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RESEARCH

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Development and validation of frailty risk prediction model for elderly patients with coronary heart disease

Siqin Liu[1,2], Xiaoli Yuan[2*], Heting Liang[2], Zhixia Jiang[3], Xiaoling Yang[3] and Huiming Gao[2]

Abstract

Objective To analyze the influential factors of frailty in elderly patients with coronary heart disease (CHD), develop a nomogram-based risk prediction model for this population, and validate its predictive performance.

Methods A total of 592 elderly patients with CHD were conveniently selected and enrolled from 3 tertiary hospitals, 5 secondary hospitals, and 3 community health service centers in China between October 2022 and January 2023. Data collection involved the use of the general information questionnaire, the Frail scale, and the instrumental ability of daily living assessment scale. And the patients were categorized into two groups based on frailty, and χ^2 test as well as logistic regression analysis were used to identify and determine the influencing factors of frailty. The nomograph prediction model for elderly patients with CHD was developed using R software (version 4.2.2). The Hosmer–Lemeshow test and the area under the receiver operating characteristic (ROC) curve were employed to assess the predictive performance of the model. Additionally, the Bootstrap resampling method was utilized to validate the model and generate the calibration curve of the prediction model.

Results The prevalence of frailty in elderly patients with CHD was 30.07%. The multiple factor analysis revealed that poor health status (OR = 28.169)/general health status (OR = 18.120), age (OR = 1.046), social activities (OR = 0.673), impaired instrumental ability of daily living (OR = 2.384) were independent risk factors for frailty (all $P < 0.05$). The area under the ROC curve of the nomograph prediction model was 0.847 (95% CI: 0.809 ~ 0.878, $P < 0.001$), with a sensitivity of 0.801, and specificity of 0.793; the Hosmer- Lemeshow χ^2 value was 12.646 ($P = 0.125$). The model validation results indicated that the C value of 0.839(95% CI: 0.802 ~ 0.879) and Brier score of 0.139, demonstrating good consistency between predicted and actual values.

Conclusion The prevalence of frailty is high among elderly patients with CHD, and it is influenced by various factors such as health status, age, lack of social participation, and impaired ability of daily life. These factors have certain predictive value for identifying frailty early and intervention in elderly patients with CHD.

Keyword Elderly, Predictive model, Frailty, Coronary heart disease, Risk factors

*Correspondence:
Xiaoli Yuan
872428494@qq.com
[1] Department of Neurology, Affiliated Hospital of Zunyi Medical University, Zunyi, China
[2] Nursing Department, Affiliated Hospital of Zunyi Medical University, Zunyi, China
[3] College Office, Guizhou Nursing Vocational and Technical College, Guiyang, China

Background

With the increasing prevalence of population aging, coronary heart disease (CHD) has emerged as a significant threat to the life and well-being of elderly individuals. According to the "Summary of China Cardiovascular Disease Report 2020", cardiovascular disease stands as the primary cause of death for urban and rural residents in China, with a CHD prevalence rate of 27.8% among people over 60 years old [1], presenting substantial challenges to patients' families, society, and public health resources.

Frailty is a non-specific condition characterized by the simultaneous decline in multiple physiological systems, resulting in heightened vulnerability and reduced resistance to stress[2]. There is mounting evidence that frailty may emerge as one of the most pressing global health concerns. Epidemiological research has demonstrated a correlation between increased mortality and age-related degenerative diseases [3], which often present as frailty, leading to significant functional limitations and adverse outcomes in older individuals.

Approximately 25% of elderly people aged over 85 experience frailty, imposing a significant burden on healthcare and elderly support systems [4]. With the growing number of elderly individuals, the prevalence of frailty is expected to rise [5]. This condition represents the primary clinical manifestation of functional decline in older adults and is associated with adverse health outcomes. It serves as a crucial indicator for assessing patient prognosis [6, 7]. Reports indicate that the incidence of frailty among elderly patients with CHD stands at 33.48% [8], serving as an independent predictor of unfavorable patient prognosis [9]. It leads to increased hospitalization costs and prolongs hospital stays, and is significantly associated with adverse events such as falls, bed falls, readmission, and all-cause mortality [10], greatly impacting the quality of life of patients. Therefore, enhancing frailty management in patients with CHD, early identification of risk factors for frailty, and implementing effective intervention measures are crucial for reducing the readmission rate of elderly CHD patients, preventing, delaying or reversing the progression of frailty. Consequently, predicting the risk of frailty in patients with CHD holds great significance.

This study aims to comprehensively assess the prevalence of frailty in elderly patients with CHD and analyze its influencing factors. Utilizing logistic regression, a visual nomograph prediction model is developed to offer a quantitative tool for healthcare professionals to promptly identify frailty risk and inform the quantification and prevention decision-making process for elderly patients with CHD.

Methods

Study population and design

Using convenience sampling, elderly patients with the present study was a cross-sectional study, CHD were recruited from 3 tertiary hospitals, 5 secondary hospitals, and 3 community health service centers in Guizhou Province between October 2022 and January 2023 in China. Inclusion criteria were as follows: ① Age $\geq$ 60 years old; ② Conformance of stable CHD diagnosis to the New York Heart Association (NYHA) diagnostic criteria for coronary atherosclerotic heart disease [11]; ③ Clear awareness and unobstructed communication; ④ Informed consent and voluntary participation of patients and their families. Exclusion criteria included: ① Acute onset or recovery period of CHD; ② Presence of other serious mental or physical diseases or end-stage tumors; ③ NYHA cardiac function grading IV; ④The current state precludes cooperation for completing the frailty assessment. The sample size was determined using the logistic regression analysis of Events Per Variable (EPV) [12]. Based on prior literature, this study was anticipated to encompass 22 risk factors. To ensure the stability of the logistic regression analysis results, an EPV value of 8 was chosen, and the incidence of frailty in elderly patients with CHD was found to be 33.48% [8]. Accounting for a 10% loss rate, the minimum required sample size was 579 cases, and eventually, 592 cases were included. This study has received approved from the Hospital Ethics Committee (KLL2022-814).

Data collection

Research instrument

General situation questionnaire The study utilized a self-designed general information questionnaire, which included inquiries about gender, age, education level, self-assessed health status, marital status, children, type and mode of residence, average monthly household income, sources of economic support, number of chronic diseases and types of medication used. Additionally assessed were alcohol and tobacco use habits, physical exercise routines, regularity of physical examinations undergone by the participants as well as their social support networks and engagement in social activities. Social activities in this context refers to the frequency with which individuals engage in group-based social activities such as chess playing or dancing.

The frail scale The concept of frailty was initially introduced by Fried et al. [13] in the cardiovascular health study (CHS), encompassing self-reported exhaustion, reduced endurance, low physical activity, weakness, and unintentional weight loss. In this study, frailty was operationalized as a binary outcome indicator, each affirmative response to an item scored 1 point while negative responses scored 0 points. The total score ranged from 0to 5 points. Individual with three or more positive responses were classified as frail, while those with one or two positive responses were categorized as pre-frail. Based on the scoring system, participants could be grouped into no frailty (0 points), pre-frailty (1–2 points), and frailty (3–5 points), and the specific assessment is as follows:

(1) Have you felt tired most or all of the past 4 weeks?
(2) If there is no midway break or climbing one floor with the assistance of walking aids, do you feel any difficulty?
(3) Do you feel any difficulty walking a 100 meters distance with the assistance of helpless walking equipment?
(4) Do you suffer from 5 or more diseases?
(5) Have you lost more than 5% of your weight in the past year?

Instrumental activities of daily living scale The Instrumental Activities of Daily Living (IADL) scale is primarily utilized for assessing the self-sufficiency of elderly individuals, encompassing 8 domains: shopping, taking transportation, meal preparation, household organization, laundry management, telephone usage, medication adherence, and financial management. The scoring ranges from 0 to 8 points, a score of 8 indicates normal functioning while a score of ≤ 7 suggests impairment [14]. In this study, the Cronbach's alpha coefficient for this scale was found to be 0.833.

Research methods

Five trained assessors provided a comprehensive overview of the survey objectives and methodology to elderly CHD patients or their families who meet the inclusion/exclusion criteria, and obtain informed consent. Throughout the investigation, standardized language was used for questioning, with detailed explanations provided as needed. In cases where questions were difficult to answer, assessors may assist in completion through inquiry. A total of 592 questionnaires were distributed, and collected on-site. with prompt feedback, verification, and correction provided for any errors or omissions. The effective questionnaire recovery rate was 100%.

Statistical methods

The SPSS26.0 software package was used to conduct statistical analysis and data description. Frequency and percentage were used to express counting data, while inter group comparisons were performed using χ 2-test and logistic regression for variable selection and model construction. The optimal critical value of the prediction model based on the Jordan index was calculated. R-studio 4.2.2 software (rms, glm, predict, etc.) was employed to generate frailty risk ROC curve and Nomogram. A bootstrap self-sampling method was applied to repeat 1000 samples for internal validation of the model. with discrimination and accuracy were used to validate the prediction model. In this study, the area under the receiver operating characteristic (ROC) curve (AUC) and C-statistic (> 0.7 indicating good model resolution) were used to assess the discrimination ability of the model, and calibration curve and Brier score (< 0.25 being appropriate) were employed to determine the level of concordance between predicted probabilities and observed outcomes. All tests were two-tailed, with $P < 0.05$ considered statistically significant.

Results

Participant characteristics

The study included a total of 592 elderly patients with CHD, as shown in Fig. 1 for the recruitment of research participants, Among them, there were 345 males (58.28%) and 249 females (42.06%), with an age range of 61–94 years old (74.37 ± 7.47 years old); The prevalence of frailty was 30.07%,with 200 cases without frailty, 214 cases of pre-frailty, and 178 cases classified as frailty. Additional demographic details are presented in Table 1.

Prevalence of frailty and related variables

The results of univariate analysis revealed a total of 16 factors, encompassing age, education level, marital status, place of origin, number of children, comorbidity, and regular physical examination. The inter group differences were found to be statistically significant ($P < 0.05$).

Logistic regression of patients with CHD

Using the presence of frailty as the dependent variable (0 = absence of frailty/pre-frailty; 1 = frailty), the statistically significant variables identified in the univariate analysis were selected as independent variables for logistic regression analysis (variable assignments are detailed in Table 2). The L-R forward stepwise method was employed to identify the influencing factors, with an inclusion criterion of 0.05 and an exclusion threshold of 0.10. The results from the multivariate regression analysis indicated that: health status (X_1), social activity (X_2)

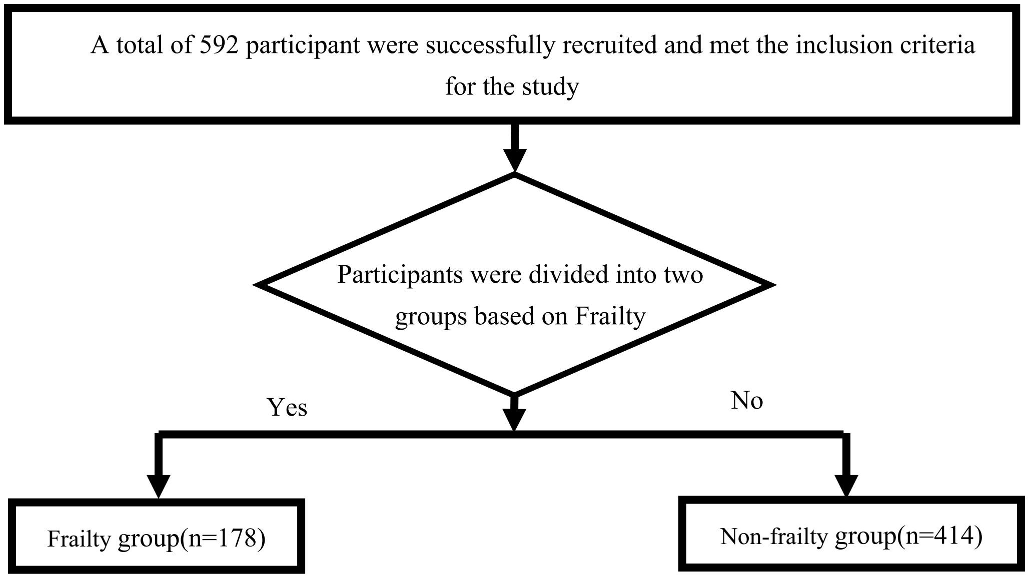

Fig. 1 Flowchart of research participant recruitment

Age (X_3) and IADL (X_4) independently contribute to the risk of frailty in elderly patients with CHD, as presented in Table 3.

Predictive model development

Based on the results of logistic regression analysis, a predictive model for frailty risk nomogram was created in R Studio (4.2.2) software, incorporating four factors: health status (X_1), social activity (X_2), Age (X_3), and IADL (X_4) as shown in Fig. 2.

Discrimination and calibration of the predictive model

The predictive model was evaluated using the ROC curve and the Hosmer–Lemeshow goodness-of-fit test ($P > 0.05$ indicates a strong degree of fit). The results indicated that the model exhibited excellent fit for both the training set ($\chi 2 = 12.646$, $df = 2$, $P = 0.125$).The ROC curve was employed to evaluate the predictive capability of the model score in identifying frailty in patients with CHD. AUC values were calculated to assess discrimination, yielding an area under the ROC curve of 0.847 (95% CI: 0.809–0.878, $P < 0.001$), as depicted in Fig. 3. The sensitivity, specificity, and accuracy of the model were found to be 0.801, 0.793, and 80.7%, respectively.

Predictive model validation

The bootstrap resampling method was employed for 1000 iterations to internally validate the constructed model. Calibration curves for the nomogram showed high level of consistency between the predicted and actual probabilities of frailty. The calibration plots, based on the multifactorial logistic regression model, are depicted in Fig. 3. The results demonstrated that the predicted values of the model were largely congruente with the actual values (refer to Fig. 4), yielding a C-statistic of 0.839 (95% CI: 0.802–0.879), and a Brier score of 0.139. These findings suggest that the nomogram model possessed strong discriminatory ability, predictive value and accuracy identifying frailty and non-frailty patients.

Discussion

Cardiovascular disease is the primary cause of hospitalization and mortality, exerting a significant impact on the health of the elderly and posing a substantial public health burden. The overall health and prognosis of elderly individuals are influenced by frailty, comorbidity, general health status, and cardiovascular disease. With the aging population in China steadily increasing, there is also a rise in the number of elderly patients with CHD. Given that frailty serves predictive indicator for adverse outcomes and healthy life expectancy in elderly patients with CHD, early and effective identification holds great significance for improving patient prognosis. According to data from the European Heart Rehabilitation Center, the prevalence of frailty among elderly patients with CHD ranges from 10 to 48% [15]. This study found that the prevalence of frailty is 30.07%, which aligns with findings from previous domestic studies (33.48%) [8]. Due to the diminished physiological reserve function across various organ systems in the elderly, combined with the interplay between frailty and CHD, the etiology is relatively intricate, leading to sustained bodily depletion,

Table 1 Prevalence of frailty and related variables in elderly patients with CHD[*n*=592(%)]

Variable		Non-frailty *n*=414	Frailty *n*=178	x^2/Chi^2	*P*-value
Gender	Male	250（60.4）	94（52.8）	2.936[a]	0.087
	Female	164（39.6）	84（47.2）		
Age, years	60～69	134（32.4）	27（15.2）	27.929[a]	<0.001
	70～79	192（46.4）	82（46.1）		
	≥80	88（21.3）	69（38.8）		
Source institution	tertiary hospital	250（60.4）	83（46.6）	9.588[a]	0.008
	Secondary hospital	39（9.4）	22（12.4）		
	Home/Community	125（30.2）	73（41.0）		
Education level	Less than lower Primary school	241（58.2）	129（72.5）	11.541[b]	0.009
	middle school	98（23.7）	30（16.9）		
	Upper secondary or vocational training	65（15.7）	17（9.6）		
	College degree or above	10（2.4）	2（1.1）		
Marital status	Unmarried	0（0.0）	4（2.2）	23.271[b]	<0.001
	Married	385（93.0）	146（82.0）		
	Divorced	0（0.0）	2（1.1）		
	Widowed	29（7.0）	26（14.6）		
Number of children	0	3（0.7）	7（3.9）	9.935[b]	0.019
	1	52（12.6）	19（10.7）		
	2	151（36.5）	52（29.2）		
	≥3	208（50.2）	100（56.2）		
Comorbidity	No	149（36.0）	38（21.3）	12.349[a]	<0.001
	Yes	265（64.0）	140（78.7）		
Place of origin	Rural	194（46.9）	92（51.7）	1.161[a]	0.281
	Urban	220（53.1）	86（48.3）		
Physical examination	No	222（53.6）	121（68.0）	10.525[a]	0.001
	Yes	192（46.4）	57（32.0）		
Living style	Living with spouse and children	103（24.9）	38（21.3）	33.665[b]	<0.001
	Living with spouse	212（51.2）	56（31.5）		
	Living with children	81（19.6）	65（36.5）		
	Living alone	12（2.9）	15（8.4）		
	Other (old people's home)	6（1.4）	4（2.2）		
Monthly household income(yuan)	<2000	115(27.8)	87（48.9）	30.425[a]	<0.001
	2000～3000	96(23.2)	35（19.7）		
	3000～4000	113(27.3)	24（13.5）		
	4000～5000	54(13.0)	14（7.9）		
	5000～6000	25(6.0)	12（6.7）		
	＞6000	11(2.7)	6(3.4）		
Source of income	Retirement pay	216（52.2）	71（39.9）	9.589[a]	0.055
	Children given	144（34.8）	77（43.3）		
	Labor income	33（8.0）	19（10.7）		
	Others	21（5.1）	11（9.6）		
Health status	Good	71（17.1）	1（0.6）	104.129[a]	<0.001
	General	294（71.0）	93（52.2）		
	Poor	49（11.8）	84（47.2）		
Quantity of medications	0	27（6.5）	1（7.9）	11.951[a]	0.003
	1～2	238（57.5）	75（42.1）		
	≥3	149（36.0）	89（50.0）		

Table 1 (continued)

Variable		Non-frailty *n*=414	Frailty *n*=178	x^2/Chi^2	*P*-value
Alcohol consumption	No	365 (88.2)	162 (91.0)	1.032[a]	0.31
	Yes	49 (11.8)	16 (9.0)		
Smoking	No	339 (81.9)	165 (92.7)	11.5[a]	0.001
	Yes	75 (18.1)	13 (7.3)		
Social activities	No	87 (21.0)	121 (68.0)	120.465[a]	<0.001
	Yes	327 (79.0)	57 (32.0)		
Exercise	No	82 (19.8)	99 (55.6)	75.207[a]	<0.001
	Yes	332 (80.2)	79 (44.4)		
Social support	Sufficient	42 (10.1)	54 (30.3)	37.355[a]	<0.001
	Insufficient	372 (89.9)	124 (69.7)		
IADL status	Normal	116 (28.0)	12 (6.7)	33.256[a]	<0.001
	Functional impaired	298 (72.0)	166 (93.3)		

a represents X^2 test, and b represents Fisher exact test

Table 2 Logistic regression analysis factor assignment

Variable	Assignment
Dependent variable (Y)	0 = Non-frailty; 1 = Frailty
Independent variable (X)	
X_1: Health status	(0.0) = good; (0,1) = general; (1,0) = poor
X_2: Social activities	1 = No; 2 = Yes
X_3: Age	Included directly as a numerical variable
X_4: IADL status	1 = Normal; 2 = Functional impaired

reduced capacity to maintain homeostasis in diverse organ systems, decreased resilience, and heightened vulnerability. This may account for the elevated incidence of frailty among elderly patients with CHD.A large cohort study conducted in the United States demonstrated a 33% reduction in heart disease mortality rate at 5 years following percutaneous coronary intervention, but an increase of 57% in non-cardiac mortality [16], This suggests that predictive factors for non-cardiac mortality are associated with the quality of life of cardiovascular disease patients. Previous research has also established a strong correlation between frailty and patient prognosis [17]. Despite its significant prognostic value, frailty is seldom assessed in clinical practice. Therefore, it is imperative to enhance awareness of frailty and bolster its management among elderly CHD patients. Early identification is crucial, and appropriate intervention measures should be implemented to mitigate the onset of frailty and improve patient outcomes.

In 2012, the International Weakness Working Group emphasized that physiological frailty is reversible and recommended clinical frailty assessment for individuals aged ≥ 70 years. The most commonly used evaluation method currently is the frailty phenotype, which categorizes frailty into three states based on phenotype: into three states based on phenotype: non frailty, pre-frailty, and frailty. These different states exhibit dynamic changes in disease progression. Therefore, early identification of high-risk populations for frailty and implementation of intervention measures can delay or reverse the onset

Table 3 Logistic regression of frailty factors in elderly patients with CHD

Variable	Regression coefficient (β)	Standard error (SE)	Wald X^2	*P*-value	OR	95% CI	
Health status (good)			38.723	< 0.001			
Health status (General)	2.897	1.025	7.984	0.005	18.120	2.429	25.168
Health status (Poor)	4.359	1.041	17.543	< 0.001	28.169	10.167	60.988
Age, years	0.045	0.018	6.359	0.012	1.046	1.010	1.083
Social activities	-0.395	0.119	11.031	0.001	0.673	0.533	0.850
IADL status	0.869	0.377	5.308	0.021	2.384	1.138	4.993
Constant	-7.186	1.707	17.724	< 0.001	0.001		

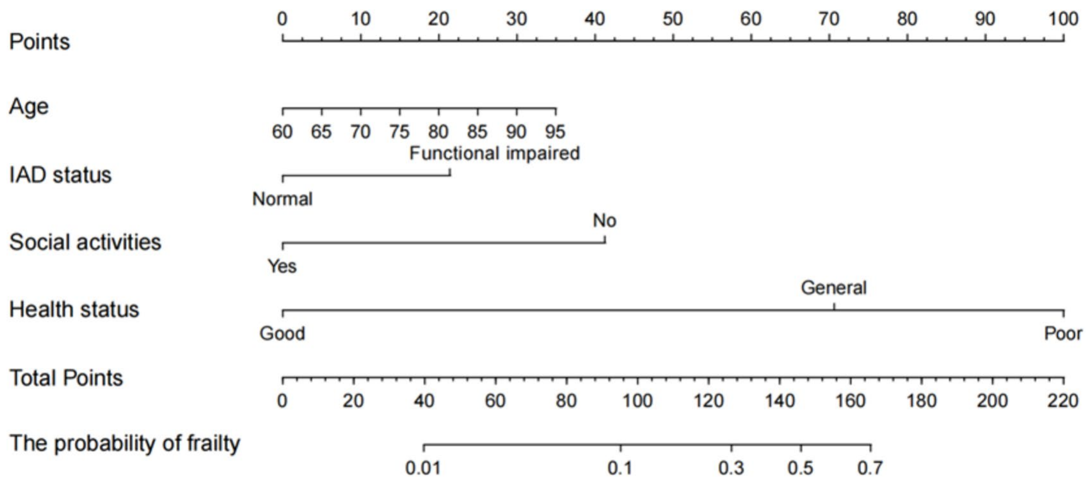

Fig. 2 Nomogram risk model of frailty in elderly patients with CHD

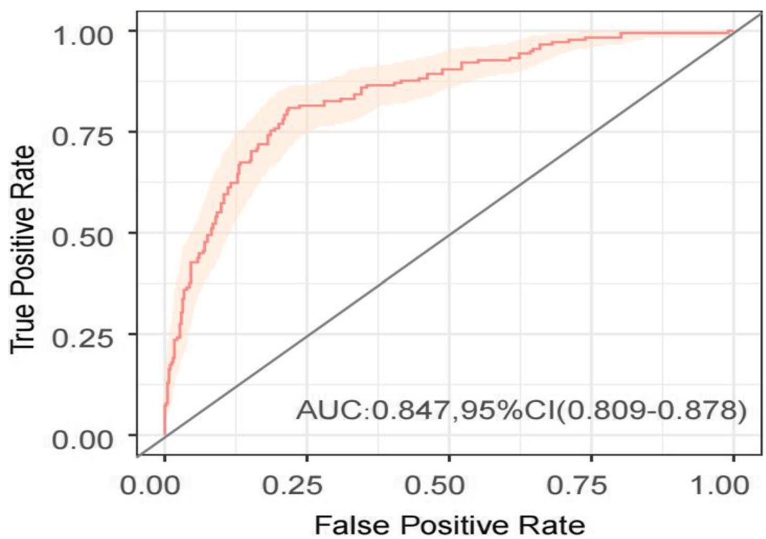

Fig. 3 ROC curve analysis of the nomogram for risk of frailty in elderly patients with CHD

of frailty. Due to the higher risk of frailty in pre-frailty patients and their responsiveness to intervention measures [18], it underscores the importance of screening for frailty and implementing early interventions to halt its progression. Due to delayed initiation of frailty assessment for CHD patients in China and the lack of routine screening in clinical practice, it is recommended to establish standards for identifying and managing frailty in CHD patients frailty in CHD patients, prioritize comprehensive assessment of elderly CHD patients' fragility using accurate tools regularly, tailor treatment by considering individual characteristics to screen specific risk factors for optimization and management, provide health education and lifestyle guidance to at-risk CHD patients regarding fragility improvement.

The assessment of health status plays a crucial role in influencing patient recovery outcomes as well as disease prognosis. A deteriorating the health condition responds directly to an elevated susceptibility towards weakness according to established evidence-based guidelines by WHO [19]. Through rigorous multivariate logistic regression analysis conducted within this study cohort revealed significantly heightened vulnerability towards developing fragility among elderly individuals diagnosed with CHD who exhibit suboptimal physical well-being (OR = 28.169; 95% CI: 10.167–60.988),these findings align closely with those reported by CURCIO et al. [20]. Owing largely due to their diminished subjective perception regarding personal physical wellness among older adults suffering from CHD may predispose them towards

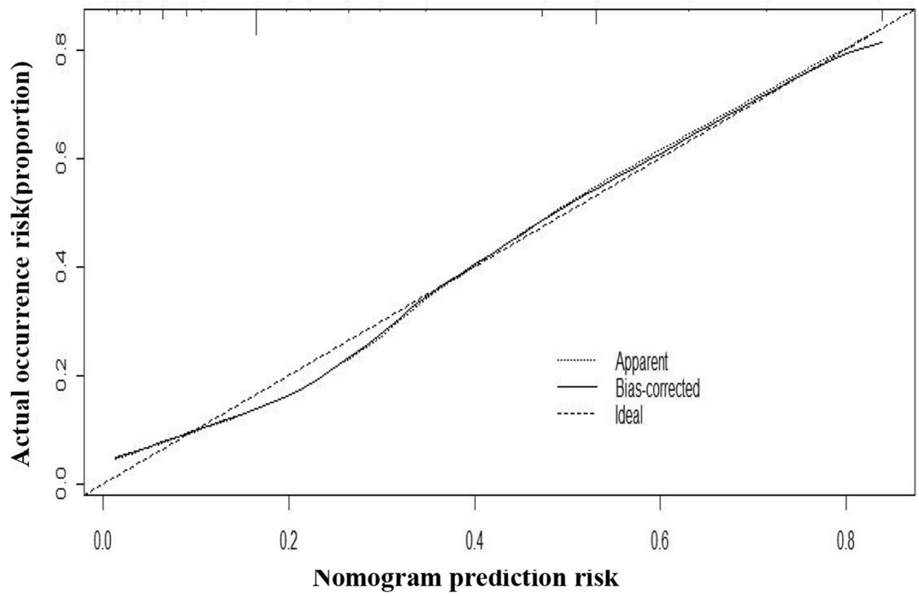

Fig. 4 Calibration of the predictive model

adopting maladaptive protective mechanisms or ineffective coping strategies thereby hastening their decline into states associated with fragility-related complications. These observations underscored implications for healthcare professionals emphasizing proactive screening protocols targeting individuals exhibiting inadequate self-assessment concerning their overall well-being while advocating tailored interventions aimed at improving individualized healthcare statuses thus mitigating risks associated specifically linked towards fragility development. Furthermore addressing concerns pertaining particularly towards individuals displaying lower levels of perceived efficacy necessitates active support initiatives facilitating adaptive coping strategies whilst fostering resilience against prevailing illnesses warranting prompt targeted interventions designed explicitly at preventing further exacerbation leading into states characterized by fragility. Univariate analyses performed within this investigation demonstrated statistically significant associations between comorbidities impacting patient susceptibility toward developing fragility ($P<0.05$) corroborating earlier reports [21]. This study identified comorbidities as autonomous contributing factors escalating risks associated specifically linked toward developing states characterized by fragility whereby older adults diagnosed concurrently presenting four or more distinct chronic ailments exhibited 27 times amplified susceptibilities toward experiencing conditions typified by fragile states. Attributable primarily due largely owing toward sustained physiological depletions stemming from concurrent afflictions coupled alongside compromised tolerances resulting from prolonged exposure underpinning these persistent pathological processes collectively contribute synergistically precipitating occurrences typified by fragile states among older adults diagnosed concomitantly presenting multiple coexistent morbidities underscoring imperative needs mandating heightened vigilance directed specifically targeting individuals afflicted simultaneously presenting complex multimorbidity profiles warranting correspondingly escalated frequencies involving screenings intended at identifying potential vulnerabilities indicative potentially evolving into fragile states.

This study revealed that age is a significant risk factor for frailty in patients with coronary heart disease (OR = 1.046, 95% CI: 1.010–1.083). Specifically, advancing age is associated with an increased vulnerability to frailty due to physiological degeneration, including telomere dysfunction, adaptive immune system aging, loss of skeletal muscle mass and function, and cognitive decline. As physiological functions deteriorate with age, muscle strength diminishes gradually leading to reduced physical activity and walking speed in elderly patients, thus highlighting old age as a contributing factor to frailty.

IADL as an essential tool for assessing older adults' capacity for independent living and social engagement by evaluating various everyday tasks such as shopping, meal preparation, medication management, and transportation usage. A decline in IADL functionality commonly manifests among older individuals. Weakness represents a transitional phase between health and disability.

Impairments in self-care capabilities may precipitate vulnerability while disability stands as one among several detrimental outcomes experienced by vulnerable individuals. This study demonstrates that diminished performance on the IALD scale constitutes an independent risk factor for vulnerability among seniors diagnosed with Coronary Heart Disease (CHD) (OR = 2.384,95% CI: 1.138–4.993).This finding underscores how compromised assessments related to instrumental activities are associated with heightened susceptibility within aging populations, Atkins [22] similarly corroborated this perspective. Impaired functional independence emerges as a prevalent characteristic among vulnerable individuals. A reduction in IALD scores signifies physical debility alongside diminished autonomy within older patient cohorts. Deterioration within these domains fosters both onset and progression of vulnerability thereby perpetuating mutual reinforcement. Henceforth, routine evaluation pertaining IADL holds significant value in facilitating early identification of vulnerability. Healthcare professionals must intensify their vigilance towards vulnerability among elderly patients with CHD patients whilst guiding them towards preventive measures or improvements via lifestyle interventions. Nonetheless, vulnerability arises from multifaceted interactions necessitating comprehensive evaluations encompassing diverse contributing factors.

The findings from this study indicate that regular engagement in social activities serves as a protective measure against frailty among elderly patients with CHD (OR = 0.673, 95% CI: 0.533–0.850), This aligns with previous research by Bunt et al. [23] suggesting that active social participation mitigates the vulnerability to frailty among CHD patients. This association can be attributed to the impact of social emotional well-being on physical health among older adults; frequent involvement in communal interactions not only stimulates cognitive function but also provides essential emotional support. Conversely, inadequate communication skills or barriers to interpersonal connections along with limited companionship may predispose individuals to feelings of isolation and insecurity which could undermine their confidence in recovery process and potentially contribute to an increased risk for developing frailty. The absence of engagement in societal interactions signifies an insufficiency in fulfilling fundamental interpersonal requirements. Addressing these needs is crucial for unlocking one's full potential for self-efficacy. In cases where individuals with CHD experience limited involvement in communal activities, it becomes imperative to nurture their confidence while encouraging suitable participation tailored to their specific physical circumstances. Previous research [24] has demonstrated that such engagements not only facilitate appropriate physical exertion but also enhance overall fitness levels, elevate sleep quality, and ameliorate the well-being of elderly CHD patients. Furthermore, they contribute to fostering holistic well-being by promoting harmony between body and mind while enhancing daily experiences for these individuals. Consequently, healthcare professionals should devise a progressive program for engaging in communal pursuits taking into account factors such as age, physical condition, and exercise routines – an approach that holds significant value in enhancing patient wellness and staving off frailty.

Model validation usually requires evaluating the discrimination and calibration dimensions of the model, and the accuracy of risk prediction results will directly affect the selection of preventive measures and the effect of intervention effectiveness. In this study, we evaluated the predictive model's discrimination and calibration using ROC curves and the Hosmer–Lemeshow test. The results showed that the area under the ROC curve of 0.847, the sensitivity of 0.801, the specificity of 0.793, and the accuracy of 80.7%. These findings demonstrated good distinguish ability and accuracy, facilitating the identification of high-risk individuals with frailty. During internal validation, a C-value of 0.839 was obtained, this value greater than 0.7 indicate favorable model resolution. Furthermore, both uncorrected and corrected calibration curves closely align with the reference line in the classification calibration curve, suggesting that the nomogram exhibits high levels of calibration precision. A nomogram is a flat graph with graduated line segments based on multivariate regression results. Its essence is a simple visual chart of the regression equation [25]. A vertical line is drawn for each variable towards the scoring standard, and the total score corresponding to the risk value obtained by adding the scores of each variable represents the predicted probability value of frailty risk in elderly CHD patients. For instance, a 70-year-old patient diagnosed with CHD (10 points), has average health status (70 points),lacking in social activity (40 points), and experienced impaired IADL function (23 points) would have a total score of 143 points, corresponding to a frailty risk value of 0.48. A higher score indicates a greater risk of frailty. Therefore, the nomogram-based frailty risk prediction model for elderly CHD patients can offer personalized, high-precision, and quantifiable assessment of frailty risk for these patients with clinical applicability. Due to frailty is influenced by multiple factors, the model developed in this study encompasses individual health status, social engagement, age, and patients' IADL status. Healthcare professionals can utilize this model to evaluate the risk of frailty in patients and implement timely preventive and nursing measures through early identification of high-risk groups, aiming to achieve early prevention and intervention and reduce the incidence of frailty.

Limitations

This study has some limitations. First, the participants included in this study were only elderly patients with CHD only from 10 communities in 3 main urban areas of Zunyi City, Guizhou Province, China, sample sources were likely to have sampling bias, due to the different economic levels in different provinces or countries, the prevalence of frailty and the research results might differ from this study's results. Second, due to the limited sample size, only internal verification was carried out during the model validation, and the external efficacy of the model needs to be further modified and verified in the future to better apply to the clinic and be widely used in patients with coronary heart disease.

Conclusion

This study confirmed that the prevalence of frailty in elderly patients with CHD is high in China, and healthcare professionals should pay more attention to it. They should actively carry out screening for frailty in elderly patients with CHD in clinical work, perform early assessment and intervention based on risk factors, strengthen knowledge education to prevent frailty, and develop intervention plans to reduce the occurrence of frailty. Furthermore, in this study, the nomogram prediction model of frailty risk developed based on the logistic regression results has good discrimination and calibration, which can provide a visual quantitative risk assessment tool for healthcare professionals to evaluate frailty, which can be used for clinical reference.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

Liu SQ carried out the conception and design of the article, was responsible for statistical analysis and writing the paper; YUAN Xiaoli, LIANG Heting, GAO Huiming, JIANG Zhixia,YANG Xiaoling carried out the project implementation and data collection; at the same time, LIANG Heting, GAO Huiming carried out the statistical review; YUAN Xiaoli was responsible for the article quality control and review . All authors participated in the discussion, interpretation, revision and final approval of the manuscript.

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Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due the data needs further analysis, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval for the study was granted by the Ethics Committee of Affiliated Hospital of Zunyi Medical University, and all the participants provided signed informed consent at the time of participation (KLL2022-814). The study methodology was carried out in accordance with approved guidelines.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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