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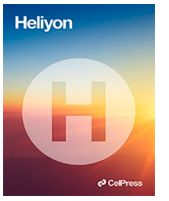

Research article

Risk factors and nomogram construction for predicting women with chronic pelvic pain:a cross-sectional population study

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ABSTRACT

Background: Chronic pelvic pain (CPP) in women is a critical challenge. Due to the complex etiology and difficulties in diagnosis, it has a greatly negative impact on women's physical and mental health and the healthcare system. At present, there is still a lack of research on the related factors and predictive models of chronic pelvic pain in women. Our study aims to identify risk factors associated with chronic pelvic pain in women and develop a predictive nomogram specifically tailored to high-risk women with CPP.

Materials and methods: From May to October 2022, trained interviewers conducted face-to-face questionnaire surveys and pelvic floor surface electromyography assessments on women from community hospitals in Nanjing. We constructed a multivariate logistic regression-based predictive model using CPP-related factors to assess the risk of chronic pelvic pain and create a predictive nomogram. Both internal and external validations were conducted, affirming the model's performance through assessments of discrimination, calibration, and practical applicability using area under the curve, calibration plots, and decision curve analysis.

Results: 1108 women were recruited in total (survey response rate:1108/1200), with 169 (15.3 %) being diagnosed as chronic pelvic pain. Factors contributing to CPP included weight, dysmenorrhea, sexual dysfunction, urinary incontinence, a history of pelvic inflammatory disease, and the surface electromyography value of post-baseline rest. In both the training and validation sets, the nomogram exhibited strong discrimination abilities with areas under the curve of 0.85 (95 % CI: 0.81–0.88) and 0.85 (95 % CI: 0.79–0.92), respectively. The examination of the decision curve and calibration plot showed that this model fit well and would be useful in clinical settings.

Conclusions: Weight, dysmenorrhea, sexual dysfunction, history of urinary incontinence and pelvic inflammatory disease, and surface electromyography value of post-baseline rest are independent predictors of chronic pelvic pain. The nomogram developed in this study serves as a valuable and straightforward tool for predicting chronic pelvic pain in women.

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1. Background

Chronic pelvic pain (CPP) is a common, incapacitating, and costly condition that disproportionately influences women. It is characterized as pain symptoms that are thought to be related to pelvic organs or structures and that continue longer than six months in most cases [1]. It frequently results in detrimental cognitive, behavioral, sexual, and emotional effects as well as symptoms that could point to gynecological, myofascial, or lower urinary tract problems [2]. CPP can manifest as mechanical, inflammatory, or neuropathic pain and is frequently underdiagnosed, impacting 5–26 % of women with varying prevalence across different countries [3–5]. The evidence suggests that CPP poses a large financial burden on women and health care systems globally, with indirect costs accounting for a sizable share of total expenses [6,7].

The etiology of CPP is complex, involving the reproductive, urinary, digestive, neuroendocrine, and musculoskeletal system, etc. It is usually accompanied by psychological and behavioral factors [8,9]. Studies have shown that CPP is associated with multiple factors such as dysmenorrhea [10], Sexual dysfunction [11], and pelvic inflammatory disease [12]. The pelvic floor muscles and myofascial membranes in CPP patients are hypertonic, which can be objectively demonstrated by surface electromyography (sEMG), usually as an increase in resting potential [13,14]. The presence of these factors complicates the assessment, diagnosis, and treatment of CPP; however, there are currently no reliable predictive models based on relevant factors for CPP.

The Brief Pain Inventory (BPI) [15] has been validated as an effective scale for assessing symptoms and pain severity. However, there is currently a lack of assessment scales specifically tailored to women with CPP. Based on existing literature and the BPI, we developed a questionnaire to gather factors associated with CPP in women. This study was based on the results of surface electromyography combined with CPP-related factors to develop a CPP prediction nomogram, which might help healthcare professionals timely and accurately predict the risk of CPP in women and contribute to planning and implementing relevant public health strategies.

2. Materials and methods

2.1. Study participants

A community hospital-based cross-sectional study design was employed in Nanjing. Females were recruited at primary hospitals in Nanjing, Jiangsu Province (including Dingshan Community Hospital, Yaohua Community Hospital, Xiaoshi Community Hospital, Dachang Community Hospital, Tangshan Community Hospital, and Tiexinqiao Community Hospital) from May 2022 to October 2022. We recorded the information and pelvic floor muscular activity of these females using questionnaire forms and electromyography. The government provides free screenings for two types of cancer (cervical and breast cancer) for this population, including electrocardiograms, breast and pelvic ultrasounds, and vaginal discharge tests. Age $\geq$18 years old; sexual history (the pelvic floor electromyography examination requires transvaginal operation); separate awareness; and the capacity of speaking and writing were required for inclusion. A requirement for exclusion were: pregnant females; any infectious diseases; acute pelvic inflammatory disease (These people are not suitable for pelvic floor electromyography to prevent aggravated infection); and unfinished medical information (who had any of the following: aphasia, severe hearing or a visual impairment, a history of mental illness or mental retardation). Each participant has written informed consent.

2.2. Design of questionnaire

The questionnaire was designed based on expert opinions and has gone through multiple internal iterations within the research team consisting of gynecologists, a clinical psychologist, pain researchers, and an epidemiologist, included demographic characteristics, sexual history, and pain assessment. We measured the sites, frequency, duration, intensity, and treatment history of pain adapted from the Brief Pain Inventory-Pain Interference (BPI-PI) [16]. Pain severity was evaluated using the Visual Analogue Scale (VAS) [17], a 100-mm line with "I don't feel any pain" on the left end and "The pain I feel can't be greater" on the right end. In this study, pain symptoms that are believed to originate from the pelvic organs or structures and continue longer than six months are known as CPP [18]. Dysmenorrhea is typically described as cramping pain in the lower abdomen beginning at the onset of menstrual flow and lasting eight to 72 h without significant cognitive behavioral or emotional impairment [19]. Female sexual dysfunction is defined as [20] "a disturbance in sexual desire and in the psychophysiological changes that characterize the sexual response cycle and cause marked distress and interpersonal difficulty." We assessed sexual function using the Female Sexual Function Index (FSFI) [21]. Participants were asked to recall the period prior to developing their chronic pelvic pain. Manual labor can be categorized into three levels of intensity: light, medium, and heavy [22]. Light manual labor typically involves sedentary or minimal movement tasks that require little physical exertion (student, office worker, etc.). Medium manual labor involves more continuous action with hands and arms (teacher, homemaker, sales, driver, etc.). Heavy manual labor is characterized by work that involves significant load-bearing tasks for the arms and trunk (farmer, laborer, etc.). Delivery mode was categorized in three hierarchical categories: cesarean section, assisted (instrumental) vaginal delivery (that is, use of forceps or vacuum extraction), and unassisted (normal) vaginal delivery [23]. For alcohol consumption history [24], patients who were current or former non-drinkers or social drinkers only were regarded as having no drinking history, and all others were considered as having a drinking history.

2.3. Assessment of pelvic floor surface electromyography

We performed the surface electromyography assessment for the pelvic floor muscles (PFMs) based on the Glazer protocol using the Vishee neuro-muscle stimulator (MyoTrac Infiniti, model SA9800, Thought Technology Ltd.) by a professional (medical doctors of attending level or higher who have received specialized training, passed assessments, and have performed over 50 such procedures). The Glazer Protocol was used to record the bioelectrical activity of the PFM by intro-vaginal electrodes, which included a series of contractions and relaxations of muscle described below: pre-baseline rest, phasic contractions, tonic contractions, isometric contractions for muscle endurance evaluation, and post-baseline rest [25]. The patient was in supine position, with a pillow under the head. The hips and knees need to be moderately bent and a pillow was placed beneath the knees for support, while the lumbar vertebrae keep neutral. To be acquainted with the testing program, the subject experienced a brief trial of phasic and tonic contractions after inserting the electromyography electrodes into the vagina. Testing occurred after a 10-min supine rest period, with verbal instructions to perform pelvic floor muscle contractions without engaging the gluteal, hip adductor, or abdominal muscles.

2.4. Study variables and design

The independent variables for this study were age, body mass index [BMI], residence, occupation, education menstruation history, obstetric history, health-related behaviors, underlying medical conditions status, history of sexual activity, pain assessment, pre-baseline rest and post-baseline rest. Women meeting the inclusion criteria were randomly divided into a training set and a validation set at a 3:1 ratio. We used the training set to construct a nomogram and conduct internal validation, while external validation was performed with data from the validation set.

2.5. Statistical analyses

Data analysis was performed using SPSS 22.0. The X^2-test was used to compare demographic characteristics. When the P-value was less than 0.05, the difference in risk factors between the CPP and non-CPP groups in the training set was significant. We used the presence or absence of CPP in the training set as the dependent variable and conducted univariate logistic regression analyses on each

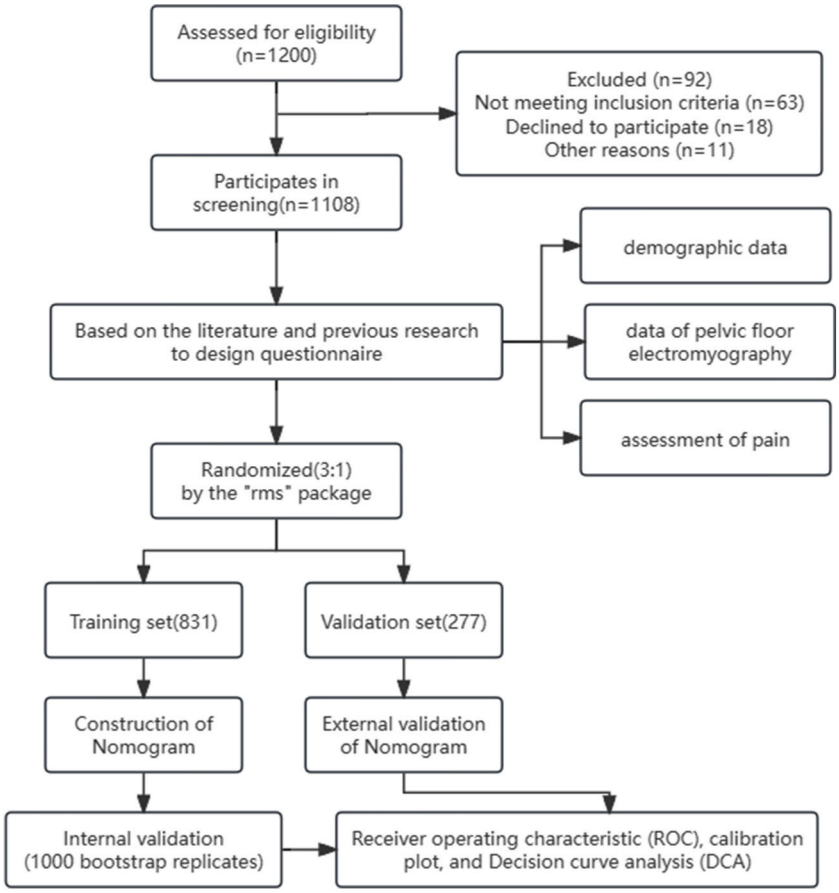

Fig. 1. Flow diagram.

Table 1
Characteristics of CPP in Nanjing, (N = 1108).

Variables	Total	CPP	NCPP	P
	(N = 1108)	(N = 169)	(N = 939)	
Age	1108	44.60 ± 6.67	46.29 ± 7.52	0.007
Height(cm)	1108	160.43 ± 4.94	159.79 ± 4.53	0.093
Weight(kg)	1108	61.62 ± 8.40	59.89 ± 8.40	0.014
BMI(kg/m^2)	1108	23.93 ± 3.04	23.44 ± 3.02	0.052
Pre-baseline rest	1108	7.11 ± 3.51	4.34 ± 2.55	< 0.001
Post-baseline rest	1108	7.39 ± 3.42	4.37 ± 2.15	< 0.001
Menopausal age	314	48.25 ± 3.52	49.68 ± 3.78	0.033
Local residence(n/%)				0.891
no	31	5(16.1 %)	26(83.9 %)	
yes	1077	164(15.3 %)	913(84.7 %)	
Residence(n/%)				0.034
Rural	204	36(17.6 %)	168(82.4 %)	
Urban	903	132(14.6 %)	771(85.4 %)	
Occupation(n/%)				0.9
light manual labor	430	67(15.6 %)	363(84.4 %)	
medium manual labor	371	54(14.6 %)	317(85.4 %)	
heavy manual labor	307	48(15.6 %)	259(84.4 %)	
Education(n/%)				0.021
less than a primary school education	183	23(12.6 %)	160(87.4 %)	
junior school education	486	64(13.2 %)	422(86.8 %)	
high school education	265	43(16.2 %)	222(83.8 %)	
more than undergraduate college education	174	39(22.4 %)	135(77.6 %)	
Delivery(n/%)				0.715
no	38	5(13.2 %)	33(86.8 %)	
yes	1070	164(15.3 %)	906(84.7 %)	
Parturition(n/%)				0.593
0	38	5(13.2 %)	33(86.8 %)	
1	685	112(16.4 %)	573(83.6 %)	
2	340	47(13.8 %)	293(86.2 %)	
≥3	45	5(11.1 %)	40(88.9 %)	
Delivery mode(n/%)				0.456
none	38	5(13.2 %)	33(86.8 %)	
unassisted vaginal delivery	776	114(14.7 %)	662(85.3 %)	
assisted vaginal delivery	23	6(26.1 %)	17(73.9 %)	
cesarean section	271	44(16.2 %)	227(83.8 %)	
FBW(n/%)				0.924
none	38	5(13.2 %)	33(86.8 %)	
< 2 kg	10	1(10 %)	9(90 %)	
2–3 kg	277	41(14.8 %)	236(85.2 %)	
3–4 kg	712	109(15.3 %)	603(84.7 %)	
> 4 kg	71	13(18.3 %)	58(81.7 %)	
Number of abortion(n/%)				0.542
0	754	107(14.2 %)	647(85.8 %)	
1	161	29(18.0 %)	132(82.0 %)	
2	138	24(17.4 %)	114(82.6 %)	
≥3	65	9(13.8 %)	46(86.2 %)	
Menopause(n/%)				0.122
no	760	125(16.4 %)	635(83.6 %)	
yes	348	44(12.6 %)	304(87.4 %)	
Dysmenorrhea(n/%)				< 0.001
no	688	60(8.7 %)	628(91.3 %)	
yes	420	109(26.0 %)	311(74.0 %)	
Sexual dysfunction(n/%)				< 0.001
no	980	123(12.6 %)	857(87.4 %)	
yes	128	46(35.9 %)	82(64.1 %)	
Age of first sexual intercourse(n/%)				0.813
< 18	40	8(20 %)	32(80 %)	
18–25	932	139(14.9 %)	794(85.1 %)	
26–36	114	18(15.8 %)	96(84.2 %)	
> 36	22	4(18.2 %)	18(81.8 %)	
Smoking(n/%)				0.856
no	1087	165(15.2 %)	922(84.8 %)	
yes	21	4(18.2 %)	17(81.8 %)	
Alcohol consumption history(n/%)				0.119
no	924	134(14.5 %)	790(85.5 %)	
yes	184	35(19.0 %)	149(81.0 %)	
Hypertension(n/%)				0.343

(*continued on next page*)

Table 1 (*continued*)

Variables	Total	CPP	NCPP	P
	(N = 1108)	(N = 169)	(N = 939)	
no	1008	157(15.6 %)	851(84.4 %)	
yes	100	12(12.0 %)	88(88.0 %)	
Diabetes(n/%)				0.773
no	1085	165(15.2 %)	920(84.8 %)	
yes	23	4(17.4 %)	19(82.6 %)	
Spinal disease(n/%)				0.004
no	1057	154(14.6 %)	903(85.4 %)	
yes	51	15(29.4 %)	36(70.6 %)	
Pelvic inflammatory disease (PID)(n/%)				< 0.001
no	806	98(12.2 %)	708(87.8 %)	
yes	302	71(23.5 %)	231(76.5 %)	
UI(n/%)				0.001
no	1033	148(14.3 %)	885(85.7 %)	
yes	75	21(28 %)	54(72 %)	
POP(n/%)				0.835
no	1093	167(15.3 %)	926(84.7 %)	
yes	15	2(13.3 %)	13(86.7 %)	
History of pelvic surgery(n/%)				0.007
no	649	83(12.8 %)	566(87.2 %)	
yes	459	86(18.7 %)	373(81.3 %)	
Pain duration(m)	169	23.18 ± 18.04		
VAS score	169	4.94 ± 1.66		
Did you noticed any pain related to skin (pain, itching, burning sensation) and muscles/joints? (n/%)				
no		129(76.3 %)		
yes		40(23.7 %)		
Pain and urinary symptoms (frequent urination, pain during holding urine, increased nocturnal urination, urethral pain) (n/%)				
no		122(72.2 %)		
yes		47(27.8 %)		
Pain and gastrointestinal symptoms (constipation, diarrhea, or other gastrointestinal-related symptoms) (n/%)				
no		123(72.8 %)		
yes		46(27.2 %)		
Pain and emotion (anxiety, depression) (n/%)				
no		110(65.1 %)		
yes		59(34.9 %)		
Pain and quality of life (n/%)				
no		4(2.4 %)		
yes		165(97.6 %)		

BMI, body mass in; *FBW*, Fetal birth weight; *PID*, pelvic inflammatory disease; *UI*, Urinary incontinence; *POP*, pelvic organ prolapse.

of the selected relevant factors as independent variables. Variables with $P < 0.1$ in the univariate analysis were included in the multivariate logistic regression analysis using the forward L.R. method. Finally, we identified the meaningful variables with $P < 0.05$ as independent risk factors associated with CPP of females. Odds ratios (ORs), 95 % confidence intervals (CIs), and P-values were used to analyze the factors. Following the results of multivariate logistic regression analysis, a predictive model was developed using the "rms" package in R version 3.6.1. Calculating the predictive probability of females developing CPP shows that higher scores are associated with an increased risk of developing CPP. We validated the constructed predictive model through both internal and external validation methods. The methods of Receiver operating characteristic (ROC), calibration plot, and Decision curve analysis (DCA) were used to evaluate the discrimination, calibration, and clinical application of this predictive model. The significance and effectiveness of this model were validated using the validation cohort.

2.6. Ethics Statement

On May 10, 2022, the Institutional Review Board of Zhongda Hospital, Southeast University, China ratified the study protocol (protocol registration no. 2022ZDSYLL107-P01).

3. Results

Out of 1200 initially screened women, 92 were excluded for various reasons, such as not meeting inclusion criteria or declining to participate. The study ultimately included 1108 patients, with no withdrawals or dropouts during the study. See Fig. 1 for a flow diagram. The overall incidence of CPP was 15.3 % (169/1108). (Table 1). Out of these participants, 831 were given to the training set for constructing the nomogram and 277 were assigned to the validation set. In the training and validation sets, CPP subjects accounted for 15.6 % (130/831) and 14.1 % (39/277) respectively. Differences in characteristics between the training and validation datasets were not statistically significant, indicating that the randomization into training and validation subsets worked quite well (Table 2).

The results of both univariate and multivariate analyses are displayed in Table 3. All thirteen factors that showed significant

Table 2
Characteristics of participants in training and validation datasets.

Variables	Training dataset (N = 831)	Validation dataset (N = 277)	P
Age	45.86 ± 7.43	46.55 ± 7.41	0.150
Height(cm)	159.85 ± 4.61	159.98 ± 4.57	0.602
Weight(kg)	60.17 ± 8.21	60.09 ± 9.05	0.787
BMI (kg/m^2)	23.54 ± 3.01	23.43 ± 3.09	0.474
Pre-baseline rest	4.76 ± 2.94	4.77 ± 2.75	0.701
Post-baseline rest	4.86 ± 2.64	4.74 ± 2.57	0.365
Menopausal age	49.29 ± 3.74	50.19 ± 3.8	0.092
Local residence(n/%)			1.000
no	2.8 %(23/831)	19.5 %(54/277)	
yes	97.2 %(808/831)	80.5 %(223/277)	
Residence(n/%)			0.655
Rural	18.1 %(150/831)	19.5 %(54/277)	
Urban	81.9 %(681/831)	80.5 %(223/277)	
Occupation(n/%)			0.236
light manual labor	37.4 %(311/831)	43 %(119/277)	
medium manual labor	33.9 %(282/831)	32.1 %(89/277)	
heavy manual labor	28.6 %(238/831)	24.9 %(69/277)	
Education(n/%)			0.223
less than a primary school education	17.1 %(142/831)	14.8 %(41/277)	
junior school education	42.5 %(353/831)	48 %(133/277)	
high school education	23.7 %(197/831)	24.5 %(68/277)	
more than undergraduate college education	16.7 %(139/831)	12.6 %(35/277)	
Delivery(n/%)			0.253
no		4.7 %(13/277)	
yes	97 %(806/831)	95.3 %(264/277)	
Parturition(n/%)			0.576
0		4.7 %(13/277)	
1	61.7 %(513/831)	62.1 %(172/277)	
2	31.2 %(259/831)	29.2 %(81/277)	
≥3	4.1 %(34/831)	4.0 %(11/277)	
Delivery mode(n/%)			0.317
none	3 %(25/831)	4.7 %(13/277)	
unassisted vaginal delivery	70.3 %(584/831)	69.3 %(192/277)	
assisted vaginal delivery	2.4 %(20/831)	1.1 %(3/277)	
cesarean section	24.3 %(202/831)	24.9 %(69/277)	
FBW(n/%)			0.423
none	3 %(25/831)	4.7 %(13/277)	
< 2 kg	1.1 %(9/831)	0.4 %(1/277)	
2–3 kg	25.9 %(215/831)	22.4 %(62/277)	
3–4 kg	63.7 %(529/831)	66.1 %(183/277)	
> 4 kg	6.4 %(53/831)	6.5 %(18/277)	
Number of abortion(n/%)			0.584
0	67.6 %(562/831)	69.3 %(192/277)	
1	14.2 %(118/831)	15.5 %(43/277)	
2	12.8 %(106/831)	11.6 %(32/277)	
≥3	5.4 %(45/831)	3.6 %(10/277)	
Menopause(n/%)			0.262
no	69.6 %(578/831)	65.7 %(182/277)	
yes	30.4 %(253/831)	34.3 %(95/277)	
Dysmenorrhea(n/%)			0.353
no	61.3 %(509/831)	64.6 %(179/277)	
yes	38.7 %(322/831)	35.4 %(98/277)	
Sexual dysfunction(n/%)			0.587
no	88.8 %(738/831)	87.4 %(242/277)	
yes	11.2 %(93/831)	12.6 %(35/277)	
Age of first sexual intercourse(n/%)			0.162
< 18	3.5 %(29/831)	4 %(11/277)	
18–25	85.3 %(709/831)	80.9 %(224/277)	
26–36	9.7 %(81/831)	11.9 %(33/277)	
> 36	1.4 %(12/831)	3.2 %(9/277)	
Smoking(n/%)			1.000
no	98.1 %(815/831)	98.2 %(272/277)	
yes	1.9 %(16/831)	1.8 %(5/277)	
Alcohol consumption history(n/%)			0.780
no	83.6 %(695/831)	82.7 %(229/277)	
yes	16.4 %(136/831)	17.3 %(48/277)	
Hypertension(n/%)			0.276

(*continued on next page*)

Table 2 (*continued*)

Variables	Training dataset (N = 831)	Validation dataset (N = 277)	P
no	90.4 %(751/831)	92.8 %(257/277)	
yes	9.6 %(80/831)	7.2 %(20/277)	
Diabetes(n/%)			0.543
no	97.7 %(812/831)	98.6 %(273/277)	
yes	2.3 %(19/831)	1.4 %(4/277)	
Spinal disease(n/%)			0.679
no	95.5 %(794/831)	94.9 %(263/277)	
yes	4.5 %(37/831)	5.1 %(14/277)	
PID(n/%)			0.755
no	73 %(607/831)	71.8 %(199/277)	
yes	27 %(224/831)	28.2 %(78/277)	
UI(n/%)			0.534
no	92.9 %(772/831)	94.2 %(261/277)	
yes	7.1 %(59/831)	5.8 %(16/277)	
POP(n/%)			0.134
no	98.3 %(817/831)	99.6 %(276/277)	
yes	1.7 %(14/831)	0.4 %(1/277)	
History of pelvic surgery(n/%)			0.379
no	57.8 %(480/831)	61 %(169/277)	
yes	42.2 %(351/831)	39 %(108/277)	

BMI, body mass in; *FBW*, fetal birth weight; *PID*, pelvic inflammatory disease; *UI*, Urinary incontinence; *POP*, pelvic organ prolapse.

associations with CPP in the univariate analysis were included as potential predictors in the multivariate logistic regression model (Table 3). The results revealed that weight (OR: 1.03, 95 % CI: 1.00–1.06, $P = 0.033$), dysmenorrhea (OR: 2.82, 95 % CI: 1.75–4.54, $P < 0.001$), sexual dysfunction (OR: 3.82, 95 % CI: 2.14–6.82, $P < 0.001$), urinary incontinence (UI) (OR: 2.43, 95 % CI: 1.15–5.13, $P = 0.020$), history of pelvic inflammatory disease (PID) (OR: 2.04, 95 % CI: 1.279–3.68, $P = 0.003$) and post-baseline rest (OR: 1.48, 95 % CI: 1.29–1.69, $P < 0.001$) were all independent influencing factors for CPP.

These independent prediction variables were combined to construct a predictive nomogram of CPP. On the top ruler, all predictive factors were predicted to produce the matching scores, while total scores and corresponding predictive probabilities were displayed at the bottom. The chance of CPP increased as the total score increased.

Through both internal and external validation, we confirmed the reliability of the nomogram as a tool for predicting CPP in women (Fig. 2). The training dataset had a C-index value of 0.85, indicating that it had enough power to identify CPPs. In the training and validation sets, the area under the curve (AUC) of the nomogram was 0.85 (95 % CI: 0.81–0.88) (Fig. 3A) and 0.85 (95 % CI: 0.79–0.92) (Fig. 3B), respectively. in the training set, the Youden index was 0.54, the cutoff value was 1.51, and the sensitivity and specificity were 0.82 and 0.72, separately.

A calibration curve was presented using the bootstrap method, which was repeated 1000 times in total. The results also revealed a good agreement between projected (Fig. 4A) and observed (Fig. 4B) CPP risks, with both the bias-corrected and apparent curves resembling the reference line. Additionally, DCA curve was produced to evaluate the clinical advantages of this nomogram. The results revealed that the model yielded net benefits to a wide range of approximately 2.0%–73.0 % in the training set and 2.0%–72.0 % (Fig. 5A) in the validation set (Fig. 5B), indicating that the model was useful in clinical decision-making.

4. Discussion

Due to the complex etiology and unknown pathogenesis, the diagnosis of chronic pelvic pain is difficult. At present, there is still a lack of research on the related factors and predictive models of chronic pelvic pain in women. This study investigated the risk factors of women with chronic pelvic pain combined with the information of pelvic floor surface electromyography, and to construct a predictive nomogram to identify the women at high risk of chronic pelvic pain, which is convenient for clinicians to carry out targeted early intervention. The prevalence of CPP in our study was 15.3 % among women in Nanjing, which is consistent with findings from previous studies. The results of our questionnaire which had been strengthened by using validated scales further proved that weight gain, dysmenorrhea, sexual dysfunction, UI, history of PID, and surface electromyography value of post-baseline rest are the risk factors for CPP. It also verifies the rationality and validity of the questionnaire to a certain extent.

Nomograms, recognized as reliable tools for assessing individual risk in various outcomes [26,27], have seen limited use in CPP prediction. The nomogram based on these 6 variables was created to predict CPP in women and had significantly high sensitivity and specificity in predicting women at high risk of CPP, which may act as a user-friendly and individualized tool for assessing CPP risk and targeting high-risk populations for intervention. According to the nomogram of this study, dysmenorrhea (12 points), sexual dysfunction (15 points), UI (10 points), and history of PID (8 points) were scored. As post-baseline rest and weight gain increase, so does the score, reflecting a corresponding increase in CPP risk among women.

Obesity is a CPP risk factor, likely due to its impact on body weight distribution, which affects the axial skeleton. This shift in the center of gravity can lead to lumbar spine hyper-lordosis, anterior pelvic tilt, and subsequent lower back pain (LBP) or pelvic girdle pain (PGP) [28] Another possible reason is that obesity causes higher venous pressure and larger femoral vein diameters [29]. These

Table 3
Factors associated with CPP among females in Nanjing in the training dataset.

Variables				Multivariate analysis		
	CPP	**NCPP**	**P**	**Exp(B)**	**95%CI**	**P**
	N = 130	N = 701				
Age	44.52 ± 6.61	46.11 ± 7.55	0.026	1.019	0.982–1.057	0.329
Height(cm)	160.38 ± 5.19	159.75 ± 4.50	0.153			
Weight(kg)	61.36 ± 8.05	59.95 ± 8.22	0.003	1.030	1.002–1.058	0.033
BMI (kg/m^2)	23.84 ± 2.84	23.48 ± 3.04	0.211			
Pre-baseline rest	7.11 ± 3.58	4.32 ± 2.58	< 0.001	1.051	0.940–1.175	0.380
Post-baseline rest	7.37 ± 3.45	4.40 ± 2.16	< 0.001	1.478	1.292–1.690	< 0.001
Menopausal age	48.28 ± 2.87	49.33 ± 3.98	0.170			
Local residence(n/%)						
no	17.4 %(4/23)	82.6 %(19/23)				
yes	15.6 %(126/808)	84.4 %(682/808)	0.815			
Residence(n/%)						
Rural	18.7 %(28/150)	81.3 %(122/150)				
Urban	15.0 %(102/681)	85 %(579/681)	0.261			
Occupation(n/%)						
light manual labor	16.1 %(50/311)	83.9 %(261/311)				
medium manual labor	14.2 %(40/282)	85.8 %(242/282)	0.521			
heavy manual labor	16.8 %(40/238)	83.2 %(198/238)	0.819			
Education(n/%)						
less than a primary school education	11.3 %(16/142)	88.7 %(126/142)		ref	ref	
junior school education	13.6 %(48/353)	86.4 %(305/353)	0.485	0.820	0.394–1.704	0.595
high school education	16.8 %(33/197)	83.2 %(164/197)	0.159	1.280	0.576–2.846	0.545
more than undergraduate college education	23.7 %(33/139)	76.3 %(106/139)	0.007	1.303	0.538–3.157	0.557
Delivery(n/%)						
no	16 %(4/25)	84 %(21/25)				
yes	15.6 %(126/806)	84.4 %(680/806)	0.960			
Parturition(n/%)						
0	16 %(4/25)	84 %(21/25)				
1	16.6 %(85/513)	83.4 %(428/513)	0.940			
2	14.7 %(38/259)	85.3 %(221/259)	0.858			
≥3	8.8 %(3/34)	91.2 %(31/34)	0.406			
Delivery mode(n/%)						
none	16 %(4/25)	84 %(21/25)				
unassisted vaginal delivery	14.6 %(85/584)	85.4 %(499/584)	0.841			
assisted vaginal delivery	30 %(6/20)	70 %(14/20)	0.268			
cesarean section	17.3 %(35/202)	82.7 %(167/202)	0.848			
FBW(n/%)						
none	16 %(4/25)	84 %(21/25)				
< 2 kg	11.1 %(1/9)	88.9 %(8/9)	0.724			
2–3 kg	14.0 %(30/215)	86.0 %(185/215)	0.781			
3–4 kg	15.9 %(84/529)	84.1 %(445/529)	0.987			
> 4 kg	20.8 %(11/53)	79.2 %(42/53)	0.620			
Number of abortion(n/%)						
0	13.3 %(75/562)	86.7 %(487/562)		ref	ref	
1	22.0 %(26/118)	78 %(92/118)	0.017	1.225	0.518–2.901	0.644
2	18.9 %(20/106)	81.1 %(86/106)	0.137	0.912	0.376–2.215	0.839
≥3	20 %(9/45)	80 %(36/45)	0.217	0.937	0.320–2.741	0.905
Menopause(n/%)						
no	16.4 %(95/578)	83.6 %(483/578)				
yes	13.8 %(35/253)	86.2 %(218/253)	0.343			
Dysmenorrhea(n/%)						
no	9.4 %(48/509)	90.6 %(461/509)		ref	ref	
yes	25.5 %(82/322)	74.5 %(240/322)	< 0.001	2.816	1.746–4.540	< 0.001
Sexual dysfunction(n/%)						
no	12.7 %(94/738)	87.3 %(644/738)		ref	ref	
yes	38.7 %(36/93)	61.3 %(57/93)	< 0.001	3.820	2.141–6.819	< 0.001
Age of first sexual intercourse(n/%)						
< 18	24.1 %(7/29)	75.9 %(22/29)				
18–25	15.1 %(107/709)	84.9 %(602/709)	0.192			
26–36	16.0 %(13/81)	84 %(68/81)	0.336			
> 36	25 %(3/12)	75 %(9/12)	0.953			
Smoking(n/%)						
no	15.7 %(128/815)	84.3 %(687/815)				
yes	12.5 %(2/16)	87.5 %(14/16)	0.727			
Alcohol consumption history(n/%)						
no	14.7 %(102/695)	85.3 %(593/695)		ref	ref	

(*continued on next page*)

Table 3 (*continued*)

Variables				Multivariate analysis		
	CPP	**NCPP**	**P**	**Exp(B)**	**95%CI**	**P**
	N = 130	N = 701				
yes	20.6 %(28/136)	79.4 %(108/136)	0.084	1.195	0.670–2.131	0.546
Hypertension(n/%)						
no	15.8 %(119/751)	84.2 %(632/751)				
yes	13.8 %(11/80)	86.2 %(69/80)	0.624			
Diabetes(n/%)						
no	15.6 %(127/812)	84.4 %(685/812)				
yes	15.8 %(3/19)	84.2 %(16/19)	0.986			
Spinal disease(n/%)						
no	13.4 %(120/794)	86.6 %(674/794)		ref	ref	
yes	27.0 %(10/37)	73 %(27/37)	0.056	1.003	0.377–2.673	0.995
Pelvic inflammatory disease (PID)(n/%)						
no	11.5 %(70/607)	88.5 %(537/607)		ref	ref	
yes	26.8 %(60/224)	73.2 %(164/224)	< 0.001	2.040	1.269–3.678	0.003
UI(n/%)						
no	14.8 %(114/772)	85.2 %(658/772)		ref	ref	
yes	27.1 %(16/59)	72.9 %(43/59)	0.014	2.430	1.150–5.134	0.020
POP(n/%)						
no	15.7 %(128/817)	84.3 %(689/817)				
yes	14.3 %(2/14)	85.7 %(12/14)	0.888			
History of pelvic surgery(n/%)						
no	11.7 %(56/480)	88.3 %(424/480)		ref	ref	
yes	21.1 %(74/351)	78.9 %(277/351)	< 0.001	1.459	0.693–3.072	0.319

CI, confidence interval; *BMI*, body mass in; *FBW*, fetal birth weight; *PID*, pelvic inflammatory disease; *UI*, Urinary incontinence; *POP*, pelvic organ prolaps

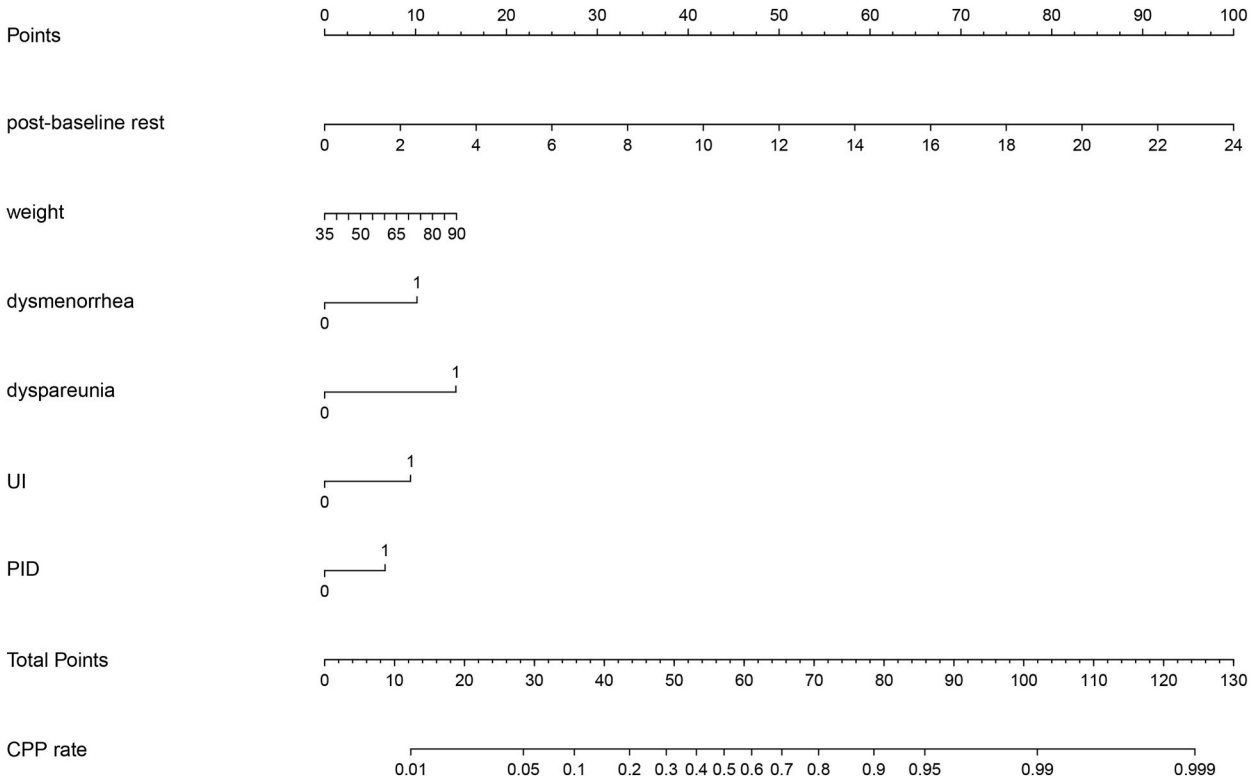

Fig. 2. Nomogram for predicting CPP in women. For an individual patient, each variable corresponds to a single point at the top of nomogram (Points). The total points are summed up by all single points and indicated in the second line from the bottom (Total Points), and each total point corresponds to a probability of CPP.

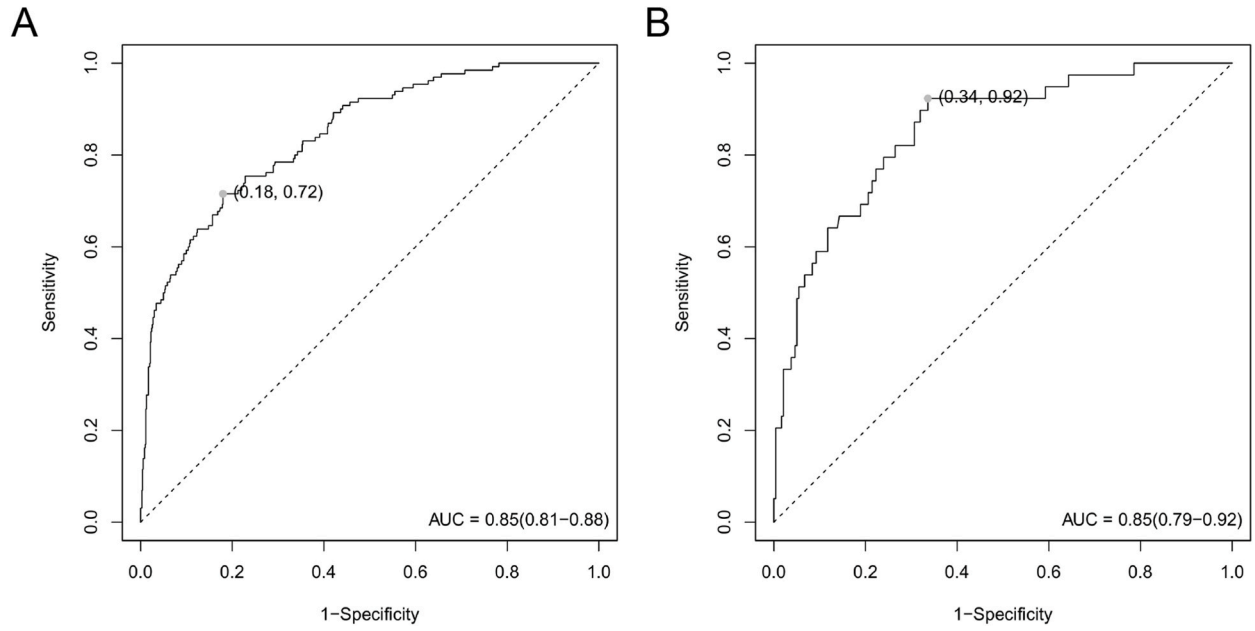

Fig. 3. ROC curves of the nomogram for predicting the probability of CPP in training set (A) and validation set (B). The horizontal axis means the false positive rate of the risk prediction. The vertical axis means the true positive rate of the risk prediction. ROC: Receiver operating characteristic curve; AUC: Area under curve; CPP: Chronic pelvic pain.

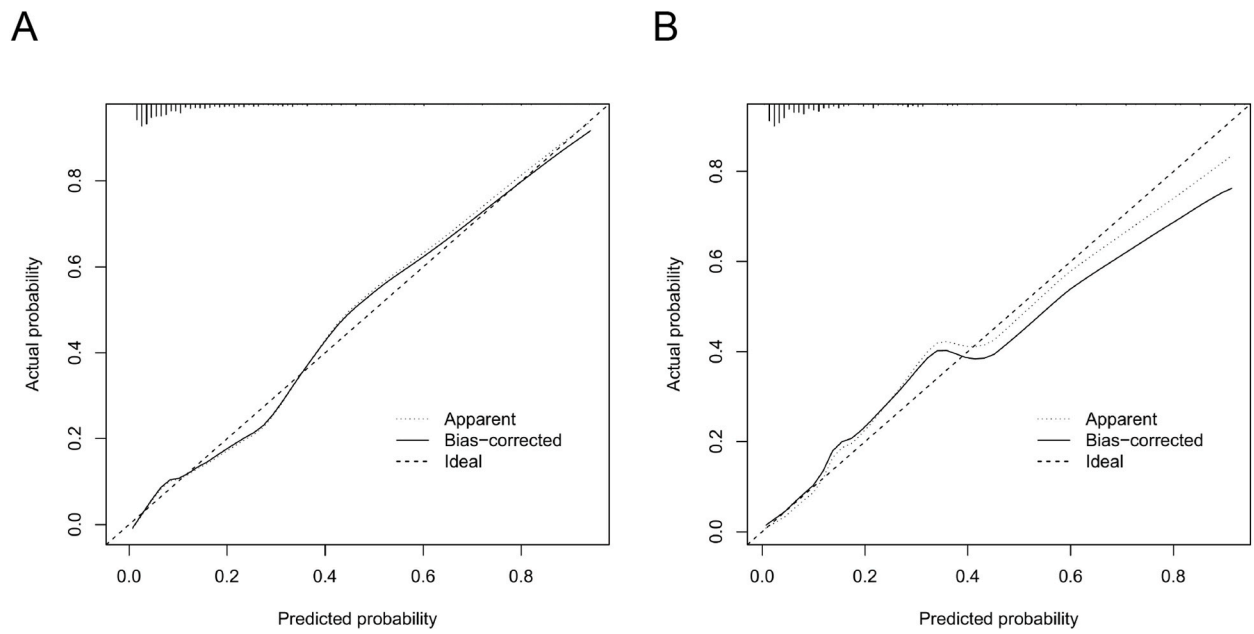

Fig. 4. Calibration curves of the nomogram for predicting the probability of CPP in training set (A) and validation set (B). Internal validation of the nomogram is performed using a corrected calibration curve within 1000 bootstrap samples. The horizontal axis represents the predictive probability of CPP. The vertical axis represents the actual CPP probability. The diagonal dotted line represents a perfect prediction of an ideal model. The solid line represents the performance of the nomogram, of which a closer fit to the diagonal dotted line represents a better prediction. CPP: Chronic pelvic pain.

influences are considered to be caused by increased abdominal pressure, which causes faster reflux, axial vein distention, more rapid retrograde flow, and higher net pressure at the ankles [30], making women with continual pelvic congestion more susceptible to CPP.

Our study found an association between dysmenorrhea and sexual dysfunction with CPP. Dysmenorrhea presents as periodic pelvic pain, which in principle does not belong to the category of CPP. However, if it is accompanied by significant adverse consequences such

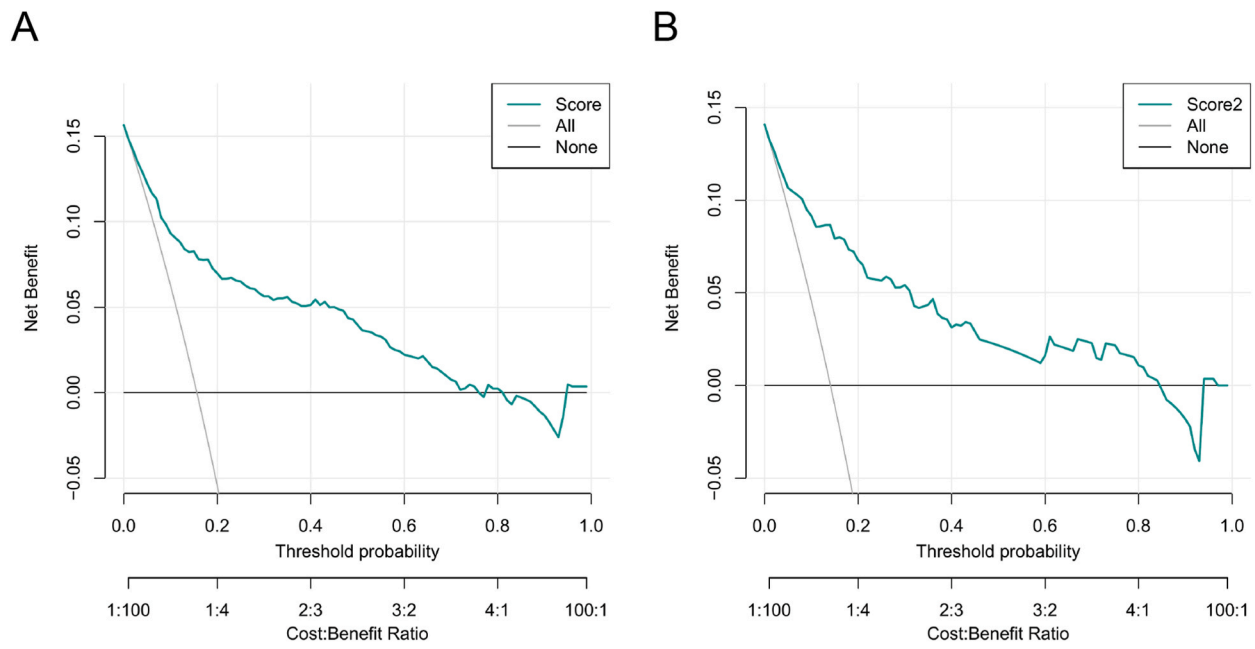

Fig. 5. DCA curves of the nomogram for predicting the probability of CPP in training set (A) and validation set (B). The horizontal and vertical axes represent the threshold probability and net benefit, respectively. The lines between the horizontal axis and vertical axis display the benefit of different predictive variables. The DCA curves show that if the threshold probability is 2%–73 %, using this nomogram in the current study to predict SI risk could add more benefit. DCA: Decision curve analysis; CPP: Chronic pelvic pain.

as cognitive behavior and emotion, then it is thought to be CPP. Peripheral sensitization, cerebral sensitization, and aberrant stress reactions may be the underlying reasons for the relationship between dysmenorrhea and chronic pain [31,32]. Central sensitization is a neurological phenomenon in which the central nervous system (CNS) becomes hypersensitive to pain signals. In conditions like endometriosis, the repeated experience of pain can lead to changes in the CNS, amplifying pain perception. Over time, the central nervous system becomes more sensitive to pain signals, intensifying the perception of pain even outside of menstruation [33,34]. Endometriosis, which occurs in 71–87 % of women with chronic pelvic pain, is associated with dysmenorrhea, chronic pelvic pain, and infertility [35]. The inflammatory response, tissue adhesions, and the presence of endometrial implants contribute to ongoing pain beyond the menstrual cycle. In addition, endometrial tissue in the pelvic area can cause adhesions and scarring, leading to pain during sexual intercourse (dyspareunia) [36,37]. As a cause of chronic pelvic pain, adenomyosis is frequently associated with endometriosis [38]and congenital uterine anomalies [39]. The exact pathogenesis of this association is not clear, but it has been proposed that the two conditions may share common genetic and developmental pathways [40,41]. In addition, the uterus in congenital anomalies may increase intrauterine pressure and promote the penetration of endometrial cells within the myometrial layer and the growth of adenomyotic foci [42]. There is no standardized therapy in place for this common cause of chronic pelvic pain presently [43]. Future studies should focus on exploring the relationship between adenomyosis and congenital malformations of the female genitalia and its pathological mechanism in order to seek more effective treatment and prevention measures. Pelvic floor muscle overactivity, such as in vaginismus, can cause pain and discomfort in women [44]. Investigating the role of sexual partners in the context of dyspareunia is crucial due to the interpersonal and relational aspects of sexual activity. Mismatched expectations, lack of sexual education, or unresolved relationship issues may contribute to dyspareunia. Furthermore, a partner's physical health or psychological state can also play a role [45,46]. Understanding these dynamics helps in identifying potential areas for intervention to improve sexual health and reduce the occurrence of painful intercourse. In conclusion, the relationships between dysmenorrhea, sexual pain, central sensitization, and chronic pelvic pain are multifaceted and interrelated. Effective management often involves a multidisciplinary approach tailored to the individual's specific needs.

The majority of participants with CPP showed signs of pelvic floor dysfunction, which typically involves a hypertonic state of the pelvic floor musculature. Some studies have reported pelvic floor muscle tenderness or hypertonia may be a hyperalgesia muscular response to noxious stimuli, reported in 22.0%–94.0 % of women with CPP [47,48]. sEMG is thought to be a valuable tool for assessing the clinical conditions of patients [49,50]. According to several other researchers and ourselves, women with PFM-related pelvic pain have an elevated sEMG signal amplitude at rest [51,52], which has traditionally been linked to an increased level of neuronal excitation [53]. Our study integrated individual pelvic floor electromyography data, revealing that CPP women had higher sEMG values in two phases (pre-baseline rest and post-baseline rest) than those without CPP. The sEMG value of post-baseline rest, but not the sEMG value of pre-baseline rest, was an independent risk factor for CPP, which might be partially explained by the patients' discomfort or nervousness at the beginning of the examination.

According to reports, 22 % of patients with acute PID develop CPP after an acute attack [54]. The pain persists after acute

inflammation disappears due to the sensitization of nerve fibers in the affected tissue. Untreated or inadequately managed PID can lead to inflammatory cell invasion, tissue destruction, tissue proliferation, adhesion formation, and scar tissue development. These pathological changes, including the fallopian tube thickening, hydronephrosis, the formation of salpingo-ovarian abscess [18], the main and sacral ligament hyperplasia and thickening, restricted uterine movement, pelvic inflammatory congestion, will finally cause CPP [55,56]. CPP incidence correlates with increasing pelvic tension, and the adhesion and damage between pelvic organs become more severe. The severity of PID and the rationality of treatment can be found to be associated with the incidence of CPP, consistent with our results.

To our knowledge, this is the first study to combine sEMG with demographic characteristics, socioeconomic status, health-related behaviors, and underlying medical conditions status to construct a nomogram for predicting CPP in women. This approach enables the identification of high-risk patients who require closer and more precise monitoring. By combining validated scales, our study enhances result reliability. In addition, effective and user-friendly nomograms are less hazardous to patients than traditional screening scales since they rarely offer suggestive or negative information. This marks a positive initial step toward integrating screening into clinical practice, which can enable medical professionals to take fast action to lower the prevalence of CPP. We hope more prospective data will validate our model predictions further and explore the model's implications as a common screening method for CPP.

It's understandable that our study has limitations. Firstly, our findings are specific to Asian females and may not be generalized to women in other regions. Further research is needed to determine if the results of this study can be applied to non-Asian populations. Secondly, due to the cross-sectional nature of the study, recall bias may have affected data on specific exposures. These limitations mean that the study can only show associations or correlations, and no definitive causal conclusions can be drawn between the relevant variables and CPP. For example, this study is an exploration of the correlation between dyspareunia and CPP, without investigation regarding the presence of sexual activity with a partner, which may influence the dyspareunia domain. Nevertheless, our study offers a valuable preliminary method for predicting CPP in women. Additionally, we only include individuals who consent to testing; those who declined testing may already have CPP, leading to underestimated incidence of CPP. Furthermore, the lack of prospective data collection limits our ability to establish causality in the identified correlations. This highlights the need for further prospective studies of the causality of these relationships.

5. Conclusion

Our research findings indicate that women who exhibit characteristics such as weight gain, dysmenorrhea, sexual dysfunction, UI, a history of PID, and elevated post-baseline rest values are at an increased risk of CPP. Therefore, these individuals should be prioritized for screening and medical attention. Moreover, our predictive model demonstrates the strong clinical utility and discriminatory power in identifying CPP risk. Using the provided nomogram, healthcare professionals can accurately assess CPP risk based on a range of individual traits. This facilitates early detection and offers an effective clinical predictive tool. This facilitates early detection and offers an effective clinical predictive tool.

Ethics approval and consent to participate

This study was performed following the CONSORT guideline and in accordance with the Declaration of Helsinki. The Institutional Review Board of Zhongda Hospital, Southeast University, China approved the study protocol (protocol registration no. 2022ZDSYLL107-P01). Each participant provided their informed consent to participate.

Consent for publication

Not applicable.

Data availability statement

Data associated with our study hasn't been deposited into a publicly available repository. Data can be obtained by applying to the corresponding author on request.

CRediT authorship contribution statement

Mingyue Zhu: Writing – original draft, Formal analysis, Conceptualization. **Fei Huang:** Writing – original draft, Data curation, Conceptualization. **Jingyun Xu:** Investigation, Conceptualization. **Wanwen Chen:** Investigation, Data curation. **Bo Ding:** Investigation. **Yang Shen:** Writing – review & editing, Validation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

CPP	Chronic pelvic pain
UI	urinary incontinence
PID	history of pelvic inflammatory disease
BMI	Body mass index
PFM	pelvic floor muscle
ROC	Receiver operating characteristic
DCA	Decision curve analysis
sEMG	Surface electromyograph

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e34534.

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