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Construction and validation of a risk predictive model for fear of disease progression in patients after percutaneous coronary intervention

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This study aimed to construct and validate a predictive model for fear of disease progression in patients after percutaneous coronary intervention(PCI). From March to October 2024, 455 post-PCI patients in the Department of Cardiovascular Medicine of a tertiary general hospital in Sichuan Province, China, were randomly divided into a training set and a validation set in a ratio of 7:3 as study subjects. LASSO regression and multifactorial logistic regression were used to analyze the factors influencing fear of disease progression in post-PCI patients, and a column chart was constructed. The predictive performance of the model was evaluated using the area under the ROC curve, Hosmer-Lemeshow test, and calibration curve. Clinical effectiveness was evaluated using clinical decision curve analysis. Among 455 post-PCI patients, 295 had a fear of disease progression, with an incidence of 64.8%. Seven influencing factors, including average monthly family income, number of chronic diseases, disease duration, number of interventional treatments, number of stent implants, psychological resilience, and perceived social support, were screened to construct the prediction model. The area under the ROC curve of the prediction model in the training set and the validation set were 0.941 (95% *CI*: 0.915–0.967) and 0.947 (95% *CI*: 0.911–0.984), respectively; the results of the Hosmer-Lemeshow goodness-of-fit test were $\chi2 = 12.564$ ($P = 0.128$) and $\chi2 = 3.758$ ($P = 0.878$); calibration curves showed significant agreement between predicted and actual values. The clinical decision curve analysis demonstrates that this model exhibits favorable net benefit and clinical effectiveness.The fear of disease progression prediction model constructed in this study has good predictive ability, which can provide a reference basis for effectively identifying high-risk groups and formulating targeted interventions to reduce the fear of disease progression in post-PCI patients.

Keywords Percutaneous coronary intervention, Fear of disease progression, Influencing factors, Columnar graphs, Predictive models

Coronary heart disease is one of the common cardiovascular diseases, which refers to heart disease caused by atherosclerosis of coronary arteries resulting in narrowing or blockage of the blood vessel lumen, leading to myocardial ischemia and hypoxia or necrosis, and its prevalence and mortality rate is increasing year by year[1]. According to survey data[2,3], as of 2019, there are approximately 197 million patients with coronary heart disease worldwide, and the prevalence of coronary heart disease is expected to increase by 18.0% by 2030. According to data from the China Cardiovascular Health and Disease Report 2023[4], as of 2020, the prevalence of cardiovascular disease in China is on a continuous rise, with the number of people now suffering from the disease reaching 330 million, including 11.39 million people with coronary heart disease, making China the country with the heaviest burden of cardiovascular disease in the world. According to reports[5], it is expected that by 2035, more than 3.4 million people will die of coronary heart disease in China. Coronary heart disease has a long course and is prone to recurring episodes, characterized by high prevalence, high recurrence rate, high mortality rate, and high medical costs. It has become an important global public health problem, which not

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only seriously affects the physical and mental health and quality of life of the patients but also imposes a heavy economic burden on the families, the society, and the country[6].

Percutaneous Coronary Intervention (PCI) is currently an effective treatment for coronary artery disease. It can effectively unblock narrowed or occluded coronary arteries and restore blood supply to the myocardium. Still, it is unable to reverse or slow down the biological process of coronary atherosclerosis development[7]. Study has shown that although PCI can effectively improve myocardial blood supply, due to a variety of factors, post-PCI patients may still have recurrent coronary artery disease and thrombus formation in the stent, leading to restenosis[8]. The incidence of in-stent restenosis in post-PCI patients is reported to be 2% to 10%[9]. In addition, the risk of recurrence within 1 month after PCI and the mortality rate after recurrence are high[10]. It has been reported that the 5-year all-cause mortality rate and 10-year all-cause mortality rate of post-PCI patients are 11.2% and 28%, respectively[11,12]. The potential complications and risk of disease progression after PCI make post-PCI patients often have concerns about disease recurrence and progression, thus creating a fear of disease progression, which affects their physical and mental health and post-procedure recovery[13,14].

In 2003, the scholar Dankert, for the first time, put forward the concept of disease progression fear, which will be defined as the individual to the disease caused by a variety of biological, psychological, and social consequences of the disease relapse again and producing a reactive, conscious fear, is a chronic disease patient commonly exist in one of the psychological problems[15]. Coronary heart disease, as a chronic progressive disease, has the characteristics of a prolonged course and a high recurrence rate. Patients are often excessively worried about disease recurrence or disease progression, easily producing fear of the disease, and this psychological state may further affect the prognosis and recovery of the disease[16]. Xu et al.[17] showed that coronary heart disease patients' fear of disease progression score was (35.19 ± 8.14), and patients who had anxiety and depression were more prone to produce fear of disease progression. Wang et al.[18] found that the rate of fear of disease progression in patients with acute myocardial infarction was 50.6%. In addition, it has been reported that the rate of fear of disease progression in Chinese post-PCI patients is even as high as 54.8%[19]. Several studies have shown that a moderate level of fear of disease progression can help stimulate patients to pay attention to their disease and encourage them to participate more actively in treatment and rehabilitation, such as taking medication on time, undergoing regular checkups, and improving their lifestyles, thus improving treatment adherence and self-management ability[13,20]. However, a high level of fear of disease progression not only affects patients' physical and mental health but may also lead to psychological problems such as anxiety and depression and even trigger dysfunctions, such as avoidance of daily activities or over-medication behaviors, which will not only increase the readmission rate of patients but also bring a heavy economic burden to the family and society[17]. In addition, relevant studies have pointed out that patients' fear of disease progression can be related to a variety of factors, mainly including socio-demographic factors[18,21] (e.g., gender, age, occupational status, etc.), disease-related factors[21,22] (e.g., duration of the disease, number of hospitalizations, etc.), and psychosocial factors[17,23,24] (e.g., social support, psychological resilience, and disease perception, etc.). Therefore, it is necessary to construct a prediction model of the factors influencing the fear of disease progression in post-PCI patients in order to identify the risk factors for the fear of disease progression early and effectively and to provide targeted interventions.

Symptom management theory is an important theoretical framework in nursing and health sciences, developed by a team of nursing scholars at the University of California, San Francisco, to assess and intervene in patients' symptom experience systematically. It is widely used in chronic disease management, cancer care, and geriatric care[25]. The theory emphasizes that symptoms are a complex, multidimensional concept that involves not only discomfort at the physiological level but also encompasses the interaction of psychological and socio-environmental factors[26]. PCI, as a stressful medical event, often produces psychological responses such as anxiety and fear in postoperative patients due to the trauma of the surgery and the uncertainty of the disease's prognosis, which in turn affects the process of their recovery[13]. Psychological resilience refers to an individual's ability to effectively cope with and recover from adversity, stress, or frustration and plays an important role in symptom management[27]. Li et al.[28] pointed out that postoperative hepatocellular carcinoma patients with higher psychological resilience are usually able to adjust their mindset better and adopt positive coping strategies, such as proactively seeking knowledge of the disease and maintaining optimistic attitudes toward life, which can effectively alleviate the progression of the disease and reduce the fear of disease. In addition, social support, as one of the key elements in symptom management theory, is also a core factor influencing patients' health outcomes. Perceived social support refers to the degree to which an individual subjectively perceives that support is available from family, friends, and other outsiders[29]. Liu et al.[24] showed that when cancer patients perceive a higher level of social support, it enhances their confidence and sense of security in the face of disease, thereby alleviating psychological loneliness and helplessness and reducing fear due to the uncertainty of the disease. Given that there are still few studies on the relationship between psychological resilience, perceived social support, and fear of disease progression in post-PCI patients. Therefore, based on the symptom management theory, this study is intended to explore and early identify the influencing factors of the fear of disease progression in post-PCI patients from the perspectives of individual characteristics, disease factors, psychological resilience, and perceived social support, which is of great significance in reducing the fear of disease progression, decreasing the occurrence of adverse cardiovascular events, and promoting the physical and mental health of patients.

Currently, the research on the factors influencing the fear of disease progression in post-PCI patients is still in its infancy. Only a small number of studies have explored the influencing factors through a single traditional statistical analysis method, which has limited predictive ability. There is currently no risk prediction model for the fear of disease progression in post-PCI patients. LASSO regression is a widely used regression analysis method in statistics. Its core lies in the compression of the coefficients to achieve the purpose of variable selection and complexity adjustment, thus improving the predictive accuracy and explanatory ability of the model, to achieve the purpose of variable selection and complexity adjustment and improve the predictive accuracy and

explanatory ability of the model[30]. Therefore, in this study, LASSO regression was used to screen the influencing factors of fear of disease progression in post-PCI patients and construct a prediction model of fear of disease progression, aiming to provide a reference basis for the early identification of high-risk groups, the development of targeted interventions to reduce the fear of disease progression in post-PCI patients, and the promotion of their physical and mental health development.

Materials and methods

Aims

This study aimed to construct and validate a predictive model for fear of disease progression in patients after PCI.

Setting and participants

The convenience sampling method was used to select patients who underwent PCI in the Department of Cardiovascular Medicine of a tertiary-level hospital in Sichuan Province, China, from March to October 2024 as the survey subjects. Inclusion criteria: ①Patients who met the diagnostic and treatment criteria of coronary artery disease[31], and met the indications of PCI surgery, and whose physical condition was stable after PCI; ②Patients ≥ 18 years old; ③Patients with clear consciousness and who could communicate verbally or in writing; ④Patients who gave informed consent and voluntarily participated in this study. Exclusion criteria: ①Patients with cognitive and mental disorders and serious deficits in vision and hearing function; ②Patients with other systematic serious diseases, such as liver, brain, kidney, and other organs or with tumor recurrence and metastasis, serious infectious diseases.

In this study, the number of events per variable (EPV) in logistic regression analysis was used to estimate the sample size[32]. The model predictions for this study were estimated to consist of 6–7 predictors. According to the 10 EPV principle, the results of previous studies showed that the incidence of fear of disease progression in post-PCI patients was approximately 54.8%[19]. Considering 20% invalid questionnaires, the minimum sample size should be $10 \times 6 \div 54.8\% \times (1 + 20\%) \approx 132$, and the maximum sample size should be $10 \times 7 \div 54.8\% \times (1 + 20\%) \approx 154$. 455 valid questionnaires were finally recovered in the present study, which was randomly divided into training set and validation set according to the ratio of 7:3, of which 318 cases were in the training set and 137 cases were in the validation set.

Instruments

General information questionnaire

A self-designed general information questionnaire, including sociodemographic and disease-related information, was used. General demographic data included gender, age, marital status, number of children, education level, average monthly family income, occupational status, place of residence, living situation, and medical payment methods; disease-related data included smoking situation, drinking situation, number of chronic diseases, disease duration, whether or not they had a family history of cardiovascular disease, the number of times they had been hospitalized for coronary heart disease, number of interventional treatments, and number of stent implants.

Fear of progression Questionnaire-Short Form(FoP-Q-SF)

The Fear of Progression Questionnaire-Short Form was developed by Mehnert et al.[33] and handwritten by Wu et al.[34] The scale consists of two dimensions, physical health, and social family, with a total of 12 entries. The scale is scored on a 5-point Likert scale, with scores ranging from 1 to 5, from "never" to "always", and a total score of 12 to 60, with higher scores indicating a more serious level of fear of disease progression, and a total score of ≥ 34 indicating the existence of fear of disease progression. This scale demonstrates good reliability and validity, and is widely used to assess the fear of disease progression among patients with chronic diseases. The Cronbach's alpha coefficient for the scale is 0.883. In this study, the Cronbach's alpha coefficient for the scale was 0.794.

Connor-davidson resilience scale(CD-RISC)

The Psychological Resilience Scale was developed by Campbell-Sills et al.[27] and Chineseized by Wang et al.[35] The scale includes two dimensions of resilience and strength, with a total of 10 entries. The scale is rated on a 5-point Likert scale, with scores ranging from 0 to 4, from "never" to "always", and a total score of 0 to 100, with higher scores indicating better psychological resilience. This scale demonstrates excellent reliability and validity and is widely used to assess psychological resilience in patients with chronic diseases. The Cronbach's alpha coefficient for the scale is 0.910. In this study, the Cronbach's alpha coefficient for the scale was 0.863.

Perceived social support scale(PSSS)

The Perceived Social Support Scale was developed by Blumenthal et al.[29] and handwritten by Jiang et al.[36] The scale consists of three dimensions: family support, friend support, and other support, with a total of 12 items. The scale is rated on a 7-point Likert scale, with scores ranging from 1 to 7, from "strongly disagree" to "strongly agree", and the total score ranges from 12 to 84, with higher scores indicating a higher level of social support felt by the individual. This scale demonstrates excellent reliability and validity, and is widely used to assess perceived social support levels among patients with chronic diseases. The Cronbach's alpha coefficient for the scale is 0.992. In this study, the Cronbach's alpha coefficient for the scale was 0.875.

Data collection

This study used a paper-based questionnaire to collect data. Prior to the survey, the research subjects were selected in strict accordance with the criteria of nativity. The unified instruction was used to explain in detail

to the research subjects the purpose, significance, method of filling in the questionnaire, and precautions to be taken. After obtaining the consent of the research subjects and completing the procedure of signing the informed consent form, the paper questionnaires were distributed and filled in in the wards. For those who were less educated or unable to fill in the questionnaire by themselves, the researcher read the questionnaires one by one in order to assist the patients in completing the questionnaires. The investigator completed information related to disease characteristics after reviewing electronic cases or interviewing patients. During the whole process of questionnaire completion, the researcher avoided suggesting and interfering with the patients. The questionnaires were collected and checked by the researcher on the spot after completion. A total of 468 questionnaires were distributed in this study, and 455 valid questionnaires were recovered, with a valid questionnaire recovery rate of 97.2%.

Statistical analysis

SPSS 26.0 and R 4.4.0 were used to analyze the data statistically. Measurement information conforming to normal distribution was described by mean ± standard deviation, and independent samples t-test was used for comparison between groups; counting information was expressed by frequency and percentage, and $\chi 2$ test was used for comparison between groups, and the Mann-Whitney U test was used for hierarchical information. The best predictor variables were screened based on LASSO regression, on the basis of which logistic regression was used further to construct the predictive model and column line graph. The predictive effect of the model was evaluated using the area under the receiver operating characteristic(ROC), and the predictive efficacy of the model was verified by sensitivity and specificity; the goodness-of-fit of the model was assessed using the Hosmer-Lemeshow test and plotting the calibration curve; clinical effectiveness was evaluated using clinical decision curve analysis. The test level $\alpha = 0.05$.

Ethical considerations

The study followed the Declaration of Helsinki and was approved by the Ethics Committee of Deyang People's Hospital (2024-04-018-K01). All study subjects gave informed consent and voluntarily participated in this study.

Results

Comparison of the incidence of fear of disease progression in the training set and validation set

Of the 455 post-PCI patients, 295 had a fear of disease progression, with an incidence rate of 64.8%. Among them, 210 of 318 post-PCI patients in the training set had a fear of disease progression, with an incidence rate of 66%; 85 of 137 post-PCI patients in the validation set had a fear of disease progression, with an incidence rate of 62.0%. Comparing the two groups, $\chi^2 = 0.010$, $P = 0.922$.

Comparison of general data between post-PCI patients who developed a fear of disease progression and those who did not create a fear of disease progression in the training set

In the training set, there were 133 males and 77 females who developed a fear of disease progression, and 61 males and 47 females who did not create a fear of disease progression; the rest of the general information is shown in Table 1.

LASSO regression screening

Whether or not fear of disease progression occurred in patients after PCI was used as the dependent variable, and LASSO regression was used to screen the variables. The LASSO regression used the 10-fold cross-validation method, and lambda.min was chosen as the optimal value of the model. At this point, when lambda.min = 0.0086, the following 15 variables were screened: age, marital status, number of children, occupational status, medical payment methods, average monthly family income, living situation, drinking situation, number of chronic diseases, disease duration, whether or not there is a family history of cardiovascular disease, number of interventional treatments, number of stent implants, psychological resilience, and perceived social support. See Figs. 1 and 2.

Multifactorial analysis of fear of disease progression in post-PCI patients

The dependent variable (no = 0, yes = 1) was whether the post-PCI patients experienced fear of disease progression, and the influencing factors screened by LASSO regression were included as independent variables in the Logistics regression model for multifactorial analysis. The results showed that post-PCI patients' average monthly family income, number of chronic diseases, disease duration, number of interventional treatments, number of stent implants, psychological resilience, and perceived social support were the influencing factors for the occurrence of fear of disease progression. See Table 2.

Construction of a fear of disease progression prediction model for post-PCI patients

Based on the results of multifactorial logistic regression analysis, a column chart of fear of disease progression in post-PCI patients was constructed and is shown in Fig. 3. The column chart was used by identifying the score corresponding to each factor in the chart, and the scores were summed up as the total score to obtain the probability of the occurrence of the fear of disease progression in post-PCI patients based on the total score on the risk axis.

For example, a patient at a certain hospital has the following characteristics: the patient's average monthly family income is between 3000 ~ < 5000 yuan, the number of chronic diseases is 2, the disease duration is < 1 year, the number of interventional treatments is 2, the number of stent implants is 2, psychological resilience is 30 points, and perceived social support is 45 points. In the line chart model, each variable corresponds to

Variables	N	Fear of disease progression		χ^2/t/Z	P
		Yes($n=210$)	No($n=108$)		
Gender					
Male	194	133(63.3)	61(56.5)	1.408	0.235
Female	124	77(36.7)	47(43.5)		
Age (years)					
18 ~ 59	85	41(19.5)	44(40.7)	21.714	<0.001
60 ~ 69	94	60(28.6)	34(31.5)		
≥ 70	139	109(51.9)	30(27.8)		
Marital status					
Married	257	162(77.1)	95(88.0)	5.386	0.020
Single/Divorced/Widowed	61	48(22.9)	13(12.0)		
Number of children					
1	193	125(59.5)	68(63.0)	0.373	0.830
2	115	78(37.1)	37(34.3)		
v≥ 3	10	7(3.3)	3(2.8)		
Education level					
Primary and below	165	131(62.4)	34(31.5)	29.317	<0.001
Junior	81	46(21.9)	35(32.4)		
High school and above	72	33(15.7)	39(36.1)		
Occupational status					
Be employed	75	40(19.0)	35(32.4)	7.063	0.008
Unemployed/Retired	243	170(81.0)	73(67.6)		
Place of residence					
Towns	176	97(46.2)	79(73.1)	20.972	<0.001
Countryside	142	113(53.8)	29(26.9)		
Medical payment methods					
Urban medical insurance	153	82(39.0)	71(65.7)	22.448	<0.001
Rural medical insurance	92	67(31.9)	25(23.1)		
Self-funded	73	61(29.0)	12(11.1)		
Average monthly family income(yuan)					
<3000	51	45(21.4)	6(5.6)	73.932	<0.001
3000~<5000	181	140(66.7)	41(38.0)		
≥ 5000	86	25(11.9)	61(56.5)		
Living situation					
Live alone	34	19(9.0)	15(13.9)	1.874	0.599
Living with children only	73	50(23.8)	23(21.3)		
Living with spouse only	88	58(27.6)	30(27.8)		
Living with children and spouse	123	83(39.5)	40(37.0)		
Smoking situation					
Never smoked	149	95(45.2)	54(50.0)	0.977	0.614
Have given up smoking	79	52(24.8)	27(25.0)		
Still smoking	90	63(30.0)	27(25.0)		
Drinking situation					
Never drank	155	100(47.6)	55(50.9)	4.659	0.097
Have given up drinking	76	45(21.4)	31(28.7)		
Still drinking	87	65(31.0)	22(20.4)		
Number of chronic diseases					
1	110	34(16.2)	76(70.4)	97.607	<0.001
2	106	82(39.0)	24(22.2)		
≥ 3	102	94(44.8)	8(7.4)		
Disease duration(years)					
<1	39	17(8.1)	22(20.4)	24.398	<0.001
1~<5	111	65(31.0)	46(42.6)		
5~<10	64	42(20.0)	22(20.4)		
≥ 10	104	86(41.0)	18(16.7)		
Continued					

Variables	N	Fear of disease progression		χ^2/t/Z	P
		Yes($n=210$)	No($n=108$)		
Whether or not they had a family history of cardiovascular disease					
No	84	43(20.5)	41(38.0)	11.220	0.001
Yes	234	167(79.5)	67(62.0)		
Number of times they had been hospitalized for coronary heart disease					
1	69	25(11.9)	44(40.7)	53.815	<0.001
2	109	67(31.9)	42(38.9)		
3	83	64(30.5)	19(17.6)		
≥4	57	54(25.7)	3(2.8)		
Number of interventional treatments					
1	95	70(33.3)	25(23.1)	15.150	0.001
2	201	119(56.7)	82(75.9)		
≥3	22	21(10.0)	1(0.9)		
Number of stent implants					
1	78	22(10.5)	56(51.9)	70.701	<0.001
2	102	72(34.3)	30(27.8)		
≥3	138	116(55.2)	22(20.4)		
Psychological resilience		23.86 ± 3.36	29.35 ± 3.08	14.209	<0.001
Perceived social support		45.25 ± 4.38	51.66 ± 4.57	12.161	<0.001

Table 1. Comparison of general information of patients who developed a fear of disease progression and those who did not create fear of disease progression in the training set[n(%)]

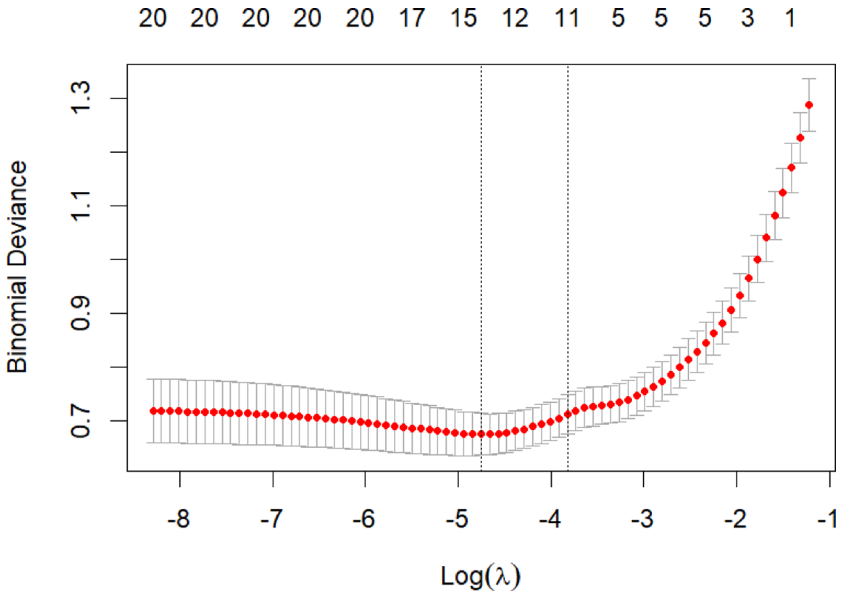


Fig. 1. LASSO regression cross-validation results.

a specific score on the assessment scale. Thus: Average monthly family income: (3000~<5000) = 20 points, number of chronic conditions (2) = 20 points, disease duration (< 1 year) = 30 points, number of interventional treatments (2) = 24 points, number of stent implants (2) = 29 points, psychological resilience (30 points) = 30 points, perceived social support (50 points) = 39 points. Total score: 192 points. The predicted probability of fear of disease progression was obtained by summing the scores of each variable and drawing a vertical line on the total score. Therefore, this patient has approximately a 90% risk of developing fear of disease progression according to the nomogram model.

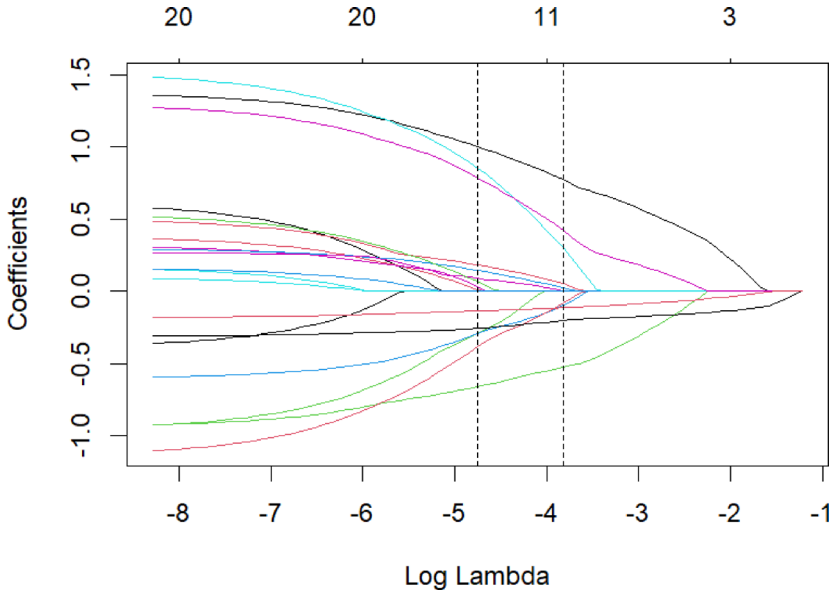


Fig. 2. Path diagram of LASSO regression coefficients.

Variables	β	SE	Waldχ^2	*P*	OR(95%CI)
Constant	15.019	3.492	18.496	<0.001	–
Average monthly family income					
3000~<5000	− 0.906	0.988	0.841	0.359	0.404(0.058 ~ 2.802)
≥ 5000	− 2.305	1.037	4.941	0.026	0.100(0.013 ~ 0.761)
Number of chronic diseases					
2	1.383	0.509	7.371	0.007	3.986(1.469 ~ 10.816)
≥ 3	2.880	0.731	15.533	<0.001	17.815(4.254 ~ 74.608)
Disease duration					
1~<5	− 0.490	0.723	0.459	0.498	0.613(0.148 ~ 2.529)
5~<10	− 2.395	0.988	5.872	0.015	0.091(0.013 ~ 0.633)
≥ 10	− 2.837	1.164	5.941	0.015	0.059(0.006 ~ 0.574)
Number of interventional treatments					
2	1.683	0.692	5.906	0.015	5.382(1.385 ~ 20.911)
≥ 3	2.687	1.719	2.443	0.118	14.689(0.505 ~ 427.060)
Number of stent implants					
2	2.072	0.584	12.577	<0.001	7.938(2.526 ~ 24.943)
≥ 3	3.136	0.903	12.065	0.001	23.020(3.922 ~ 135.117)
Psychological resilience	− 0.300	0.084	12.612	<0.001	0.741(0.628 ~ 0.874)
Perceived social support	− 0.184	0.061	9.143	0.002	0.832(0.738 ~ 0.937)

Table 2. Logistic regression analysis of fear of disease progression in post-PCI patients.

Evaluation and validation of a fear of disease progression prediction model for post-PCI patients

The area under the ROC curve for the training set is 0.941 (95% *CI*: 0.915 ~ 0.967, $P < 0.001$), the best critical value was 0.547, the sensitivity and specificity were 90.5% and 88.0%, respectively, and the result of Hosmer-Lemeshow goodness-of-fit test was $\chi2 = 12.564$ ($P = 0.128$). The area under the ROC curve for the validation set is 0.947 (95% *CI*: 0.911 ~ 0.984, $P < 0.001$), the best critical value is 0.575, the sensitivity and specificity are 91.8% and 88.5%, respectively, and the result of the Hosmer-Lemeshow goodness-of-fit test is $\chi2 = 3.758$ ($P = 0.878$), which indicates that the model has a good differentiation and calibration. See Figs. 4 and 5. From the clinical decision curve analysis, when the probability threshold is set, a decision curve that lies above the reference line indicates that the predictive model generally demonstrates good clinical utility. In this study, when the model predicts that no patient experiences fear of disease progression and no intervention is taken, the net benefit rate is zero, represented by the solid green line; When the model predicts fear of disease progression in all patients and intervention is implemented, the net benefit rate exhibits a negative slope, represented by the red solid

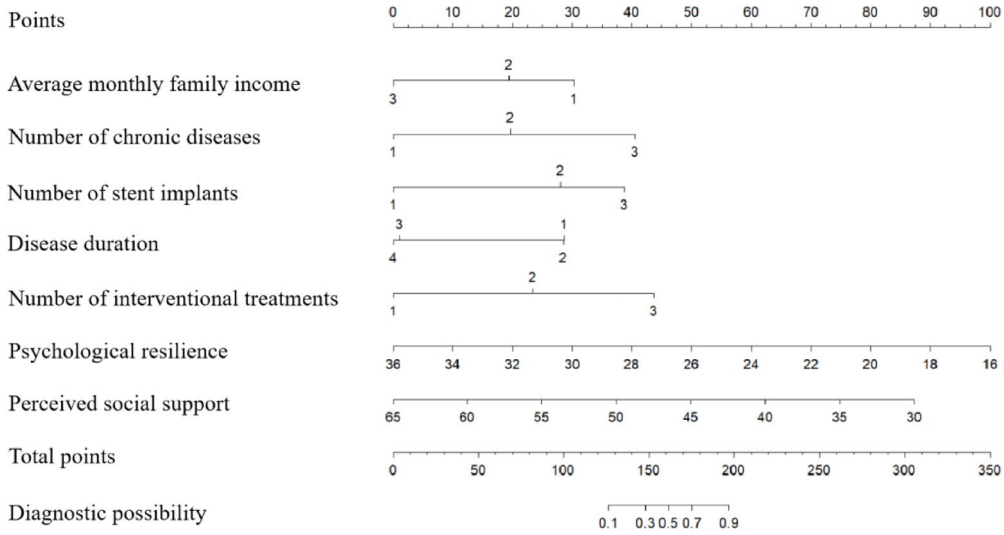


Fig. 3. Column line diagram of the fear of disease progression prediction model for post-PCI patients.

line. The further the decision curve of the predictive model deviates from the green and red solid lines and approaches the upper-right corner, the better the model's clinical efficacy. The predictive model in this study demonstrated significantly higher net benefits for both the modeling and validation cohorts compared to the two extreme scenarios, indicating that model-driven decisions can benefit patients. See Fig. 6.

Discussion

Higher incidence of fear of disease progression in post-PCI patients

The results of this study showed that the incidence of fear of disease progression in post-PCI patients was 64.8%, which was higher than the results of Lu et al.'s survey study on post-PCI patients (54.8%)[19], indicating that the fear of disease progression of the post-PCI patients in this study was at a high level. Analysis of the reasons suggests that, compared to studies by Lu et al.[19], patients in this study may have had a higher average age and more chronic comorbidities following PCI. Increasing age typically signifies a natural decline in physical function and recovery capacity, while multiple comorbidities may create a complex interplay where conditions exacerbate each other. This not only heightens the actual risk of recurrent cardiovascular events but also intensifies patients' sense of loss of control over their health, thereby amplifying their anxiety and uncertainty about disease recurrence[18]. Secondly, PCI is a stressful medical event. PCI surgery, although only a minimally invasive surgery, will still cause some physiological and psychological trauma to patients. On the one hand, patients may experience chest pain, palpitations, and other discomfort symptoms after PCI, which may lead to patients mistakenly believing that their condition has worsened, thus generating fear of disease progression[13]. On the other hand, patients may still face the risk of complications such as in-stent restenosis, thrombosis, and so on, and the uncertainty in the process of disease recovery may also increase the patient's fear of disease progression[10]. Therefore, we should pay active attention to the psychological status of post-PCI patients and strengthen the early screening and identification of their fear of disease progression.

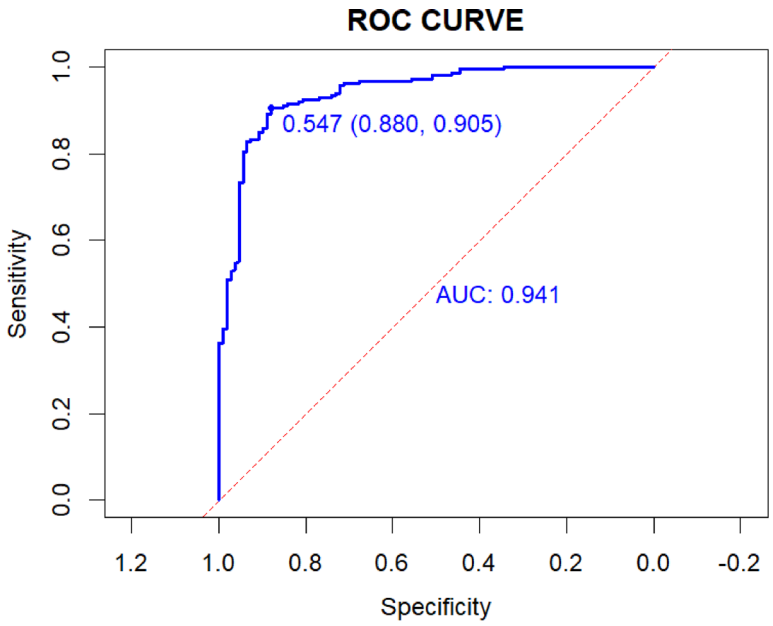
Analysis of factors influencing fear of disease progression in post-PCI patients

Average monthly family income

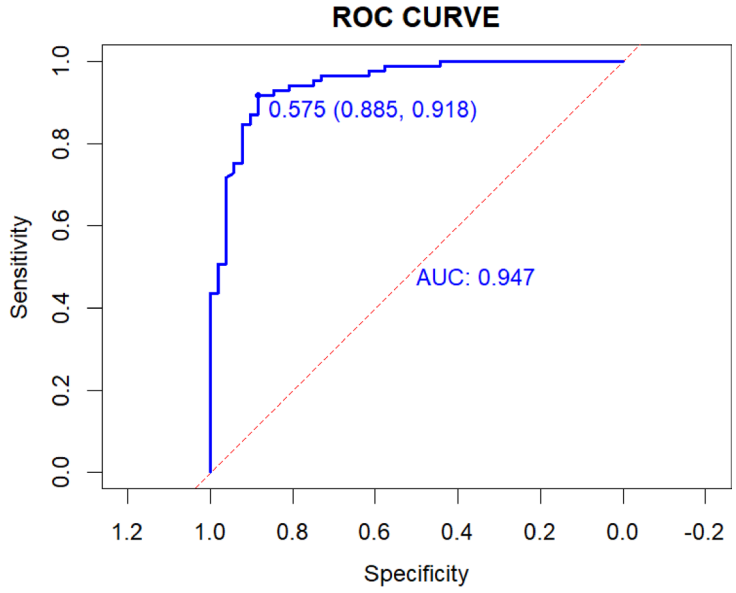
The results of this study showed that the lower the average monthly family income of post-PCI patients, the more serious the fear of disease progression, which is consistent with the results of previous study[37]. The reason for this analysis may be related to the fact that post-PCI patients still need long-term medication and regular review, and patients with lower average monthly family income often experience psychological stress due to the fear of increased medical costs, which leads to greater concern about disease recurrence and exacerbates the fear of disease progression. In addition, the study also pointed out that patients with poorer family economic status may have poorer accessibility to medical resources and single access to information, leading to insufficient knowledge of the disease and fear of disease progression[38]. Therefore, it is suggested that healthcare professionals should focus on the low-income patient population and call on the government to optimize the healthcare insurance system and expand the scope of subsidies for chronic diseases to effectively reduce the financial burden of patients, thereby alleviating their fear of disease and enhancing their treatment experience and recovery effects.

Number of chronic diseases

The results of this study showed that the level of fear of disease progression was higher in post-PCI patients with more chronic diseases, similar to the results of previous study[39]. In this study, 65.4% of post-PCI patients had ≥ 2 chronic diseases. Related study has also pointed out that with the increase in the number of chronic diseases, the burden of disease management and the psychological burden of patients increases[40]. On the one hand, when the organism is in a state of multimorbidity, various disease pathologies interact with each other, which may increase



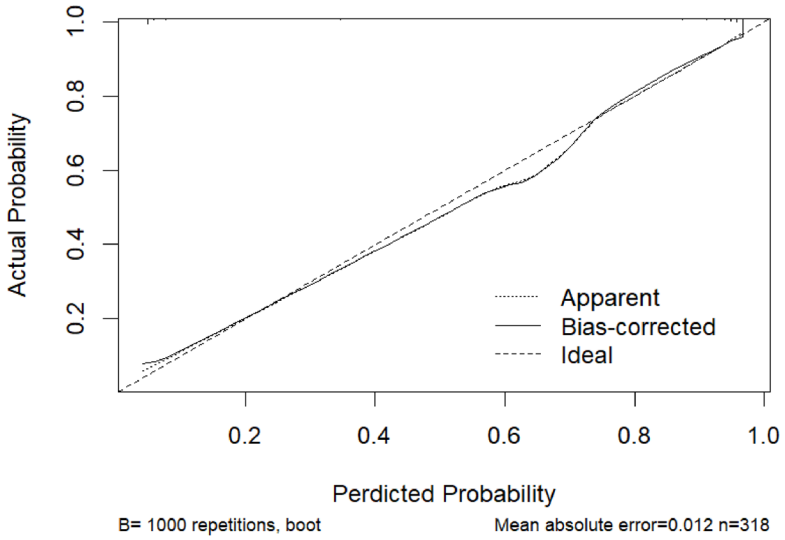
A: Training set



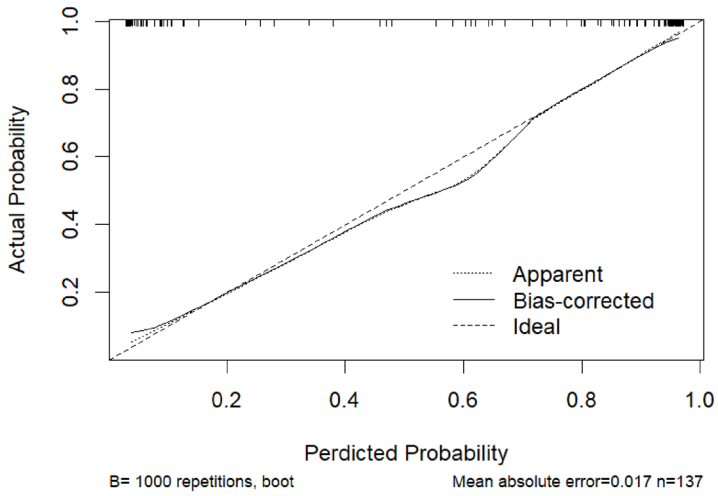
B: Validation set

Fig. 4. ROC curves of the fear of disease progression prediction model for post-PCI patients in both groups.

the incidence of adverse cardiovascular events and readmission rates in post-PCI patients, thus intensifying patients' fear of disease progression[41]. On the other hand, disease treatment for patients with multi-disease coexistence is more complex than that for single diseases. Usually, it requires combined medications, which not only increases the risk of drug interactions but may also expose patients to greater economic pressure and psychological burden, reducing their confidence and adherence to health management and thus affecting their physical and mental health[42]. Therefore, it is suggested that healthcare professionals should focus on the physical and mental conditions of patients with a large number of comorbid chronic diseases, strengthen personalized psychological guidance, and optimize disease management strategies to help patients establish a scientific knowledge of health and improve treatment adherence, thus effectively alleviating the fear of disease progression.



A: Training set

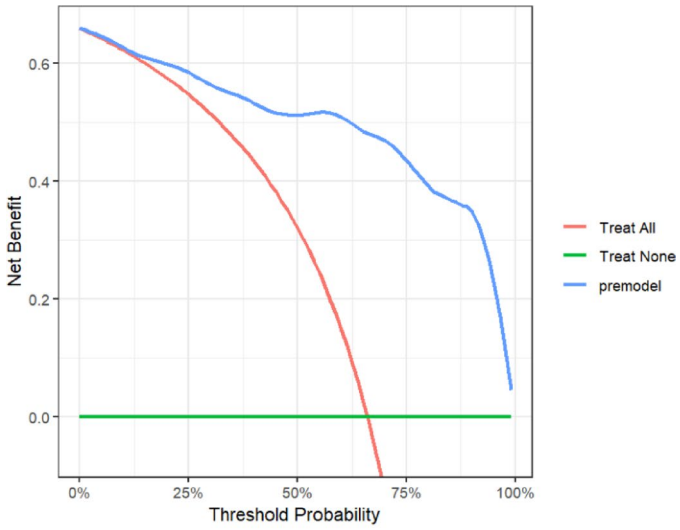


B: Validation set

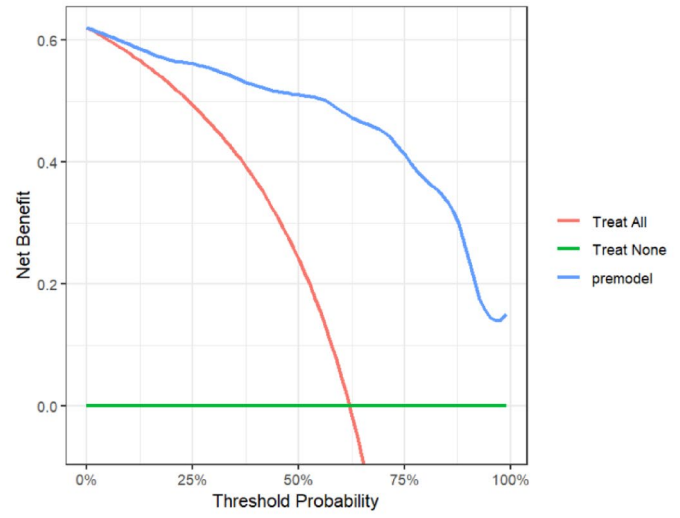
Fig. 5. Calibration curve of the fear of disease progression prediction model in two groups of post-PCI patients.

Disease duration

The results of the present study showed that the longer the disease duration, the lower the level of fear of disease progression in post-PCI patients. Analyzing the reasons, first, from a physiological perspective, prolonged postoperative status allows the patient's body to gradually adapt and establish a new equilibrium. Cardiac function and related physiological indicators stabilize, reducing physical discomfort. This enables patients to intuitively perceive that their condition is not deteriorating rapidly, thereby alleviating concerns about disease progression. Second, psychologically, patients with longer disease duration have had more time to accept their condition, undergoing a psychological shift from denial to acceptance, resulting in a more peaceful mindset[17]. Furthermore, as the disease progresses, patients gain a deeper understanding of their illness and treatment process, becoming well-informed about self-care and treatment compliance. This sense of control over their condition alleviates excessive fear of disease progression, thereby reducing fear levels. However, findings from a study by Chinese researchers, Zhao et al. on chronic heart failure patients contradict the results of this study[43]. Analyzing the reasons for this discrepancy, chronic heart failure is characterized by irreversible, prolonged, and recurrent episodes, and the patient's symptoms, signs, and cardiac function status will gradually deteriorate over time, which leads to the longer the duration of heart failure patients, the more serious the fear of disease progression[44]. However, PCI surgery has the characteristics of "small trauma, short treatment course, and



A: Training set



B: Validation set

Fig. 6. Clinical decision curves for two post-PCI patients fear of disease progression risk prediction models.

remarkable therapeutic effect", and with the prolongation of the disease course, patients may have a stronger knowledge of the disease after PCI surgery and their understanding of the disease is more in-depth, which reduces the fear and uncertainty of the early stage of the disease[16]. Therefore, it is recommended that healthcare personnel implement targeted health education programs according to the characteristics of patients at different stages after surgery. For example, for patients in the early post-PCI period, healthcare professionals should strengthen health education and introduce in detail the principles and effects of PCI surgery and postoperative precautions so that patients can have a clear understanding of their condition and treatment and alleviate their nervousness. For post-PCI patients with a longer course of disease, healthcare professionals can organize regular sharing sessions on recovery experience so that patients can share their experiences and enhance their confidence in recovery. In addition, according to the specific conditions of the patients, personalized rehabilitation plans are formulated, and appropriate exercise and rehabilitation training is instructed so that the patients can feel their recovery and further reduce their fear.

Number of interventions, number of stent implants

The results of this study showed that the more interventions and the number of stents implanted, the more serious the fear of disease progression in post-PCI patients, which is similar to the results of the study conducted by Chinese scholars Liu et al.[45] Analyzing the reasons, the number of interventional procedures and stents implanted in patients after PCI serves as an objective surrogate indicator of coronary artery disease severity and complexity to a certain extent. They also profoundly reflect patients' psychological fear of postoperative complications and the long-term treatment burden. Specifically, first, from the perspective of disease nature,

a higher number of interventional procedures and multiple stent implants typically indicate more diffuse and severe coronary artery disease. Patients' awareness of their condition's severity directly intensifies their concerns about disease progression and future cardiovascular events. Second, regarding the treatment process and prognosis, patients who receive multiple stents may still face risks of complications such as in-stent restenosis and thrombosis[46]. As noted by Xia et al., patients with multiple stents often require more complex postoperative management and long-term medication. This heavy treatment burden, coupled with perceptions of uncertain prognosis, collectively form a significant source of psychological fear[47]. Therefore, it is suggested that healthcare professionals should focus on the psychological status of patients with a high number of interventions and stent implantation, and according to the actual situation of the patients, adopt an easy-to-understand way to introduce the condition and treatment plan in detail, to help the patients to understand the disease correctly, and to reduce the fear caused by uncertainty. At the same time, necessary psychological support is provided to help patients cope with the psychological pressure caused by the disease and alleviate their unnecessary worries.

Psychological resilience

The results of this study showed that the higher the psychological resilience of post-PCI patients, the lower the level of fear of disease progression, which is consistent with the results of previous studies[23,44]. As a positive psychological resource, patients with higher psychological resilience are more able to positively face the physical changes brought about by PCI, the challenges in the recovery process, and the threat of possible disease progression, and are able to proactively seek solutions to the problems, thus reducing the fear of disease progression. Previous study has also shown that patients' psychological resilience is negatively correlated with the fear of disease progression[28], i.e., patients with high psychological resilience usually have stronger emotional regulation and are more inclined to actively seek information and participate in treatment decisions, which is conducive to reducing the fear of disease uncertainty. In addition, as PCI is a stressful event, patients with high psychological resilience are able to effectively regulate their stress response system, reduce the release of pro-inflammatory cytokines, and mitigate the effects of stress on cardiac injury. Therefore, healthcare professionals should promptly assess patients' preoperative and postoperative psychological status and can help patients correctly recognize their health status, reduce their psychological burden, and lower their fear of disease progression through measures such as positive stress reduction therapy[48] and cognitive-behavioral therapy[49].

Perceived social support

The results of this study showed that the higher the social support patients perceive after PCI, the lower the level of fear of disease progression, which is consistent with the results of previous studies[50,51]. According to the stress process theory[52], individuals can cope and adapt through a series of physiological, psychological, and social mechanisms when facing stressful events. Social support, as an important external resource, can significantly influence an individual's stress response and adaptive capacity. On the one hand, patients with a high level of social support often feel more care and encouragement from family, friends, and society. The material and emotional support can effectively alleviate the negative emotions of patients' anxiety and nervousness, which is conducive to enhancing the patient's sense of security and reducing the fear due to the uncertainty of the disease and loneliness in the process of treatment[53]. On the other hand, patients with high perceived social support can better utilize social resources to obtain health information, which helps them better understand disease-related knowledge, corrects their misperceptions of the disease, enables them to look at the disease more rationally, and reduces their blind fear of disease progression[16]. Therefore, it is suggested that healthcare professionals should, on the one hand, encourage patients' family members to actively participate in patients' disease management and enhance family support so that they can better cooperate with the treatment and promote the recovery of the disease; on the other hand, they should establish and maintain a good social support network, build a three-level hospital-community-family linkage management platform, and give patients multifaceted support by carrying out continuity of care and follow-up services to create a good internal and external support to reduce the fear of disease progression of the patients.

Fear of disease progression prediction model has good predictive efficacy in post-PCI patients

In this study, we determined and screened seven factors that influence the fear of disease progression in post-PCI patients through LASSO regression and logistic regression analysis, and we established a column-line graph model on this basis. The model had an area under the ROC curve of 0.941 in the training set and an area under the ROC curve of 0.947 in the internal validation set, indicating that the model was well differentiated. The calibration curve shows that the model is well-calibrated. Analysis of the clinical decision curve indicates that this model possesses good clinical utility. Therefore, the prediction model constructed in this study can provide a facilitated screening tool for healthcare professionals to identify patients with high fear of disease progression after PCI at an early stage.

Limitations

This study also has some limitations. First, this study was a single-center study, and only patients from a tertiary general hospital in Sichuan Province, China, were selected for the survey, which resulted in a limited representative sample. The generalizability of our model may be limited, as patient psychology can be influenced by regional variations in healthcare standards, socioeconomic conditions, and culture. Although internal validation demonstrated satisfactory performance, its generalizability requires further validation through future prospective, multi-center studies with large samples from diverse geographic areas and hospital tiers. Another limitation is that this study did not fully account for pharmacological and lifestyle factors, such as detailed medication history and dietary patterns, which could influence fear of disease progression. Future research should prospectively incorporate these parameters to construct a more comprehensive model. Furthermore,

our measurement of economic burden was limited. We used "average monthly household income" as a proxy for socioeconomic status, lacking direct data on healthcare-related financial stress, such as insurance types, reimbursement rates, or out-of-pocket expenses. Future studies should employ more granular economic indicators to better elucidate this relationship. Lastly, we did not administer specialized anxiety/depression scales (e.g., HADS) to all participants, so undiagnosed subclinical symptoms may constitute an unmeasured confounder. Incorporating standardized baseline psychological assessments is essential in future work to strengthen the robustness of the findings.

Conclusions

In this study, we constructed a prediction model for the fear of disease progression in post-PCI patients based on LASSO regression and logistic regression. The model mainly included seven influencing factors: average monthly family income, number of chronic diseases, disease duration, number of interventional treatments, number of stent implants, psychological resilience, and perceived social support. The predictive model developed in this study demonstrates excellent discrimination, calibration, and clinical utility, providing a reliable assessment tool for early screening and identification of high-risk populations.

Data availability

The dataset generated and analyzed during the current study are available from the corresponding authors on reasonable request.

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Author contributions

L.Y.X contributed to interpreting the data, and participated in writing and revising the manuscript. Z.X.L., D.P., C.B.X., Z.F.M., and F.Y.T. designed the study, collected the data. W.J.J. and H.L. made substantive intellectual contributions to the conception of the work and the interpretation of the data and revised the manuscript. All authors have read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Additional information
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