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Development of Predictive Risk Models of Postpartum Stress Urinary Incontinence for Primiparous and Multiparous Women

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Keywords
Stress urinary incontinence · Postpartum · Predictive model · Nomogram

Abstract
Objectives: To develop risk predictive models of postpartum stress urinary incontinence (SUI) for both primiparous and multiparous women. ***Materials and Methods:*** From July 2016 to July 2017, 815 singleton pregnant women without incontinence before pregnancy who were 18 years or older and admitted to 2 hospitals in Shenzhen, China, were enrolled. Pregnancy-related data were collected at enrollment. Delivery information was obtained from electronic medical records. Telephone follow-up was conducted to investigate SUI at 6 weeks postpartum. Multivariable logistic regression analyses using stepwise selection were used to establish predictive models for postpartum SUI for all women, and separately for primiparous and multiparous. Internal validation of the models was performed with discrimination and calibration using a bootstrapping (1,000 resampling) method. ***Results:*** The analysis included 727 participants. The prevalence of postpartum SUI was 15.96% (116/727), 12.5% (49/393) for primiparous women and 20.1% (67/334) for multiparous women, with a significant difference between them (p = 0.008). For primiparous women, the predictive postpartum SUI model included age, abortion/miscarriage history, SUI during pregnancy, and mode of delivery. For multiparous women, pre-pregnancy BMI, abortion/miscarriage history, SUI during pregnancy, and mode of delivery were included in the model. There was satisfactory calibration between the models' predicted probability of postpartum SUI and the observed probability for both primiparous and multiparous women (Hosmer-Lemeshow test, p = 0.390 for primiparous and 0.364 for multiparous women). The optimism-corrected C-statistic of the models by bootstrapping stepwise was 0.763 (95% confidence interval [CI]: 0.693–0.833) for primiparous women and 0.783 (95% CI: 0.726–0.841) for multiparous women. ***Conclusion:*** We developed predictive models of postpartum SUI for both primiparous and multiparous women. This approach may provide a useful tool for high-risk prediction of postpartum SUI before and after delivery.

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Introduction

Urinary incontinence was defined as a complaint of involuntary loss of urine [1]. Pregnancy and birth are 2 well-known risk factors for postpartum urinary incontinence. Stress urinary incontinence (SUI) is the most common type of postpartum urinary incontinence, accounting for ~70% of all cases [2, 3]. SUI has negative impacts on sexual, psychological, and social health in women, reducing quality of life [4, 5]. Viktrup et al. [6] found that SUI during the puerperal period increases the risk of long-lasting symptoms.

With the advancement of modern medical services and public health, early screening and prevention of SUI have become increasingly widespread for improving women's quality of life. A recent Cochrane review found that antenatal pelvic floor muscle training (PFMT) exhibits efficacy for decreasing the risk of postpartum urinary incontinence for pregnant women with or without preexisting urinary incontinence [7]. However, the supervised PFMT methods used in the randomized controlled trials included in the review are unrealistic for many women in daily life, and a pragmatic trial failed to find significant efficacy of supervised antenatal PFMT for preventing postpartum urinary incontinence [8]. Because of its voluntary nature, compliance in the physiotherapy group was relatively low, which may have at least partially explained the negative result. Therefore, it is necessary to explore predictive tools for identifying women at a high risk of SUI, so that supervised PFMT can be delivered to the women most in need.

Jelovsek et al. [9] developed a method using antenatal and postnatal nomograms for predicting postpartum urinary incontinence. However, the study only included primiparous women as participants. Evidence showed that parity was significantly associated with urinary incontinence [10]. To the best of our knowledge, few studies have attempted to predict postpartum SUI for multiparous women, particularly in China. The purpose of the present study was to explore the possibility of developing predictive models of postpartum SUI for both primiparous and multiparous women.

Materials and Methods

Study Design and Setting

A prospective cohort study was conducted. Pregnant women attending prenatal clinics were recruited via convenience sampling at Shenzhen Maternal and Child Healthcare Hospital between July 2016 and July 2017, and Shenzhen Hospital, Southern Medical University between January 2017 and July 2017. The inclusion criteria were (1) women who were undergoing a singleton pregnancy and (2) aged 18 years or above. The exclusion criteria were as follows: (1) urinary incontinence before pregnancy; (2) history of abdominal and vaginal surgery; (3) diabetes and hypertension, and (4) placenta previa, threatened abortion, amniotic fluid abnormalities, fetal growth restriction, or vaginal bleeding. Participants were followed up by telephone at 6 weeks after delivery.

Data Collection

Pregnancy-related data were collected, including maternal age, height, prepregnancy weight, number of pregnancies, prior abortions/miscarriages, delivery history, constipation, and SUI during pregnancy. Except for constipation, SUI during pregnancy and pregnancy-related data were collected at the time of inclusion. Delivery information, including gestational weeks, the mode of delivery, episiotomy, oxytocin use in induced labor, and neonatal weight, were obtained by checking the electronic medical records system after delivery.

Telephone follow-up was performed at 6 weeks postpartum by a trained midwife who was not relevant to this study. Women who experienced abortion or miscarriage at the last pregnancy were not followed up. At the telephone interview, current weight and SUI after delivery were investigated. In addition, information about constipation, SUI, and performance of PFMT during the last pregnancy were retrospectively collected.

SUI was diagnosed if responded "Yes" to the question "did you experience involuntary loss of urine on effort or physical exertion (e.g., sporting activities) or on sneezing or coughing?" [1]. When asked about SUI during pregnancy, the question was "during pregnancy, did you experience involuntary loss of urine on effort or physical exertion (e.g., sporting activities) or on sneezing or coughing?" Accordingly, when asked about SUI after delivery, the question was "after delivery, did you experience involuntary loss of urine on effort or physical exertion (e.g., sporting activities) or on sneezing or coughing?" The following question regarding the performance of antenatal PFMT was included: "Did you exercise the pelvic floor muscles (muscles around the urethra, vagina, and rectum) during pregnancy?" [11]. If the woman answered "Yes" to that question, she was asked to further specify the frequency and period with which she performed PFMT.

Data Analysis

The χ^2 test and 2-sided Student's t test were used to examine the distribution differences of variables between the SUI group and non-SUI group, stratifying by parity. Multivariable logistic regression by backward stepwise selection was used to establish the predictive models for all the participants and separately for primiparous and multiparous women. The performance of the models was evaluated by discrimination and calibration. Internal validation of the models was performed using a bootstrap technique with 1,000 resamplings to adjust for overfitting and overoptimistic model performance. Decision curve analyses (DCAs) were conducted to determine the clinical utility of the model by quantifying the net benefit of the different threshold probabilities. Finally, nomograms were constructed based on the predictive models.

R software, version 3.4.3 (http://www.R-project.org), and EmpowerStats software (www.empowerstats.com, X&Y solutions, Inc., Boston, MA, USA) were used for all other statistical analyses. All statistical tests were 2-tailed. The level of significance was set at 0.05.

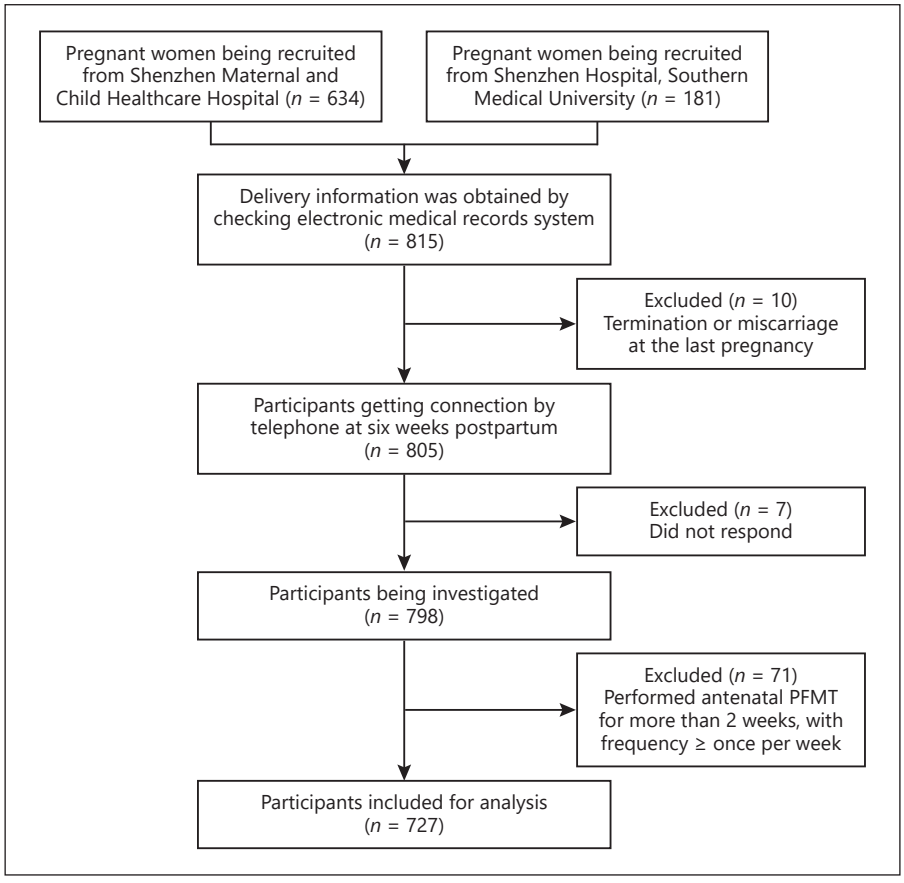

Fig. 1. Flowchart of women being included 1 month after delivery. PFMT, pelvic floor muscle training.

Results

Study Participants

A sample of 634 women was enrolled from Shenzhen Maternal and Child Healthcare Hospital between July 2016 and July 2017, and 181 women were enrolled from Shenzhen Hospital, Southern Medical University, between January 2017 and July 2017. Ten participants had an abortion/miscarriage at the last pregnancy and 7 did not respond at 6 weeks postpartum follow-up. Taking into account the possible potential impact on postpartum SUI, 71 participants who performed antenatal PFMT for >2 weeks with a frequency ≥ once per week were excluded. Therefore, 727 women were included in the final data analysis (Fig. 1), of which 226, 232, and 269 were in their first, second, and third trimester, retrospectively. The mean age of the study group was 30.5 ± 4.1 years (range 20–46).

Comparison of Pregnancy-Related Factors and Obstetrics-Related Factors between Women with and without Postpartum SUI

The prevalence of postpartum SUI was 15.96% (116/727). All of the demographic and pregnancy-related factors exhibited significant differences between the 2 groups (see Table 1).

Development of Predictive Model for Postpartum SUI

Multivariate logistic regression analysis based on all the participants revealed that the high-risk predictive model of postpartum SUI included prepregnancy BMI, abortion/miscarriage history, SUI during pregnancy, and the mode of delivery (Table 2). The variable of previous delivery mode was not included in the final regression model. We also developed predictive models of postpartum SUI for primiparous and multiparous separately. The results revealed that the model for multiparous women included the same variables as the model for all women. In addition, age, instead of prepregnancy BMI, was entered into the model for primiparous women (see Table 2).

Table 1. Comparisons of pregnancy-related and obstetrics-related variables by groups of non-SUI and postpartum SUI by parity

	All (n = 727)	Primiparous (n = 393)			Multiparous (n = 334)		
		no SUI (n = 344)	SUI (n = 49)	p value	no SUI (n = 267)	SUI (n = 67)	p value
Pregnancy-related factors							
Maternal age (mean ± SD), years	30.48±4.11	28.75±3.52	30.16±3.54	0.009[a]	32.37±4.02	32.03±3.81	0.526[a]
Prepregnancy BMI (mean ± SD), kg/m^2	20.94±2.86	20.76±2.86	21.37±2.88	0.167[a]	20.94±2.94	21.57±2.41	0.108[a]
Constipation during pregnancy (yes), n (%)	175 (24.07)	77 (22.38)	17 (34.69)	0.059[b]	61 (22.85)	20 (29.85)	0.232[b]
SUI during pregnancy (yes), n (%)	238 (32.74)	72 (20.93)	28 (57.14)	<0.001[b]	90 (33.71)	48 (71.64)	<0.001[b]
Pregnancies (mean ± SD), n	2.00±1.07	1.33±0.64	1.51±0.71	0.023[c]	2.73±0.95	2.93±0.99	0.097[c]
Abortion/miscarriage history (yes), n (%)	261 (35.90)	79 (22.97)	20 (40.82)	0.007[b]	122 (45.69)	40 (59.70)	0.040[b]
Previous delivery mode, n (%)							
Nulliparous	393 (54.06)	344 (100.00)	49 (100.00)	–	–	–	0.008[b]
Cesarean section	110 (15.13)	–	–		97 (36.33)	13 (19.40)	
Vaginal delivery	224 (30.81)	–	–		170 (63.67)	54 (80.60)	
Obstetrics-related factors							
Gestational week	39.00±1.40	39.14±1.49	38.96±1.24	0.209[c]	38.83±1.31	39.04±1.34	0.140[c]
Oxytocin use in induced labor (yes), n (%)	141 (19.34)	93 (27.03)	21 (42.86)	0.026[b]	19 (7.12)	8 (11.94)	0.211[b]
Vaginal delivery,[d] n (%)	469 (64.51)	234 (68.02)	39 (79.59)	0.100[b]	141 (52.81)	55 (82.09)	<0.001[b]
Episiotomy, n (%)	100 (13.76)	54 (15.70)	11 (22.45)	0.234[b]	25 (9.36)	10 (14.93)	0.184[b]
New birth weight (mean ± SD), kg	32.66±4.65	3.24±4.56	3.31±6.57	0.360[a]	3.28±4.31	33.07±4.79	0.666[a]
BMI postpartum (mean ± SD), kg/m^2	22.84±2.84	22.80±2.98	23.11±3.02	0.503[a]	22.86±2.71	22.83±2.46	0.936[a]
Postpartum SUI, n (%)	116 (15.96)	–	–	–	–	–	–

SUI, stress urinary incontinence. [a] t. [b] χ^2. [c] Z. [d] Cesarean section as reference.

Performance of the Predictive Model for Primiparous and Multiparous Women

The C-index of the model for primiparous women was 0.763 (95% confidence interval [CI]: 0.692–0.833), and for multiparous women was 0.783 (95% CI: 0.725–0.841), as shown in Figure 2. There was satisfactory calibration between the predicted probability of postpartum SUI by the models and the actual observed postpartum SUI probability for both primiparous and multiparous women (Hosmer-Lemeshow test, p = 0.390 for primiparous and 0.364 for multiparous women).

Internal Validation of the Predictive Model for Primiparous and Multiparous Women

Validation of the model using data from primiparous and multiparous women revealed that the optimism-corrected C-statistic of the models by bootstrapping was 0.762 (95% CI, 0.693–0.832) for primiparous women and 0.781 (95% CI, 0.723–0.839) for multiparous women.

The Clinical Utility of the Predictive Model for Primiparous and Multiparous Women

A DCA of the model is presented in online suppl. Fig. S1 (see www.karger.com/doi/10.1159/000508416 for all online suppl. material). DCA revealed that using the model to predict SUI postpartum was more beneficial than the "treat-all individuals" plan or the "treat-none" plan, when the threshold predicted probability was 2.8–45.0% for primiparous women (online suppl. Fig. S1, left) and 4.8–52.3% for multiparous women (online suppl. Fig. S1, right).

Development of the Nomogram for Primiparous and Multiparous Women

R software was used to establish 2 nomograms (Fig. 3, 4) of postpartum SUI based on the results of the multivariable logistic analyses for primiparous and multiparous women.

Discussion

In the current study, the prevalence rate of SUI at 6 weeks postpartum was 15.96% (116/727). A review by Chan et al. [12] reported that the prevalence rate of urinary incontinence at 8 weeks postpartum was 18.6% (61/328), which was largely consistent with the current finding. The prevalence of SUI (12.5%, 49/393) in multiparous women was significantly higher than that in pri-

Table 2. Multivariable logistic regression analysis for predicting SUI at 6 weeks postpartum in primiparous and multiparous women

Variables	All (n = 727)					Primiparous (n = 393)					Multiparous (n = 334)				
	B	p value	OR	95% CI for OR		B	p value	OR	95% CI for OR		B	p value	OR	95% CI for OR	
				lower	upper				lower	upper				lower	upper
Intercept	−5.301	<0.001	0.005			−5.980	<0.001	0.003			−5.489	<0.001	0.004		
Maternal age						0.087	0.058	1.091	0.997	1.195					
Prepregnancy BMI	0.085	0.016	1.088	1.016	1.165						0.097	0.054	1.101	0.998	1.215
Abortion/miscarriage history	0.801	<0.001	2.228	1.442	3.441	0.814	0.023	2.258	1.121	4.548	0.561	0.065	1.753	0.965	3.183
SUI during pregnancy	1.598	<0.001	4.945	3.202	7.638	1.589	<0.001	4.901	2.578	9.317	1.493	<0.001	4.452	2.422	8.183
Vaginal delivery[a]	1.093	<0.001	2.984	1.765	5.045	0.818	0.043	2.266	1.027	4.999	1.405	<0.001	4.074	2.007	8.269

CI, confidence interval; SUI, stress urinary incontinence. [a] Cesarean section as reference.

miparous women (20.1%, 67/334) in the current study (p = 0.008). Our results are consistent with a small number of previous studies [13] investigating the prevalence of postpartum SUI in both primiparous (8.18%) and multiparous women (20.25%). To explore the feasibility of the model for primiparous and multiparous women, we performed multivariable analyses to distinguish them. To the best of our knowledge, the present study was the first to explore tools for predicting postpartum SUI for primiparous and multiparous women.

The Development, Performance, and Clinical Utility of the Predictive Models for Postpartum SUI

The results of the multivariable analysis of all women in the current study indicated that prepregnancy BMI, SUI during pregnancy, abortion/miscarriage history, and vaginal delivery were significant predictors of postpartum SUI. Surprisingly, previous delivery mode was not a significant predictive factor for postpartum SUI after adjusting for confounding factors. Among the variables included in the predictive model, the most valuable predictor was SUI during pregnancy. The risk of postpartum SUI at 6 weeks after delivery among women who experienced SUI during pregnancy was 4.95 times that of women who did not experience SUI during pregnancy. The present results also revealed that women who underwent vaginal delivery were more likely to develop SUI at 6 weeks postpartum. This result might be expected, because vaginal delivery has been confirmed to contribute to levator ani muscle injury [14, 15], which plays an important role in the development of postpartum SUI.

In accord with the current results, several previous studies reported that women with cesarean sections had a lower risk of pelvic floor dysfunction than women with vaginal delivery [6, 16, 17]. In addition to SUI during pregnancy and vaginal delivery, abortion/miscarriage history was found to be a significant contributor to postpartum SUI regardless of parity, similar to the findings reported in a previous study [18]. It should be noted that the variable "prepregnancy BMI," which was included in the model for multiparous women, appeared to have no effect on the occurrence of postpartum SUI for primiparous women. Instead, age was entered into the model for primiparous women.

In general, predictive models achieve poor discrimination performance when the area under the curve is between 0.5 and 0.7 and have better discrimination performance when the area under the curve is above 0.8 [19]. We internally validated the 2 models by bootstrapping; the results revealing that the optimism-corrected C-sta-

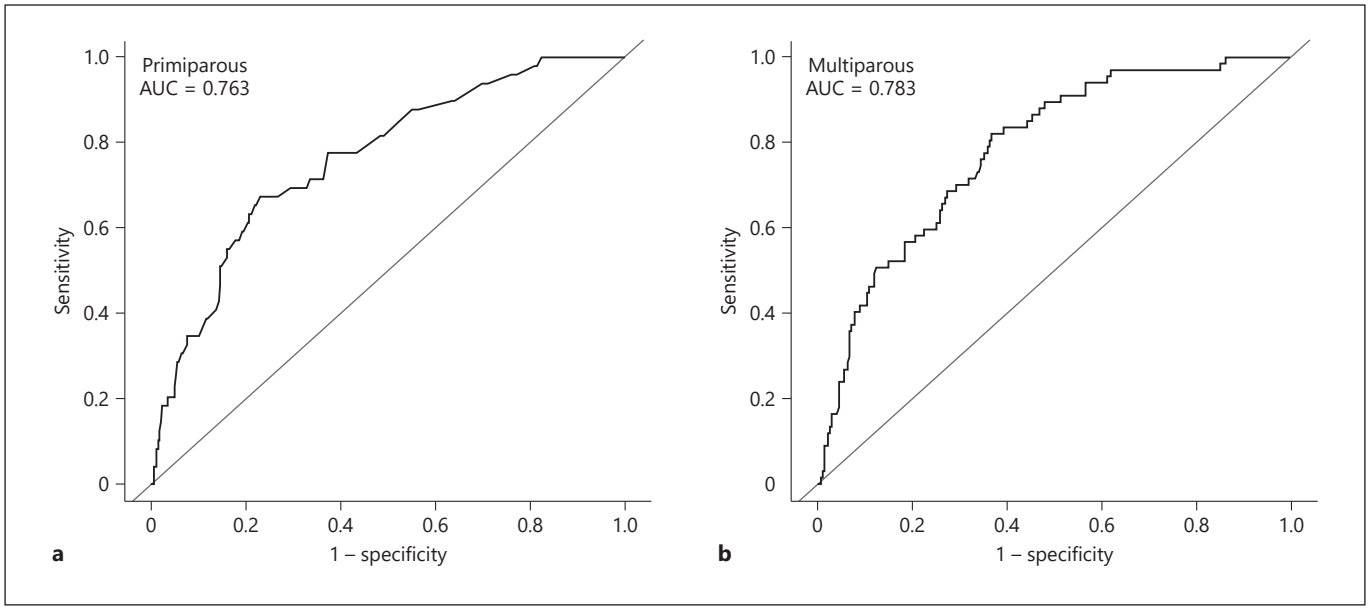

Fig. 2. ROC curve regarding the predictive model of SUI postpartum for primiparous (**a**) and multiparous (**b**). AUC, area under the curve; ROC, receiver operating characteristic; SUI, stress urinary incontinence.

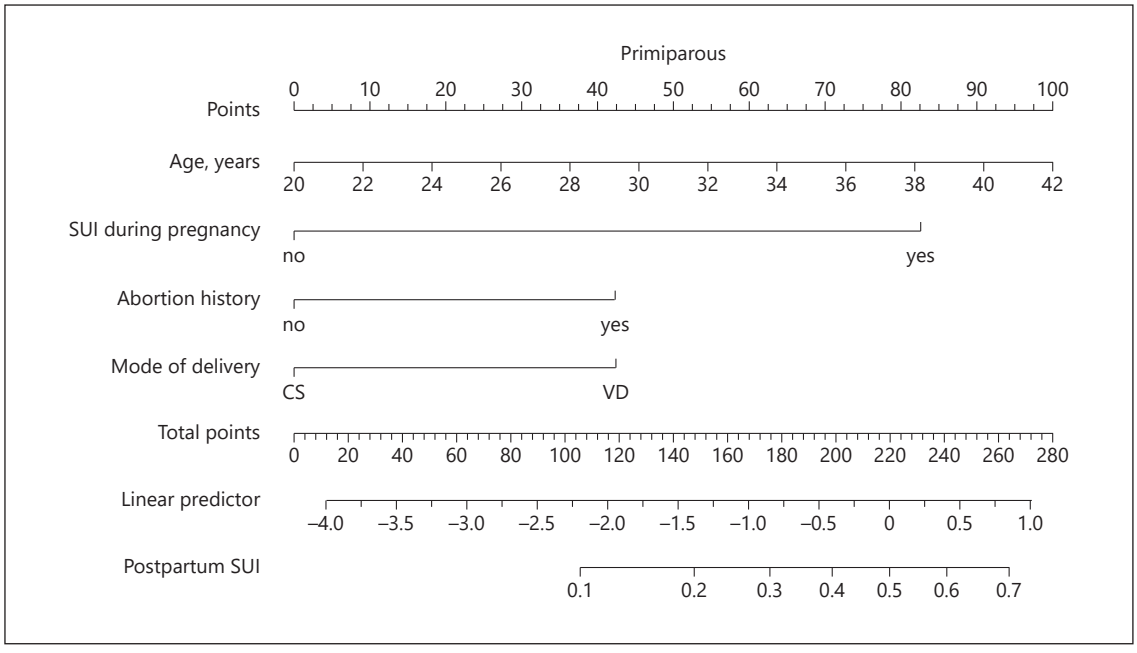

Fig. 3. The developed nomograms of SUI postpartum for primiparous women. SUI, stress urinary incontinence.

tistic of the models was 0.763 (95% CI: 0.693–0.833) for primiparous women and 0.783 (95% CI: 0.726–0.841) for multiparous women. The results indicate that our predictive model achieved acceptable discrimination for both primiparous women and multiparous women. In addition, good agreement was shown between probability based on the models and actual observation of postpartum SUI.

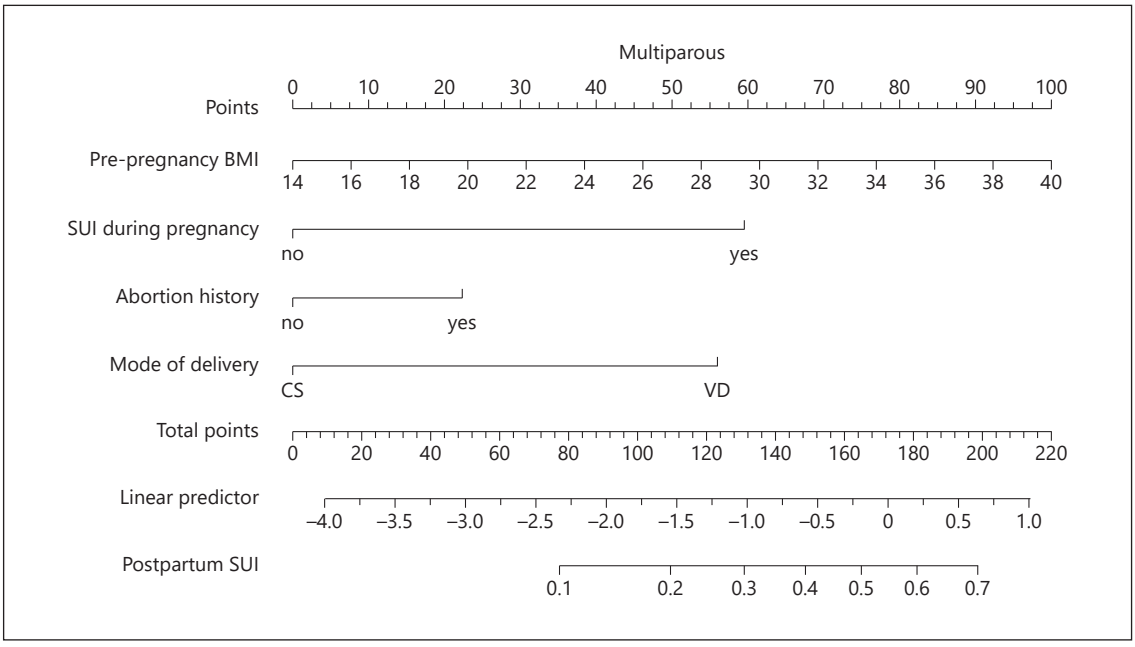

Fig. 4. The developed nomograms of SUI postpartum for multiparous women. SUI, stress urinary incontinence.

The current study is not the first application of predictive nomograms in the field of obstetrics. A disease predictive model in obstetrics field was previously explored by Grobman et al. [20] who developed a model for predicting the success rate of vaginal delivery after cesarean section to provide relevant information for obstetricians' decision-making. Jelovsek et al. [9] established antenatal and postnatal nomograms by analyzing clinico-demographic and pregnancy-related variables, with or without labor and delivery factors. With primiparous women as participants, the discrimination values of the antenatal and postnatal nomogram method developed by Jelovsek et al. [9] were 0.69 and 0.68, retrospectively. As reported by the authors, the discriminatory power of the 2 models was not satisfactory [9].

Considering the clinical utility of the models, we assessed whether the decision based on the models would improve the situation of postpartum SUI. DCA revealed that using the models to predict postpartum SUI was more beneficial than the "treat-all-individuals" plan or the "treat-none" plan, if the threshold predicted probability for primiparous women was between 2.8 and 45.0% and that for multiparous women was between 4.8 and 52.3%. We recommend setting the cutoff value for the models based on maximizing the Youden index score. In that case, the cutoff values were 0.141 and 0.159 for primiparous and multiparous models, respectively. An index presenting the predictive value of the 2 models is shown in online suppl. Table S1.

Clinical Implications of the Predictive Models

Importantly, the predictive model in the current study can also be used postpartum, as well as for antenatal assessment. Maternal age, prepregnancy BMI, abortion history, and SUI during pregnancy can be identified before delivery. Although the mode of delivery cannot be determined antenatally, in some cases, the planned delivery mode can be determined. We assumed that pregnant women without clinical indications of cesarean section in the third trimester were planning to give birth vaginally. If a woman was regarded as high-risk for postpartum SUI based on the model, antenatal PFMT instead of preventive cesarean section would be preferable to reduce the likelihood of postpartum SUI. Some previous studies advocated the adoption of selective cesarean section, restrictive episiotomy, and postpartum PFMT to prevent pelvic dysfunction [6, 21, 22]. Importantly, Nygaard [23] raised the question of whether women should be offered elective cesarean section to preserve pelvic floor function. In response, Milsom [24] proposed that pregnant women with a high risk of pelvic floor disorders and their health-care providers should consider which is the most suitable mode of delivery. Based on the current findings, we agree with Kokabi and Yazdanpanah's [25] pro-

posal that decisions regarding the mode of delivery should be based on clinical indications rather than the risks and benefits of pelvic floor disorders. The currently proposed predictive model may provide a useful alternative approach. However, the assumed benefits of antenatal PFMT for women at high risk of postpartum SUI should be verified in randomized controlled trials.

Strengths and Limitations of the Current Study

Previous studies have explored the prevalence rate and risk factors of postpartum SUI in primiparous women [9, 26, 27]. The current study investigated both primiparous and multiparous women, demonstrating that multiparous women can also be evaluated using the proposed predictive model. However, the current study involved several limitations that should be considered. First, the predictive models were constructed on the basis of a short postpartum duration. Although we attempted to follow up participants at 1 year after delivery, only one-third of participants responded. Among those who were followed up, the prevalence of SUI 1 year after delivery was 13.2% (32/242). Because the sample size at 1 year postpartum was not sufficient for model development, follow-up data at 6 weeks postpartum were used to develop the predictive models. A previous systematic review [28] revealed small changes in prevalence over time in the first year after delivery. However, postpartum SUI does improve over time in some cases. Therefore, the models developed in the present study should be used with caution when predicting long-term SUI after delivery. Second, owing to the limited duration of the study period, external validation of the model was not performed in the current study. The generalizability of the models in both primiparous and multiparous women should be further confirmed.

Conclusion

Overall, we developed predictive models of SUI postpartum for both primiparous and multiparous women, confirming the possibility of predicting SUI postpartum for multiparous women. Because of the relatively short postpartum follow-up period, the current results should be interpreted carefully. Importantly, clinical application is not recommended unless external validation of the models supports the robustness of the models. External validation with a longer postpartum follow-up period is currently underway in our research team, and the results will be reported in follow-up studies in the future.

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Statement of Ethics

This study was approved by the Ethics Committees of ShenZhen Hospital, Southern Medical University (No. NYSZYYEC20170014), and ShenZhen Maternal and Child Health Care Hospital (No. 2016-30). All participants gave written informed consent before participating.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest to disclose.

Author Contributions

C.L.: Protocol development, data analysis, and manuscript revision. D.L.: Protocol development, data analysis, and manuscript writing. X.Y.: Protocol development and data collection. M.J.: Data collection. X.C.: Data collection. W.C.: Protocol development and manuscript revision.

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