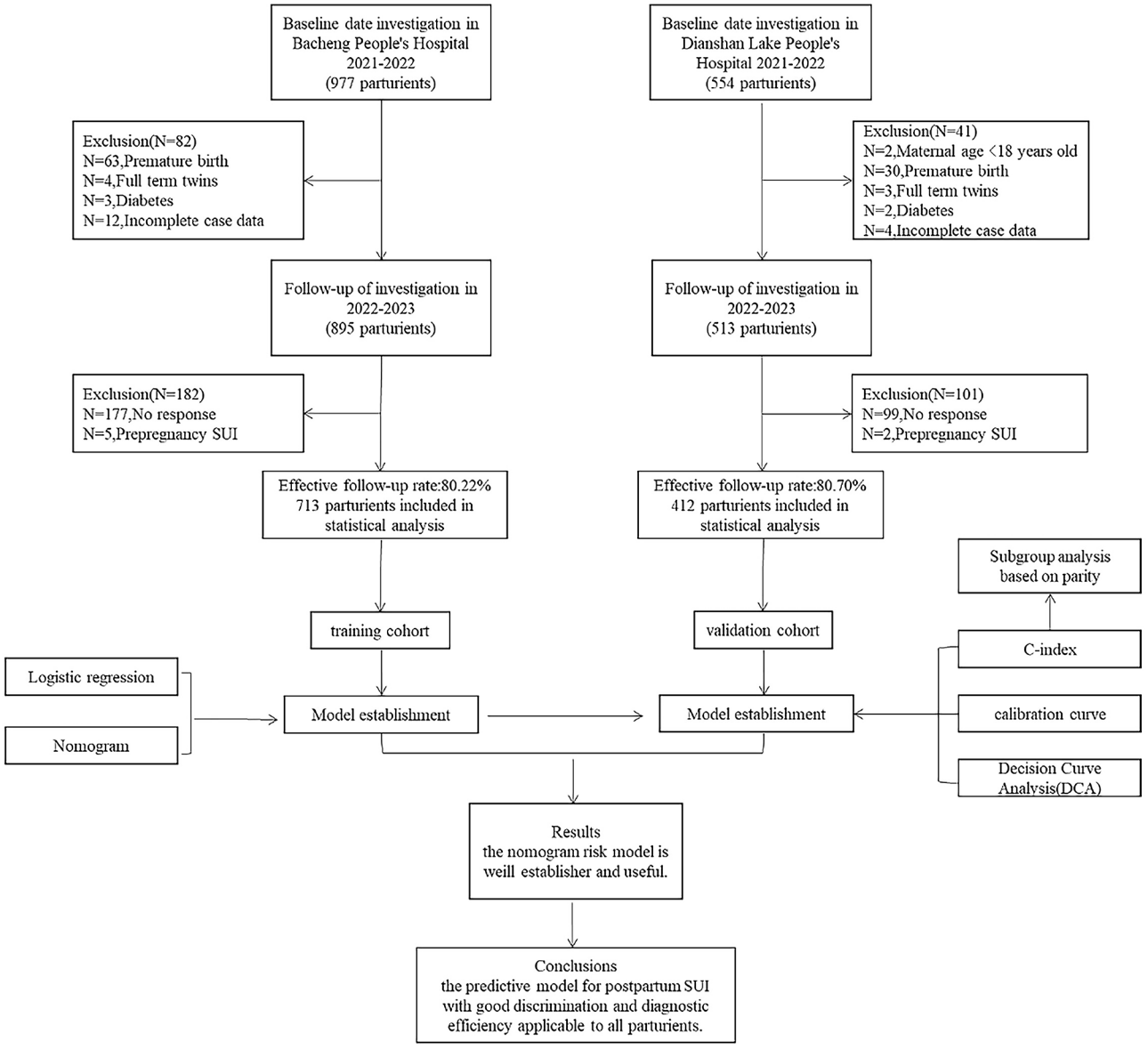

Fig. 1 Flow diagram of study design

and the characteristics of its symptoms; (d) Breastfeeding status after delivery and the duration of breastfeeding; (e) Whether pelvic floor muscle training (PFMT) was performed during pregnancy or postpartum and the frequency of its implementation; (f) For multiparous women, details about the time and mode of delivery of previous pregnancies and the occurrence of urinary incontinence (UI) were collected.

The independent variables included were:

(a) General demographic characteristics: maternal age, height, pre-pregnancy BMI, number of pregnancies, and parity; (b) Pregnancy conditions: presence of SUI during pregnancy, constipation during pregnancy, and pelvic floor muscle training during pregnancy; (c) Obstetrical characteristics: gestational age, mode of labor, mode of delivery, condition of the perineum, and neonatal weight; (d) Postpartum conditions: constipation postpartum, pelvic floor muscle training postpartum, and breastfeeding; (e) Other related factors: previous mode of delivery, SUI during the first pregnancy, and birth interval.

SUI during the first pregnancy was defined as the occurrence of SUI during the first pregnancy or within one year postpartum, excluding any UI present before the first pregnancy. The birth interval was defined as the time between two consecutive deliveries minus the gestational age of the second fetus, measured in years, with every 52 weeks considered one year.

Outcomes

The primary outcome of this study was postpartum SUI. The SUI was diagnosed by the physicians. According to the definitions provided by the International Urogynecological Association (IUGA) and the International Continence Society (ICS), SUI is characterized by involuntary urine leakage during periods of increased abdominal pressure. This can occur during activities such as laughing, coughing, sneezing, or physical exertion, with urine flow ceasing immediately once the pressure is relieved.

Sample size

In this study, Data for this study were divided into two groups based on their source. Data from Bacheng People's Hospital were used as the training dataset, while data from Dianshan Lake People's Hospital were used as the testing dataset. The training dataset was utilized to develop the predictive model and nomogram, whereas the testing dataset was employed to evaluate their predictive performance.Therefore, the calculation of sample size is based on the training dataset. Initially, we estimated there might be 8–10 significant independent variables. Following the rule of 'at least 10 events per variable,' we estimated that a minimum of 80–100 events were necessary. Fortunately, Our training dataset has 183 positive samples, surpassing this threshold. This abundance ensures both robust statistical power and model stability, underpinned by the data we've incorporated.

Statistical analysis

For normally distributed measurement data, the mean±standard deviation was used for representation, and the t-test was employed for group comparisons. For non-normally distributed data, the median (P25, P75) was used, and the Mann-Whitney U test was applied for group comparisons. Categorical data were expressed as rates (%) and analyzed using the chi-square test or Fisher's exact test, as appropriate.

In the entire training set, univariate analysis is employed to identify significant factors associated with SUI.Variables with a p-value less than 0.1 in the univariate analysis were inserted into the multivariate logistic regression model using the backward selection strategy. A parallel model of the regression equation was constructed for visualization. The model's fitness was evaluated using the Hosmer-Lemeshow (H-L) goodness-of-fit test. Its predictive capabilities were assessed through discrimination, measured by the C-statistic, and calibration, visualized by calibration curves. To mitigate the risk of overfitting and quantify optimism, the nomogram underwent rigorous internal validation involving 1000 bootstrap resamplings, resulting in an optimism-adjusted C-statistic. Furthermore, a Decision Curve Analysis (DCA) was performed to ascertain the clinical utility and net benefit of the nomogram in guiding decision-making.

The model was validated using a separate validation dataset. The H-L v2 statistic was employed to compare the difference between the average predicted probabilities and observed probabilities. A large p-value (>0.05) indicates good calibration. The Receiver Operating Characteristic (ROC) curve assessed the model's discriminative ability.Statistical analysis was conducted using SPSS 27.0 .R version 4.3.2 was used with the packages of rms, rmda, pROC and PredictABEL. p-value<0.05 was considered statistically significant.

Result

General characteristics

During the study, 1,531 women gave birth. Out of these, 406 were excluded due to the following reasons: 93 had preterm deliveries, 7 had full-term twins, 2 were under the age of 18, 5 had pregnancies complicated by diabetes, 7 lacked baseline data on pre-pregnancy UI, and 276 did not respond during follow-up. Consequently, a total of 1,125 women were included in the study, with 713 in the training set and 412 in the validation set. The overall incidence of SUI within one year postpartum was 26%. The incidence in the training set was 25.7%, and 26.7% in the validation set, with a p-value of 0.704, indicating no significant difference between the two groups. Additionally, there were no significant differences in maternal age, height, pre-pregnancy BMI, gestational age, number of pregnancies, number of childbirths, labor mode, delivery mode, perineal condition, neonatal weight, SUI during pregnancy, breastfeeding status, previous delivery mode, SUI during the first pregnancy, and interbirth interval (Table 1).

Risk factor analysis

Univariate analysis identified several factors associated with the risk of SUI within one year postpartum, including maternal age, height, pre-pregnancy BMI, number of pregnancies, number of deliveries, labor mode, delivery mode, perineal condition, neonatal weight, SUI during pregnancy, constipation during pregnancy, postpartum constipation, postpartum pelvic floor muscle training, mode of previous delivery, SUI during the first pregnancy, and interbirth interval. After adjusting for confounding factors, multivariate analysis indicated that SUI within one year postpartum was significantly associated with height, pre-pregnancy BMI, mode of labor, delivery mode, perineal condition, neonatal weight, SUI during pregnancy, and SUI during the first pregnancy. However, maternal age, number of pregnancies, number of deliveries, constipation during pregnancy, postpartum constipation, postpartum pelvic floor muscle training, mode of previous delivery, and interbirth interval were not

Table 1 Baseline characteristics of training cohort and validation cohort

variables	training cohort, m(SD)/*N*(%)				validation cohort, m(SD)/*N*(%)				*p*
	overall(*N* = 713)	Non-SUI(*N* = 530)	SUI(*N* = 183)	*p*.train	overall(*N* = 412)	Non-SUI(*N* = 302)	SUI(*N* = 110)	*p*.test	
Maternal age, y	29.6(4.34)	29.4(4.39)	30.2 (4.15)	0.035	29.5(4.13)	29.3(4.03)	30.0(4.38)	0.184	0.771
Gestational age, d	276 (6.85)	276 (6.93)	276(6.61)	0.623	276(6.56)	276(6.79)	276(5.91)	0.513	0.952
Pre-pregnancy BMI, Kg/m^2	22.1(3.24)	21.9(3.21)	22.6(3.25)	0.012	22.4(3.64)	22.2(3.69)	23.1(3.42)	0.024	0.156
Heigh, m	1.61(0.05)	1.61(0.05)	1.60(0.05)	0.008	1.61(0.05)	1.61(0.05)	1.60(0.05)	0.178	0.525
Delivery mode				<0.001				0.013	0.068
Natural vaginal delivery	302 (42.4%)	209 (39.4%)	93 (50.8%)		208 (50.5%)	139 (46.0%)	69 (62.7%)		
Analgesic delivery	109 (15.3%)	59 (11.1%)	50 (27.3%)		52 (12.6%)	38 (12.6%)	14 (12.7%)		
Emergency cesarean section	35 (4.91%)	32 (6.04%)	3 (1.64%)		19 (4.61%)	16 (5.30%)	3 (2.73%)		
Selective cesarean section	267 (37.4%)	230 (43.4%)	37 (20.2%)		133 (32.3%)	109 (36.1%)	24 (21.8%)		
SUI during pregnancy				<0.001				<0.001	0.28
No	599 (84.0%)	492 (92.8%)	107 (58.5%)		356 (86.4%)	282 (93.4%)	74 (67.3%)		
Yes	114 (16.0%)	38 (7.17%)	76 (41.5%)		56 (13.6%)	20 (6.62%)	36 (32.7%)		
Gravidity				0.013				0.179	0.364
≤ 2	585 (82.0%)	446 (84.2%)	139 (76.0%)		329 (79.9%)	246 (81.5%)	83 (75.5%)		
> 2	128 (18.0%)	84 (15.8%)	44 (24.0%)		83 (20.1%)	56 (18.5%)	27 (24.5%)		
Parity				0.044				0.017	0.942
Primipara	323 (45.3%)	251 (47.4%)	72 (39.3%)		184 (44.7%)	147 (48.7%)	37 (33.6%)		
Second pregnancy	340 (47.7%)	248 (46.8%)	92 (50.3%)		197 (47.8%)	136 (45.0%)	61 (55.5%)		
Multipara (> 2)	50 (7.01%)	31 (5.85%)	19 (10.4%)		31 (7.52%)	19 (6.29%)	12 (10.9%)		
Fetal weight				0.052				0.983	0.071
< 4 kg	665 (93.3%)	500 (94.3%)	165 (90.2%)		395 (95.9%)	289 (95.7%)	106 (96.4%)		
≥ 4 kg	48 (6.73%)	30 (5.66%)	18 (9.84%)		17 (4.13%)	13 (4.30%)	4 (3.64%)		
Perineal condition				<0.001				0.009	0.791
Intact	353 (49.5%)	296 (55.8%)	57 (31.1%)		209 (50.7%)	165 (54.6%)	44 (40.0%)		
Episiotomy	91 (12.8%)	69 (13.0%)	22 (12.0%)		47 (11.4%)	36 (11.9%)	11 (10.0%)		
Perineal laceration	269 (37.7%)	165 (31.1%)	104 (56.8%)		156 (37.9%)	101 (33.4%)	55 (50.0%)		
Induction method				0.008				0.765	0.399
None	71 (9.96%)	51 (9.62%)	20 (10.9%)		33 (8.01%)	25 (8.28%)	8 (7.27%)		
Natural membrane rupture	138 (19.4%)	97 (18.3%)	41 (22.4%)		79 (19.2%)	60 (19.9%)	19 (17.3%)		
Artificial rupture of membranes	458 (64.2%)	356 (67.2%)	102 (55.7%)		264 (64.1%)	189 (62.6%)	75 (68.2%)		
Oxytocin	46 (6.45%)	26 (4.91%)	20 (10.9%)		36 (8.74%)	28 (9.27%)	8 (7.27%)		
Constipation during pregnancy				0.003				0.113	<0.001
No	561 (78.7%)	431 (81.3%)	130 (71.0%)		362 (87.9%)	270 (89.4%)	92 (83.6%)		
Yes	152 (21.3%)	99 (18.7%)	53 (29.0%)		50 (12.1%)	32 (10.6%)	18 (16.4%)		
Postpartum constipation				0.01				0.628	0.004
No	630 (88.4%)	478 (90.2%)	152 (83.1%)		386 (93.7%)	284 (94.0%)	102 (92.7%)		
Yes	83 (11.6%)	52 (9.81%)	31 (16.9%)		26 (6.31%)	18 (5.96%)	8 (7.27%)		
Breastfeeding				0.976				0.962	0.271
No	51 (7.15%)	38 (7.17%)	13 (7.10%)		37 (8.98%)	27 (8.94%)	10 (9.09%)		
Yes	662 (92.8%)	492 (92.8%)	170 (92.9%)		375 (91.0%)	275 (91.1%)	100 (90.9%)		
Kegel during pregnancy				0.669				0.759	0.018
No	649 (91.0%)	481 (90.8%)	168 (91.8%)		391 (94.9%)	286 (94.7%)	105 (95.5%)		
Yes	64 (8.98%)	49 (9.25%)	15 (8.20%)		21 (5.10%)	16 (5.30%)	5 (4.55%)		

Table 1 (continued)

variables	training cohort, m(SD)/*N*(%)				validation cohort, m(SD)/*N*(%)				*p*
	overall(*N* = 713)	Non-SUI(*N* = 530)	SUI(*N* = 183)	*p*.train	overall(*N* = 412)	Non-SUI(*N* = 302)	SUI(*N* = 110)	*p*.test	
Postpartum Kegel training				0.001				0.003	<0.001
No	408 (57.2%)	322 (60.8%)	86 (47.0%)		286 (69.4%)	222 (73.5%)	64 (58.2%)		
Yes	305 (42.8%)	208 (39.2%)	97 (53.0%)		126 (30.6%)	80 (26.5%)	46 (41.8%)		
Previous delivery mode				<0.001				<0.001	0.261
Primipara	323 (45.3%)	251 (47.4%)	72 (39.3%)		184 (44.7%)	147 (48.7%)	37 (33.6%)		
Vaginal delivery	238 (33.4%)	145 (27.4%)	93 (50.8%)		154 (37.4%)	95 (31.5%)	59 (53.6%)		
Cesarean section	152 (21.3%)	134 (25.3%)	18 (9.84%)		74 (18.0%)	60 (19.9%)	14 (12.7%)		
SUI in first pregnancy				<0.001				<0.001	0.854
No	666 (93.4%)	520 (98.1%)	146 (79.8%)		386 (93.7%)	300 (99.3%)	86 (78.2%)		
Yes	47 (6.59%)	10 (1.89%)	37 (20.2%)		26 (6.31%)	2 (0.66%)	24 (21.8%)		
Interpregnancy interval, y				0.134				0.001	0.486
Primipara	323 (45.3%)	251 (47.4%)	72 (39.3%)		184 (44.7%)	147 (48.7%)	37 (33.6%)		
≤ 3	136 (19.1%)	92 (17.4%)	44 (24.0%)		87 (21.1%)	59 (19.5%)	28 (25.5%)		
4—6	122 (17.1%)	92 (17.4%)	30 (16.4%)		58 (14.1%)	47 (15.6%)	11 (10.0%)		
> 6	132 (18.5%)	95 (17.9%)	37 (20.2%)		83 (20.1%)	49 (16.2%)	34 (30.9%)		

significantly associated with the incidence of SUI within one year postpartum (Table 2).

Establishment, evaluation, and verification of prediction model

The final regression analysis led to the creation of a nomogram for predicting SUI (Fig. 2). Total scores were derived from variables such as height, pre-pregnancy BMI, mode of labor induction, mode of delivery, perineal condition, neonatal weight, SUI during pregnancy, and SUI during the first pregnancy. Each variable corresponds to a score on the scale axis based on its weight. The individual scores were summed to form a total score, which was then used on the total score scale to calculate the probability of SUI. The nomogram exhibited a good discriminative ability. The area under the curve (AUC) of the nomogram was 0.829 (95% CI 0.790 to 0.867) for the training set and 0.746 (95% CI 0.689 to 0.804) for the external validation set (Fig. 3). A discriminative subgroup analysis based on childbearing history was conducted to test the nomogram's predictive ability for both primiparous and multiparous women. The AUC for primiparous women was 0.760 (95% CI 0.704 to 0.816), and for multiparous women, it was 0.821 (95% CI 0.782 to 0.861), indicating good discriminative ability for both groups (Fig. 4). The calibration curve showed that the predicted probability closely matched the actual probability, demonstrating a good degree of fit for the prediction model (Fig. 5).

Clinical applicability of the predictive model

Figure 6 presents the decision curve analysis (DCA) of the nomogram. A DCA was performed on our predictive model to assess the net benefits it could offer to patients. As shown in the decision curve, the nomogram model provides substantial net benefits across nearly all threshold probabilities, particularly within the 10–90% range.

Discussion

In this study, we analyzed data from 1,125 pregnant women. The overall incidence of SUI within one year post-delivery was 26%, which aligns closely with other studies conducted in China [1, 9, 13]. Following a comprehensive multivariate analysis, we identified pre-pregnancy BMI, height, mode of labor induction, mode of delivery, SUI during pregnancy, fetal weight, perineal laceration, and SUI during the first pregnancy as significant predictors of SUI within one year post-delivery. Among them, high pre-pregnancy BMI [6, 14, 15], vaginal delivery [6, 16–19], SUI during pregnancy [15, 17, 20], macrosomia [12, 16, 20, 21], and SUI during the first pregnancy [1, 20, 22] were consistent with previous studies.

Additionally, we assessed the impact of epidural analgesia during labor on postpartum SUI, as its widespread use has become common. Our results indicated that epidural analgesia during labor increased the risk of postpartum SUI. This may be due to the prolonged labor stage caused by epidural anesthesia, extending the stress duration on pelvic floor muscles and nerves [6, 23], and resulting in reduced pelvic floor muscle strength post-delivery. Zhu et al. [4] found that women with perineal laceration or

Table 2 Univariate and multivariate logistic regression analysis of predictors in the training cohort

Variate	Univariate analysis		Multivariate analysis	
	OR(95%CI)	*p*.value	OR(95%CI)	*p*.value
Maternal age, y	1 (1–1.1)	0.041	1 (0.97–1.1)	0.337
Gestational age, d	1 (0.98–1)	0.63		
Pre-pregnancy BMI, Kg/m^2	1.1 (1–1.1)	0.012	1.1 (1–1.1)	0.041
Heigh, m	0.0087 (0.00027–0.28)	0.007	0.0064 (9.1e − 05–0.45)	0.02
Delivery mode				
Natural vaginal delivery	ref			
Analgesic delivery	1.9 (1.2–3)	0.005	2.5 (1.4–4.3)	0.001
Emergency cesarean section	0.21 (0.063–0.71)	0.012	0.32 (0.072–1.5)	0.143
Selective cesarean section	0.36 (0.24–0.55)	< 0.001	0.66 (0.25–1.7)	0.383
SUI during pregnancy				
No	ref			
Yes	9.2 (5.9–14)	< 0.001	8 (4.7–14)	< 0.001
Gravidity				
≤2	ref			
>2	1.7 (1.1–2.5)	0.013	1.7 (0.9–3.2)	0.104
Parity				
Primipara	ref			
Second pregnancy	1.3 (0.91–1.8)	0.155	0.63 (0.25–1.6)	0.336
Multipara (> 2)	2.1 (1.1–4)	0.018	0.96 (0.26–3.6)	0.953
Fetal weight				
<4 kg	ref			
≥4 kg	1.8 (0.99–3.3)	0.055	2.3 (1.1–4.9)	0.031
Perineal condition				
Intact	ref			
Episiotomy	1.7 (0.95–2.9)	0.076	1.2 (0.48–3.2)	0.663
Perineal laceration	3.3 (2.2–4.8)	< 0.001	2.1 (1–4.4)	0.048
Induction method				
None	ref			
Natural membrane rupture	1.1 (0.57–2)	0.816	0.45 (0.21–0.98)	0.046
Artificial rupture of membranes	0.73 (0.42–1.3)	0.274	0.44 (0.22–0.86)	0.017
Oxytocin	2 (0.9–4.3)	0.09	0.74 (0.28–2)	0.542
Constipation during pregnancy				
No	ref			
Yes	1.8 (1.2–2.6)	0.004	1.5 (0.86–2.6)	0.16
Postpartum constipation				
No	ref			
Yes	1.9 (1.2–3)	0.01	1.2 (0.62–2.5)	0.553
Breastfeeding				
No	ref			
Yes	1 (0.53–1.9)	0.976		
Kegel during pregnancy				
No	ref			
Yes	0.88 (0.48–1.6)	0.669		
Postpartum Kegel training				
No	ref			
Yes	1.7 (1.2–2.4)	0.001	0.99 (0.64–1.6)	0.979
Previous delivery mode				
Primipara	ref			
Vaginal delivery	2.2 (1.5–3.2)	< 0.001	1.4 (0.56–3.6)	0.467
Cesarean section	0.47 (0.27–0.82)	0.008		
SUI in first pregnancy				
No	ref			

Table 2 (continued)

Variate	Univariate analysis		Multivariate analysis	
	OR(95%CI)	*p*.value	OR(95%CI)	*p*.value
Yes	13 (6.4–27)	< 0.001	8.6 (3.6–21)	< 0.001
Interpregnancy interval, y				
Primipara	ref			
≤3	1.7 (1.1–2.6)	0.024	0.74 (0.34–1.6)	0.437
4—6	1.1 (0.7–1.9)	0.607	0.58 (0.27–1.2)	0.148
>6	1.4 (0.86–2.2)	0.194		

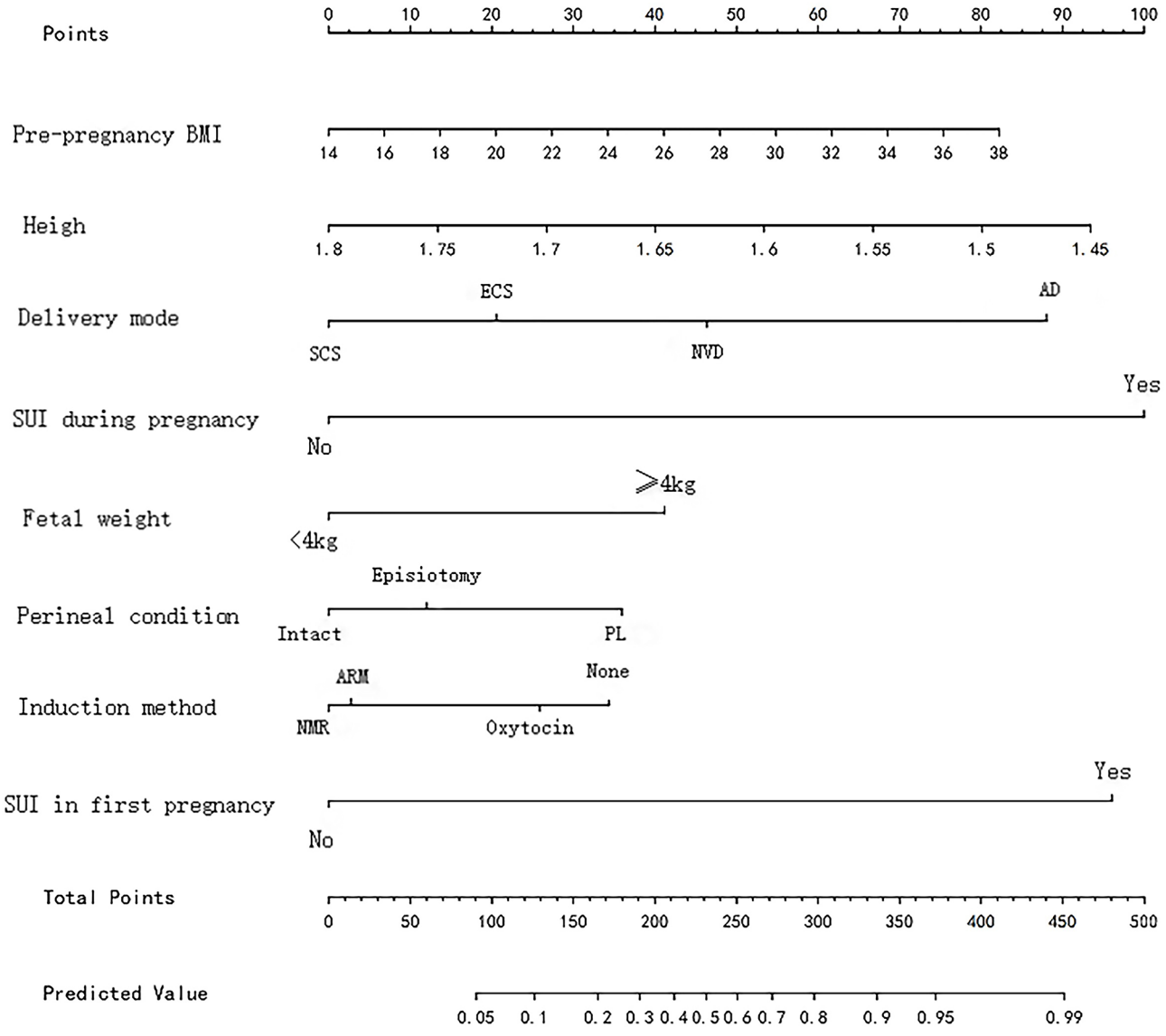

Fig. 2 Nomogram predictive model of maternal SUI risk. Legends: Note: SCS: Selective cesarean section; ECS: Emergency cesarean section; NVD: Natural vaginal delivery; AD: Analgesic delivery; PL: Perineal laceration; NMR: Natural membrane rupture; ARM: Artificial rupture of membranes

lateral episiotomy have a high incidence of postpartum SUI This is consistent with our findings. (OR=2.1, 95% CI 1-4.4).Perineal tears may increase severe damage to the puborectalis muscle and some pelvic fascia, as well as injury to the pudendal nerves, leading to the occurrence of SUI [4, 24]. Therefore, properly shorten the delivery time, proactive perineal protection, selective episiotomy, and perineal warm compresses during the second stage of labor to reduce the occurrence of perineal laceration impose higher requirements on midwives [25].

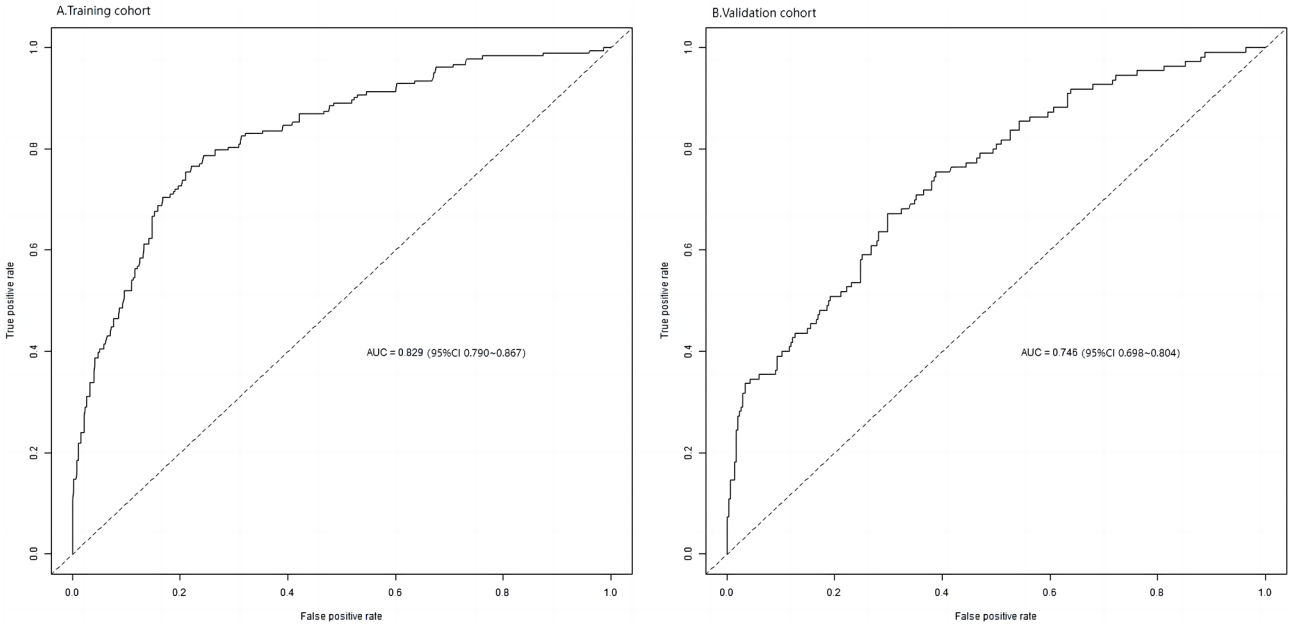

Fig. 3 Receiver operating characteristic (ROC) curve

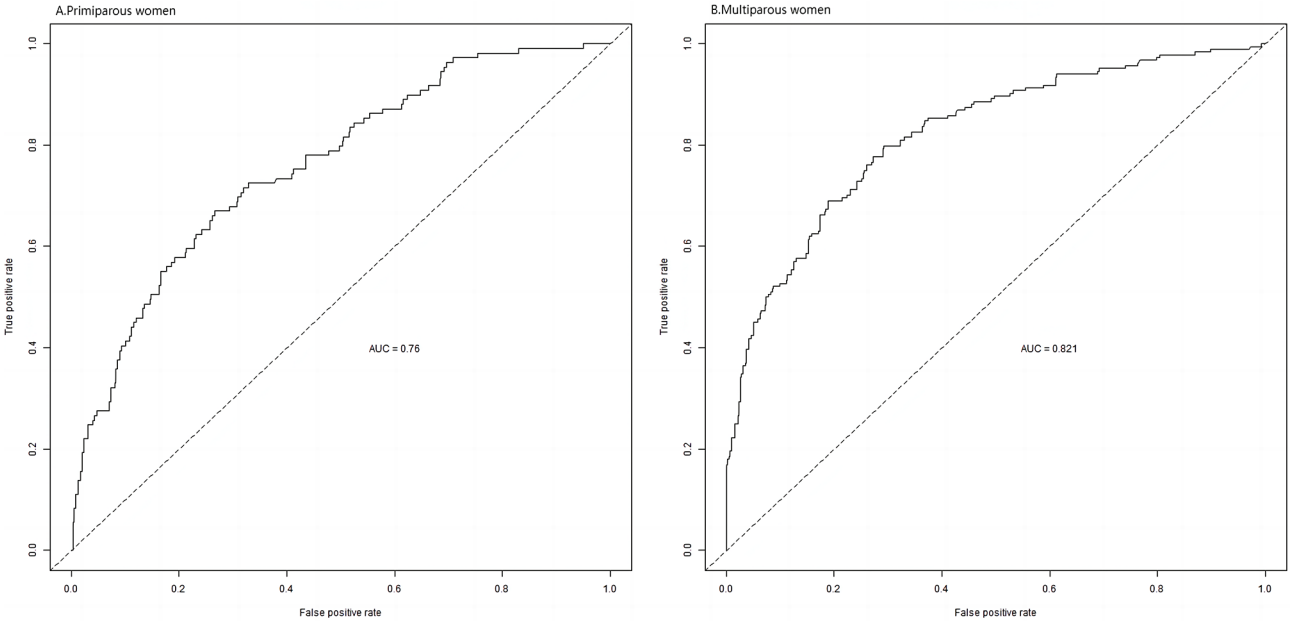

Fig. 4 The subgroup analysis based on parity

Interestingly, after accounting for confounding factors, we found that the age of delivery was not a significant predictor of postpartum SUI. This finding is consistent with a 10-year prospective study by Daniel et al. [26], which also indicated that maternal age was not associated with postpartum SUI. Another noteworthy discovery was that height might be a significant predictor of postpartum SUI. This could be related to previous studies focusing primarily on BMI (weight/height) and waist-to-height ratio (waist/height), thereby neglecting the impact of height itself. Several studies have demonstrated that women with shorter stature tend to possess narrower pelvic structures [27]. Additionally, a Mexican study found that higher birth weight combined with shorter maternal height suggests cephalopelvic disproportion [28]. Related research has indicated that a persistent occiput posterior position is associated with shorter maternal stature [29], therefore increasing the likelihood of dystocia and surgical midwifery during delivery [30]. This could result in injury to the pelvic floor muscles and nerves, leading

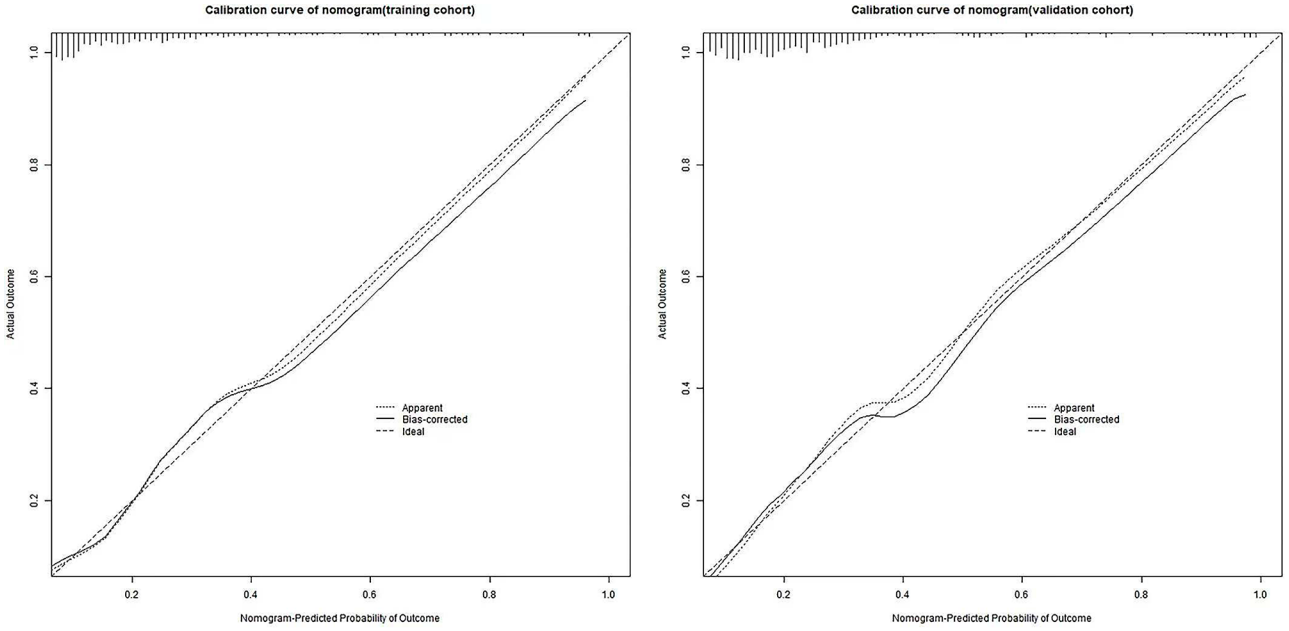

Fig. 5 Calibration curves for the nomogram

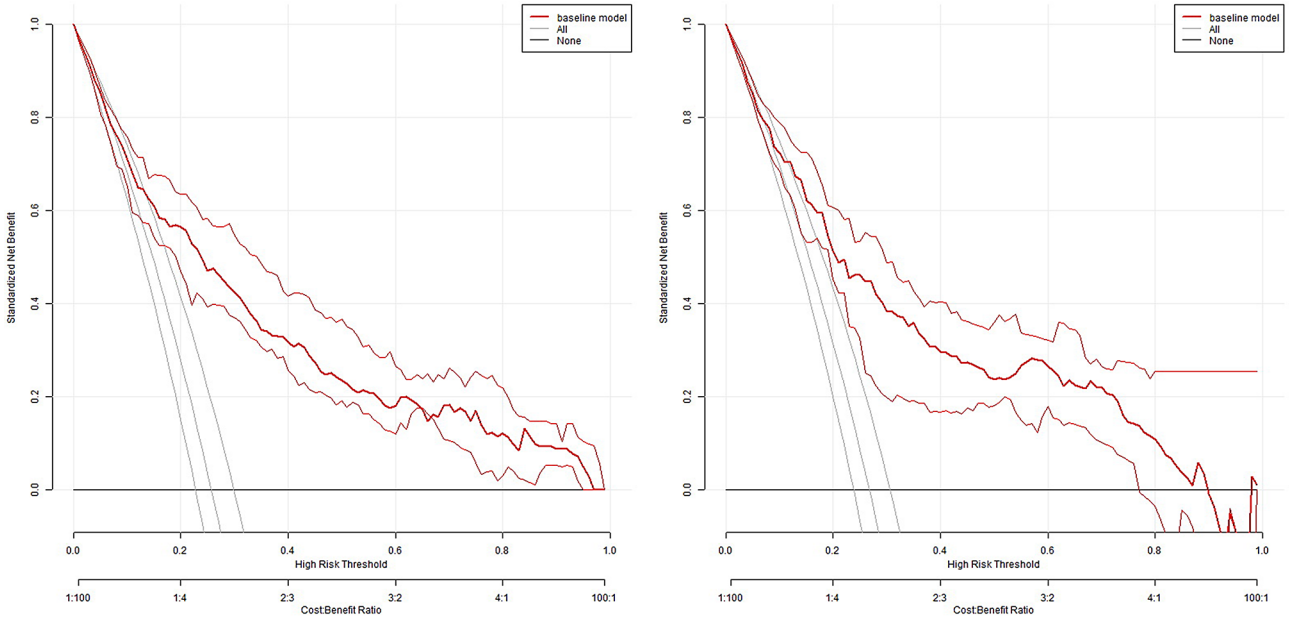

Fig. 6 The decision curve analysis (DCA) of the nomogram

to SUI. These findings highlight the need for clinicians to focus on weight management during pregnancy, especially for shorter women, including reasonable control of fetal weight.

Treatment for SUI typically includes conservative management, pelvic floor physical therapy, pharmacotherapy, and surgical options [31, 32]. Among these, pelvic Floor Muscle Training (PFMT) is generally considered the first-line treatment for SUI [33, 34]. The latest literature review and meta-analysis [35] have also confirmed the protective effect of PFMT on UI three months post-delivery. However, in our study, pregnant women who engaged in PFMT during pregnancy did not show a preventative advantage against postpartum SUI. We speculate that this may be due to a lack of guidance and long-term supervision from professional therapists, inadequate self-discipline, knowledge, and confidence of trainers in performing exercises, and poor perception of the effectiveness of PFME [36], leading to less significant training effectiveness.

SUI significantly affects patients' sexual function, psychological well-being, and physical health, thereby reducing their overall quality of life. Consequently, the development of tools for early detection and intervention of SUI is of paramount importance. In recent years, interdisciplinary collaborations have fostered remarkable progress in the creation of visual prediction models within the medical domain. Cheng et al. [9] previously developed a prediction model to assess the probability of early postpartum SUI in 360 parturients. However, this model was limited to primiparae and was constrained by a small sample size and lack of validation. Xu et al. [12] later expanded the sample size to create a prediction model that evaluated the probability of early postpartum SUI, which was internally validated and showed good discrimination. However, this model only included women who had vaginal deliveries and assessed the probability of SUI within a short postpartum period (within 6 weeks) and lacked external validation. In our study, we developed a nomogram to predict the likelihood of SUI within one year postpartum, and validated the performance of the prediction model using independent external data, Despite the baseline of the external validation data being consistent with the training set, significant differences remained in factors such as constipation during pregnancy, postpartum constipation, and pelvic floor muscle training during and after pregnancy. Nevertheless, our validation achieved good results, demonstrating the model's generalizability. Our team is actively utilizing the developed nomogram in clinical settings to evaluate the risk of SUI among postpartum women. For those identified as high-risk individuals, we are implementing comprehensive early intervention and management strategies. This approach not only aims to improve patient outcomes but also serves to continually refine our model. The findings from this ongoing work will be reported in future research.

Strengths and limitations

This study has several potential limitations. Firstly, SUI symptoms are self-reported and lack objective measurement. Although we have implemented some measures, there remains an unavoidable possibility of recall bias Secondly, the SUI parameter was simply categorized, ignoring severity and duration. Thirdly, certain demographic factors such as education, economic level, and professional attributes were not accounted for.

However, our research has some strengths. It was a multicenter study which based on a large sample with a long-term follow-up, not only short-term follow as in the previously published study [9, 12]. We comprehensively analyzed risk factors, collected data to construct and external validate the nomogram, and the model has wide applications and is not affected by certain factors.

Conclusion

We have successfully developed an individualized prediction model for postpartum SUI within the first year postpartum. This model is inclusive of all parturients, demonstrates high efficiency, and has proven to be effective in external validation. It is instrumental in identifying high-risk parturients, thereby facilitating early prevention measures. This achievement represents a significant advancement in the field. Nevertheless, future prospective research are essential to further optimize and refine the model.

Abbreviations

SUI	Stress Urinary Incontinence
UI	Urinary incontinence
BMI	Body mass index
PFMT	Pelvic floor muscle training

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Author contributions

D Z: Project development, data collection, data analysis, manuscript writing; MZ1: Project development, data collection, manuscript editing; MZ2:Project development, data analysis; YZ, DW and RW: Project development, data collection; MT and MZ.P.R: English Proofreading; HZ: Project development, data analysis, manuscript editing. All authors discussed the results and contributed to the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate

This retrospective cohort study was approved by the Institutional Research Ethics Committee of the Dianshan Lake People's Hospital in Kunshan City(No: FK2024001).In accordance with the approval of the ethical review board, each participant read and gave written informed consent. This process included informing participants about their right to refuse participation and the freedom to withdraw from the study at any time without penalty.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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