Clinical Interventions in Aging

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ORIGINAL RESEARCH

Frailty Trajectories and Determinants in Older Adults After PCI: A Longitudinal Study

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Aim: To identify distinct frailty trajectories and their determinants in older adults during the first six months after percutaneous coronary intervention (PCI), guided by the Health Ecology Model.

Design: A prospective observational design.

Methods: This study investigated the frailty status of elderly patients who underwent PCI surgery at a tertiary hospital in Ningxia, China, from November 2023 to May 2024, within six months after discharge. The Latent Growth Mixture Model was utilized to identify trajectories of frailty and classify participants based on these trajectories. Then, multivariable logistic regression analysis was employed to analyze the predictive factors of different trajectories. The reporting of this study adhered to the STROBE checklist.

Results: 218 elderly patients completed follow-up after PCI. There were three frailty trajectories among elderly people after PCI: the Low-Ascending Group (32.6%), the Middle-Alleviation Group (37.6%), and the High-Fluctuating Group (29.8%). Multivariate logistic regression analysis showed that depression, self-efficacy, occupation, NYHA class, and types of medication were influencing factors of their frailty trajectories ($P<0.05$).

Conclusion: The high proportion of frailty among elderly individuals after PCI should be a cause for concern. Additionally, targeted interventions based on frailty trajectories and measures like depression screening, self-efficacy support, and polypharmacy management are needed to address frailty in elderly post-PCI patients.

Impact: This study highlights the importance of tracking the frailty status of elderly patients after PCI, providing a new perspective and theoretical basis for healthcare professionals to design personalized and targeted intervention plans to prevent or ameliorate frailty.

Patient or Public Contribution: No patient or public contribution. The study only included patients who were research participants.

Keywords: older adults, percutaneous coronary intervention, health ecology, frailty, trajectories, influencing factors

Introduction

Coronary atherosclerotic heart disease, also known as coronary heart disease (CHD), refers to heart conditions caused by the narrowing or obstruction of the coronary arteries due to atherosclerosis, leading to myocardial ischemia or necrosis. It is a common and frequently occurring disease in the cardiovascular system, resulting in various adverse outcomes and has become a severe public health issue globally. In 2017, an article published in the Lancet journal reported on the national incidence, prevalence, and years lived with disability for 328 diseases and injuries in 195 countries worldwide from 1990 to 2016.[1] The study found that in 2016, there were approximately 154 million people affected by coronary heart disease, accounting for 32.7% of the global burden of cardiovascular diseases and 2.2% of the total global disease burden.[1] The "China Cardiovascular Health and Disease Report 2022" indicates that there are about 11.39 million people currently suffering from coronary heart disease in China, with a prevalence rate of 27.8% among people aged 60 and above.[2] Moreover, the mortality rate has been increasing year by year, posing a serious threat to the health of the elderly.

Percutaneous coronary intervention (PCI) is a minimally invasive nonsurgical treatment method used to improve blood flow in one or more segments of the coronary circulation, which can alleviate angina symptoms in patients with coronary heart disease. It has the advantages of minimal trauma, good therapeutic effects, and short hospital stays, and

https://doi.org/10.2147/CIA.S567029
Received: 11 September 2025
Accepted: 23 December 2025
Published: 8 January 2026

has become an important means of coronary blood flow reconstruction for patients with coronary heart disease.[3] However, while PCI can address coronary artery stenosis and improve symptoms of myocardial ischemia, it cannot reverse or delay the progression of atherosclerosis, and patients still have the possibility of restenosis in the coronary arteries or even at the stent site after surgery.[4] Studies show that in China, the readmission rate for elderly people after PCI treatment ranges from 12.02% to 15.00%.[5,6] Frailty has been proven to be a strong predictive factor for patient outcomes after PCI, characterized by reduced physiological reserves, decreased functional capacity, and increased susceptibility to stressors.[7,8] Research indicates that frail elderly people after PCI have a higher mortality rate and are more likely to experience adverse outcome events, such as falls and bed falls.[9] Studies suggest that the degree of frailty is dynamically changing and still has a certain degree of reversibility in the early stages.[10] However, investigations based on frailty trajectories in different populations indicate that the degree of frailty also varies over time.[11] Currently, it is unclear how frailty changes over time in elderly people after PCI, what factors are associated with changes in their frailty trajectories, and there is a lack of comprehensive, systematic research on their physiological, psychological, and social aspects based on relevant theories. The exact impact of frailty on elderly people after PCI remains a topic of ongoing scientific exploration and discussion. Therefore, it is necessary to identify the frailty trajectories of elderly people after PCI as early as possible and to explore the influencing factors of their trajectories comprehensively under the guidance of relevant theoretical frameworks. Longitudinal studies with more comprehensive patient data can enhance our understanding of the relationship between PCI and frailty in the elderly, which can help to develop personalized intervention measures to improve the prognosis and quality of life of elderly people after PCI.

Background

Previous studies have indicated that frailty trajectories are influenced by a variety of factors, such as age, gender, illiteracy, etc.[12] and are also related to adverse psychological conditions, lifestyle habits, and chronic diseases.[1] The Health Ecological Model posits that an individual's health is the result of the combined effects of their personal characteristics and their living environment.[13] At present, the Health Ecological Model is widely applied in the analysis of influencing factors, model construction, and intervention research.[14,15] The Health Ecological Model consists of five layers, with the core being personal traits, followed outwardly by behavioral characteristics, interpersonal networks, work and living conditions, and policy environments. The factors included in the five layers interact with each other and collectively impact human health. Zeng Lin's research[16] found that the factors affecting the occurrence of frailty in community-dwelling elderly diabetic patients are multi-dimensional and complex, involving the aforementioned five levels of the Health Ecological Model. Hou et al[17] conducted a longitudinal study based on the Health Ecological Model to explore factors related to cognitive frailty in middle-aged and elderly populations, indicating that attention should be focused on physiological factors (underweight, chronic diseases), psychological factors (depression), and health behaviors (alcohol consumption) in the elderly. Ding et al[18] found that nutrition, comorbidities, objective support, anxiety, and economic income are health ecological factors affecting preoperative frailty in elderly gastric cancer patients. Wang Y[19] conducted a search of studies applying the Health Ecological Model to the field of chronic diseases, and the results demonstrated that the Health Ecological Model can comprehensively and multi-angle analyze the influencing factors of diseases in the field of chronic disease management, providing a theoretical basis for the development of targeted and multi-dimensional intervention measures.

Therefore, based on a review of the literature and discussions within the research group, this study selects representative factors from each level of the Health Ecological Model to systematically explore the factors influencing the frailty trajectory of elderly people after PCI. The overall approach of the final model is as follows: the personal traits layer includes general demographic information (age, gender, height, weight) and disease-related data (comorbidities, types of medication, heart function classification, history of falls, history of coronary heart disease); the behavioral characteristics layer includes smoking, alcohol consumption, anxiety, depression, self-efficacy, and self-care ability; the interpersonal network layer includes social support, marital status, and living alone; the work and living conditions layer includes educational level, monthly household income, and employment status; and the policy environment layer includes medical insurance.

Summarizing the above, (1) this study, in conjunction with the "Expert Consensus on Exercise Rehabilitation after Percutaneous Coronary Intervention",[20] employs a prospective longitudinal study to investigate the frailty of elderly patients from the time of discharge after PCI to six months post-discharge; (2) based on the Health Ecological Model, it explores the factors influencing their frailty trajectories, providing a theoretical basis for the development of comprehensive nursing intervention strategies for the frailty of elderly patients following PCI.

The Study

Aim

This study aims to determine the frailty trajectories and associated factors in elderly people after PCI.

Methods

Design

This is a prospective observational design.

Participants

This study randomly recruited participants from the cardiology department, cardiac center cadre ward, and geriatrics and special needs medicine department of a tertiary hospital in Ningxia, China, from November 2023 to May 2024. The following were the inclusion criteria: 1) aged≥60 years; 2) meeting the 2020 International Society of Cardiology and World Health Organization (WHO) diagnostic criteria for coronary heart disease;[21] 3) capable of communicating adequately with the researchers and cooperating to complete the assessment; 4) successful implementation of PCI;[22] 5) patients or their families providing consent and signing an informed consent form. The following were the exclusion criteria: 1) Patients who are critically ill and at risk of life-threatening conditions at any time; 2) Patients with severe cognitive dysfunction, mental illness, or advanced-stage malignant tumors. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) was chosen as a checklist for this study.

Sample Size: When the Bayesian Information Criteria (BIC) is used as the primary indicator for model selection, the sample size should meet the requirement of N≥200.[23] Considering a 10% dropout rate, at least 223 subjects needed to be included. After four rounds of follow-up, complete data were available for 218 participants, which meets the sample size requirement.

This study conducted a questionnaire survey on 241 elderly patients after PCI at discharge (T1). Follow-ups were completed by 237, 228, and 218 patients at 1 month (T2), 3 months (T3), and 6 months (T4) after discharge, respectively. The dropout rates were 1.66% (T2), 3.73% (T3), and 4.15% (T4), with an overall dropout rate of 9.54%. The main reasons for dropout were withdrawal from the study, the presence of other serious diseases, and inability to contact. Statistical analysis revealed no significant differences in the distribution of general demographic and disease-related information between the dropout and non-dropout groups. Specific details of dropout are shown in Figure 1.

Measures

Demographic Characteristics

The questionnaire includes 1) Socio-demographic variables, which collect relevant information about the characteristics of the participants, such as gender, age, marital status, level of education, employment status, personal financial situation, occupation (current job type, eg, Retired, worker, farmer), housing, and medical insurance. 2) Health-related variables, such as smoking, drinking, family history of coronary heart disease, body mass index (BMI) [BMI = weight (kg)/height (m^2)] was categorized as underweight (<18.5 kg/m^2), normal (18.5–25.0 kg/m^2) and overweight and above (≥25.0 kg/m^2), NYHA (New York Heart Association) class, history of falls within six months, and types of medication (total number of prescribed drugs at discharge, categorized as 3-<5, 5–7, or≥7). Participants were also asked if they had other chronic diseases; a list of eight diseases was provided, and if a disease was not on this list, participants could add other diseases. Multimorbidity is defined as the coexistence of two or more diseases (Johnston et al, 2019), as shown in Table 1.

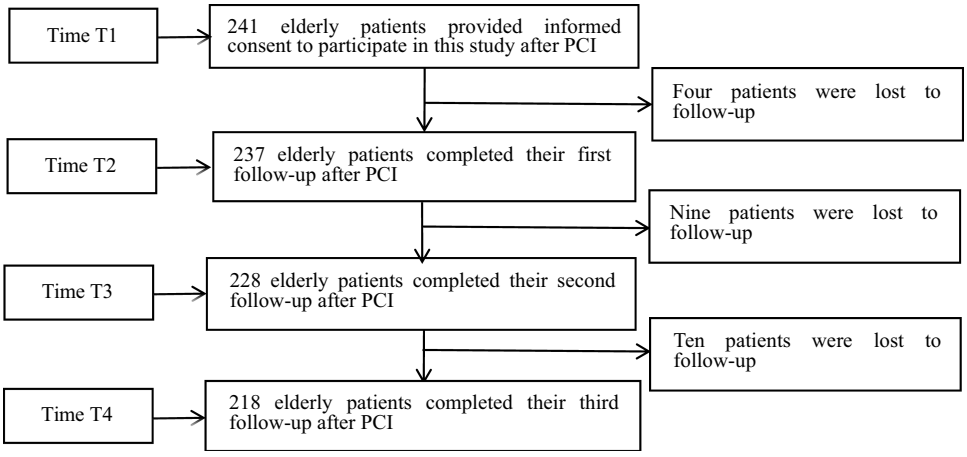

Figure 1 Flowchart of participant recruitment and follow-up at the four study timepoints after Percutaneous Coronary Intervention (PCI).

Frailty Scale

In our study, the FRAIL Scale[24] was used to assess frailty status. This is a valid but brief scale that includes 5 items: fatigue, resistance, ambulation, illness, and weight loss. Additionally, this scale has previously been shown to effectively measure the degree of physical frailty in Chinese older adults, with a Cronbach's α of 0.705.[25] The total score ranges from 0 to 5, with higher scores indicating more severe frailty. A score of 3 or above indicates frailty.

Table 1 Characteristics According to Frailty Trajectories at Baseline (N = 218)

Variables	Overall (N=218)	Low-Ascending Group (N=82)	Middle-Alleviation Group (N=71)	High-Fluctuating Group (N=65)	χ^2	*P*
Sociodemographic variables						
Age						
60–69	137(62.8)	56(68.3)	41(57.7)	40(61.5)	4.408	0.354
70–79	73(33.5)	22(26.8)	29(40.8)	22(33.8)		
≥80	8(3.7)	4(4.9)	1(1.4)	3(4.6)		
Gender						
Male	135(61.9)	50(61.0)	45(63.4)	40(61.5)	0.099	0.952
Female	83(38.1)	32(39.0)	26(36.6)	25(38.5)		
Marital status						
Married	187(85.8)	71(86.6)	64(90.1)	52(80.0)	2.931	0.231
Divorced or Widowed	31(14.2)	11(13.4)	7(9.9)	13(20.0)		
Working status						
Active	6(2.8)	1(1.2)	5(7.0)	0(0.0)	7.441	0.024
Retired or unemployed	212(97.2)	81(98.8)	66(93.0)	65(97.2)		
Occupation						
Retired	95(43.6)	35(42.7)	34(47.9)	26(40.0)	13.790	0.008
Worker	15(6.9)	5(6.1)	10(14.1)	0(0.0)		
Farmer	108(49.5)	42(51.2)	27(38.0)	39(60.0)		
Monthly income						
<2000 RMB	96(44.0)	41(50.0)	28(39.4)	27(41.5)	11.046	0.087
2000-2999 RMB	37(17.0)	10(12.2)	9(12.7)	18(27.7)		
3000-4999 RMB	42(19.3)	13(15.9)	18(25.4)	11(16.9)		
≥5000 RMB	43(19.7)	18(22.0)	16(22.5)	9(13.8)		
Live alone						
Yes	24(11.0)	5(6.1)	9(12.7)	10(15.4)	3.491	0.175
No	194(89.0)	77(93.9)	62(87.3)	55(84.6)		

(*Continued*)

Table 1 (Continued).

Variables	Overall (N=218)	Low-Ascending Group (N=82)	Middle-Alleviation Group (N=71)	High-Fluctuating Group (N=65)	χ^2	*P*
Education						
Primary school or lower	97(44.5)	39(47.6)	31(43.7)	27(41.5)	9.352	0.155
Junior high schools	66(30.3)	21(25.6)	27(38.0)	18(27.7)		
High school/technical	22(10.1)	9(11.0)	2(2.8)	11(16.9)		
Undergraduate/College	33(15.1)	13(15.9)	11(15.5)	9(13.8)		
Medical Insurance						
Medical insurance for employees	68(31.2)	27(32.9)	23(32.4)	18(31.2)	0.534	0.766
Basic medical insurance for residents or self paid	150(68.8)	55(67.1)	48(67.6)	47(72.3)		
Health-related variables						
Smoking						
Never	116(53.2)	43(52.4)	37(52.1)	36(55.4)	0.307	0.989
Past	64(29.4)	24(29.3)	21(29.6)	19(29.2)		
Current	38(17.4)	15(18.3)	13(18.3)	10(15.4)		
Drinking						
Never	134(61.8)	46(56.1)	46(65.7)	42(64.6)	5.227	0.265
Past	57(26.3)	21(25.6)	19(27.1)	17(26.2)		
Current	(39.0)	15(18.3)	5(7.1)	6(9.2)		
BMI						
Normal	56(25.7)	27(32.9)	17(23.9)	12(18.5)	4.592	0.332
Underweight	4(1.8)	2(2.4)	1(1.4)	4(1.8)		
Overweight or Obese	158(72.5)	53(64.6)	53(74.6)	158(72.5)		
Family history of CHD						
Yes	60(27.5)	22(26.8)	14(19.7)	24(36.9)	5.067	0.079
No	158(72.5)	60(73.2)	57(80.3)	41(63.1)		
NYHA class						
I	18(8.3)	0(0.0)	16(22.5)	2(3.1)	42.931	<0.001
II	93(42.7)	37(45.1)	34(47.9)	22(33.8)		
III	91(41.7)	34(41.5)	21(29.6)	36(55.4)		
IV	16(7.3)	11(13.4)	0(0.0)	5(7.7)		
Falls within half a year						
Yes	30(13.8)	15(18.3)	9(12.7)	6(9.2)	2.613	0.271
No	188(86.2)	67(81.7)	62(87.3)	59(90.8)		
Types of Medications						
3–<5	19(8.7)	8(9.8)	9(12.7)	2(3.1)	26.131	<0.001
5–7	140(64.2)	66(80.5)	40(53.6)	34(52.3)		
>7	59(27.1)	8(9.8)	22(31.0)	29(44.6)		
Multimorbidity						
No	17(7.8)	11(13.4)	3(4.2)	3(4.6)	5.774	0.056
Yes	201(92.2)	71(86.6)	68(95.8)	62(95.4)		

Abbreviations: CHD, coronary heart disease; NYHA, New York Heart Association; BMI, Body Mass Index.

Self Efficacy

The General Self-Efficacy Scale (GSES) was used to assess the patients' self-efficacy. This scale was originally developed by German clinical and health psychologists Schwarzer et al[26] in 1981 and later revised by Wang et al,[27] in whose study it demonstrated excellent internal consistency with a Cronbach's α of 0.926. The scale consists of 10 items, using a 4-point Likert scale: 1 to 4 points indicate a range from "not correct at all" to "completely correct". The total score ranges from 10 to 40 points, with higher scores indicating better self-efficacy.

Social Support

The Social support rate scale (SSRS) was used to measure social support. This scale comprises 10 items and across three dimensions (subjective support, objective support, and support utilization), designed by Xiao.[28] Items 1–5 and 8–10 are scored on a 4-point scale (1 to 4), while items 6–7 use a 2-point scale (0 to 1). The total score ranges from 12 to 66. Higher scores signify higher levels of social support. The SSRS was specifically designed for use in a Chinese context, demonstrating good validity and reliability, with a Cronbach's α of 0.890.[29]

Anxiety and Depression

The Hospital Anxiety and Depression Scale (HADS) was used to assess the psychological state of the patients. This scale, developed by Zigmond et al[30] in 1983, consists of 14 items, with 7 items (HADS-D) for assessing depressive symptoms and 7 items (HADS-A) for assessing anxiety symptoms. Each item is scored on a 4-point (0–3) response scale, with total scores for anxiety and depression ranging from 0 to 21. A total score greater than 8 on each subscale is considered indicative of anxiety and depression in the subjects. Both the HADS-A anxiety subscale and the HADS-D depression subscale have shown good concurrent validity, with a Cronbach's α of 0.890.[31]

Self-Care Ability

The Exercise of Self-Care Agency Scale (ESCA) was used to assess the patients' self-care abilities. This scale was designed by American scholars Kearney et al[32] in 1979 based on Orem's self-care theory. In 2000, Wang et al[33] translated it into Chinese, and it has been proven to have good reliability and validity, with a Cronbach's α of 0.77–0.80. It is the most widely used tool for measuring self-care ability in Mainland China, including 43 items across 4 dimensions: Self-Care Concept (8 items), Self-Care Responsibility (6 items), Self-Care Skills (12 items), and Health Knowledge Level (17 items). Each item is scored from 0 to 4, with a total score ranging from 0 to 172. Higher scores on the scale indicate a higher level of self-care ability: 116–172 points for high level; 58–115 points for moderate level; 0–57 points for low level.

Data Collection

This study combines the "Expert Consensus on Post-Percutaneous Coronary Intervention Exercise Rehabilitation", and in conjunction with the outpatient follow-up times after patient discharge, ultimately selects the survey time points as the time of patient discharge, one month after discharge, three months after discharge, and six months after discharge. On the day before the patient's discharge, the researchers conducted a face-to-face survey and obtained two or more contact methods from the patient. During the survey, the researcher uses a unified set of instructions to explain the requirements for completing the questionnaire, ensuring that the patients fully understand the content of the survey. The questionnaires are distributed and collected on the spot, with any missing or ambiguous items in the questionnaires supplemented by verbal inquiry to ensure the completeness and reliability of the information. After the completion of the questionnaire, the next stage of the survey is scheduled with the patient. In the follow-up survey phase, surveys are conducted at one, three, and six months after discharge, using two methods: outpatient follow-up at this hospital's cardiac rehabilitation clinic (which is basically consistent with the patient's review time) and telephone follow-up.

Statistical Analysis

Mplus 7.4 software was used to conduct Latent Growth Mixture Modeling (LGMM) analysis to explore the frailty trajectories of elderly people after PCI. An unrestricted conditional latent class growth model was used to determine the trajectory classes and their characteristics. In the Latent Growth Mixture Modeling, both linear and quadratic growth parameters were freely estimated to allow for the identification of trajectories that could capture both steady changes and fluctuations over time. The baseline model was a 1-class model, and the number of classes in the model was increased one by one, comparing the fit indices between models. The best model was determined by combining practical significance and statistical indicators, ultimately determining the number and characteristics of frailty trajectories. Among them, the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and sample-corrected BIC (aBIC) are smaller, indicating a better model fit; when the P-values of the Vuong-Lo-Mendell-Rubin likelihood ratio

test (VLMR) and the bootstrap likelihood ratio test (BLRT) for a k-class model are both significant, it indicates that the k-class model is significantly better than the (k-1)-class mo entropy reflects the precision of the latent class classification, with an entropy greater than 0.8 representing a 90% classification precision, and the higher the entropy, the more precise the classification. The parameter estimation method to be used in this study is the robust maximum likelihood estimation (RMLE), which allows for missing values in the follow-up data, assuming that the missing values are missing at random and do not affect the results.

Statistical analyses were performed using SPSS 26.0. Baseline characteristics across the identified frailty trajectories were described using frequencies and percentages [N(%)] for categorical data, and compared using the chi-square test. Continuous, normally distributed data were presented as mean (standard deviation) and compared using analysis of variance (ANOVA). Guided by the Health Ecology Model, predictor variables from its five layers were selected a priori. Subsequently, indicators that showed statistical significance in the univariate analyses were entered into a multinomial logistic regression model, with the frailty trajectory categories as the dependent variable. $P<0.05$ was considered statistically significant.

Ethical Considerations

The study design and procedures complied with the Declaration of Helsinki. The Ethics Committee of the General Hospital of Ningxia Medical University reviewed and approved the study (approval number: KYLL20221049). All participants gave written informed consent after being fully informed about the study's objectives, procedures, potential risks, and benefits.

Results

Characteristics of the Study Sample

After four rounds of follow-up, the study sample included 218 participants, of which 135 (61.9%) were male and 83 (38.1%) were female. The majority of the elderly participants were in the age group of 60 to 69 years old (62.8%), identified as farmers (49.5%), not living alone (89.0%), had basic medical insurance for residents or paid for it themselves (68.8%), and were retired or unemployed (97.2%), as detailed in Table 1.

Frailty Trajectories

To determine the optimal number of frailty trajectory classes, we used latent class growth modeling (LCGM), and the fit indices (including AIC, BIC, and entropy) for different class models are presented in Appendix Table S1 and Appendix S1. The model fit indices supported a three-class solution as the optimal model (AIC = 4352.294, BIC = 4410.593; VLMR P < 0.001, BLRT P < 0.001; Entropy = 0.858). The three identified trajectories were: the Low-Ascending Group (32.6%), the Middle-Alleviation Group (37.6%), and the High-Fluctuating Group (29.8%), as shown in Figure 2. As illustrated in Figure 2, the Low-Ascending Group started from the lowest frailty scores, which then gradually increased over time. The Middle-Alleviation Group began with moderate scores and showed an alleviating trend. The High-Fluctuating Group started from the highest scores and demonstrated a fluctuating pattern throughout the follow-up period.

5.3. The results of the analysis on the predictive factors of frailty trajectories in elderly people after PCI.

The Results of the Univariate Analysis

Based on the chi-square test and univariate analysis of variance, the results indicate that there are statistically significant differences ($P < 0.05$) in anxiety, depression, social support, self-efficacy, self-care ability, working status, occupation, NYHA class, and types of medications among participants across different frailty trajectory categories. The univariate results are detailed in Table 1 and Table 2.

The Results of the Multiple Logistic Regression Analysis

Using the variables that showed statistically significant differences in the univariate analysis as independent variables, and the three categories of frailty trajectories as dependent variables, a multinomial logistic regression analysis for

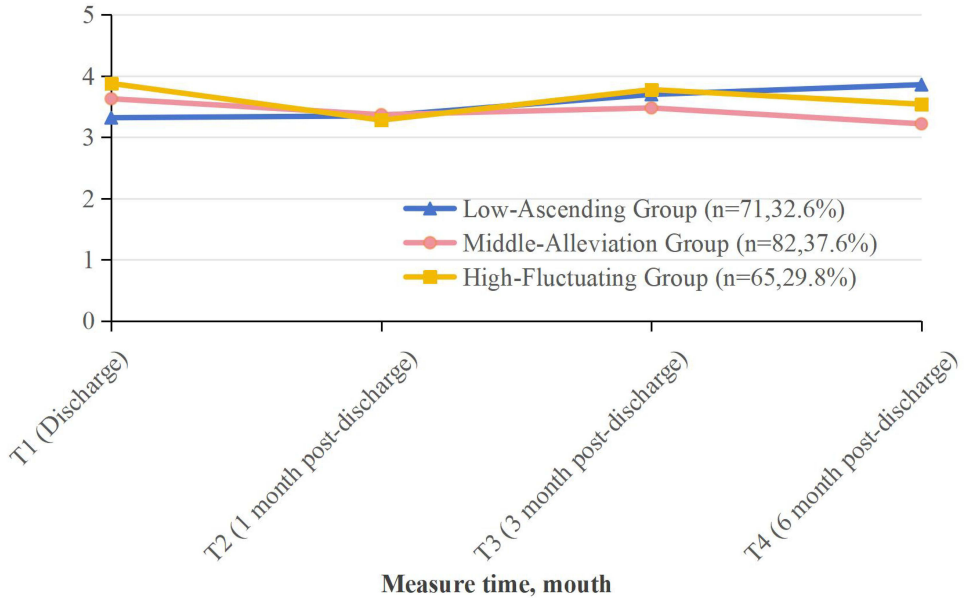

Figure 2 Trajectories of frailty in older adults during the six months following Percutaneous Coronary Intervention (PCI). Three distinct trajectories were identified: the Low-Ascending Group (37.6%), the Middle-Alleviation Group (32.6%), and the High-Fluctuating Group (29.8%).

unordered polytomous logistic regression was conducted. The regression results (Table 3) showed that factors significantly associated with frailty trajectories were depression, self-efficacy, occupation, type of medication, and NYHA class ($P < 0.05$). Compared to the Low-Ascending group trajectory, three risk factors were significantly associated with the middle-alleviation group trajectory: depression (OR=1.23, P=0.015), self-efficacy (OR=0.82, P=0.003), and occupation [retired and workers respectively (OR=3.05, 6.64, P=0.033, 0.032)]. Compared to the Low-Ascending group trajectory, NYHA class III (OR=5.04, P=0.003) was significantly associated with the high-fluctuating group trajectory. The type of medication was another influencing factor for the low, moderate, and high frailty group trajectories, with odds ratios for 3-<5 types of medication being 0.09 (P=0.007) and for 5–7 types of medication being 0.17 (P=0.002), and for the high-fluctuating group trajectory, the odds ratios were 0.05 for 3-<5 types of medication (P=0.003) and 0.14 for 5–7 types of medication (P<0.001).

Discussion

This study identified three distinct trajectories of frailty among elderly individuals aged 60 and above after PCI: the Low-Ascending Group; the Middle-Alleviation Group; and the High-Fluctuating Group. Furthermore, based on the health ecology theory model, we found that in addition to occupation, NYHA class, and types of medication from general demographic data, depression and self-efficacy also have a significant impact on the frailty trajectories of elderly

Table 2 Comparison of Anxiety, Depression, Social Support, Self-Efficacy, and Self-Care Ability Scores Across Different Frailty Trajectory Categories [n=218, M(SD)]

Variables	Low-Ascending Group (N=82)	Middle-Alleviation Group (N=71)	High-Fluctuating Group (N=65)	*F*	*P*
Anxiety score	7.17(3.21)	8.66(4.09)	7.62(3.83)	3.193	0.043
Depression score	7.82(3.14)	10.04(3.40)	9.38(3.69)	8.745	<0.001
Social support score	23.45(4.12)	22.54(3.89)	21.05(4.08)	6.476	0.002
Self-efficacy score	20.11(3.73)	18.00(5.05)	18.54(3.77)	5.222	0.006
Self-care ability score	94.44(23.74)	94.79(22.60)	83.06(20.87)	5.982	0.003

Abbreviations: M, mean; SD, standard deviation.

Table 3 Multivariate Logistic Regression Analysis of Frailty Trajectories in Elderly Patients After PCI

Reference	Trajectory	Variable	OR	95% CI	*P*-value
Low-Ascending Group	Middle-Alleviation Group	Depression score	1.23	1.04–1.45	0.015
		Self-efficacy score	0.82	0.72–0.94	0.003
		Occupation			
		Retired	3.05	1.10–8.47	0.033
		Worker	6.64	1.18–37.40	0.032
		Farmer[b]			
		Types of Medications			
		3–<5	0.09	0.02–0.508	0.007
		5-7	0.17	0.06–0.54	0.002
		>7[b]			
Low-Ascending Group	High-Fluctuating Group	NYHA class: III	5.04	1.13–22.30	0.033
		NYHA class: I[b]			
		Types of Medications			
		3-<5	0.05	0.01–0.37	0.003
		5-7	0.14	0.05–0.37	<0.001
		>7[b]			

Notes: [b]denotes the reference category for each variable: "Farmer" (Occupation), ">7" (Types of Medications), and "Class I" (NYHA).
Abbreviations: OR, odds ratio; CI, confidence interval.

individuals post-PCI, showing potential as intervention measures. The ultimate goal is to prevent or reverse frailty by early screening and timely intervention of these risk factors.

The results of this study reveal that the frailty trajectories of different subgroups of elderly individuals post-PCI exhibit varying trends and characteristics, categorized into three distinct groups: "Low-Ascending Group (32.6%)", "Middle-Alleviation Group (37.6%)", and "High-Fluctuating Group (29.8%)". The "High-Fluctuating Group" consists of elderly patients with high frailty scores at discharge, which then fluctuate over time, initially decreasing, followed by an increase, and then a subsequent decrease. The "Low-Ascending Group" patients have low frailty scores at discharge, but these scores gradually increase and worsen over time post-discharge. The "Middle-Alleviation Group", which is the largest in proportion, includes patients with moderate frailty scores at discharge, and their frailty levels follow a pattern similar to the "High-Fluctuating Group", but with a more stable overall trend, remaining at a moderate level. These findings differ from those reported by other scholars on the frailty trajectories of the elderly. Tchalla et al[34] identified four frailty trajectories among community-dwelling elderly in Limoges, France, over two years: "Robust stable Trajectory (26.8%)", "Pre-frail worsening to frailty (35.8%)", "Frail improving to less frailty (23.3%)", and "Frail worsening to more frailty (14.1%)". Yang et al[35] identified three frailty trajectories among Chinese elderly aged 65 and above over 16 years: "Non-frail (56.5%)", "Moderate progression (32.1%)", and "High progression (11.4%)". Du et al[12] identified four trajectories of physical frailty among Chinese elderly: "no-frailty (58.82%)", "increasing frailty (17.02%)", "worsened-frailty (12.17%)", and "improved-frailty (11.99%)". The differences in these frailty trajectory patterns may be attributed to the use of various frailty assessment tools, follow-up durations, frequencies, and study populations. Yang et al utilized the Frailty Index proposed by Rockwood[36] to assess frailty, while Achille et al employed Fried's[37] frailty phenotype (CHS index) for measurement. Both this study and Du et al used the FRAIL Scale[24] questionnaire for investigation, but this study did not observe the "no-frailty" trajectory, indicating that the frailty level among elderly post-PCI is significantly higher than that of the general elderly population. Therefore, healthcare professionals should pay close attention to the frailty changes in this population and prioritize the prevention of frailty. In summary, despite some differences in measurement tools, time points, and study outcomes, all studies have found that frailty symptoms in the elderly exhibit various trajectories of change.

Our results indicate that compared to the "Low-Ascending Group" trajectory, elderly individuals with lower self-efficacy scores and higher depression scores, particularly those whose occupation is manual labor, are more likely to fall into the "Middle-Alleviation Group". This is similar to the findings of Wu Z,[38] which demonstrated a significant

association between frailty trajectories and depressive symptoms among middle-aged and older adults in China. Notably, this study also found that self-efficacy and occupation as manual labor are significantly correlated with frailty trajectories. Firstly, self-efficacy is defined as an individual's confidence in their ability to mobilize cognitive resources, motivation, and behavior to perform important tasks, such as chronic disease management.[39] Individuals with high self-efficacy are more likely to engage in positive health behaviors, such as regular exercise and a healthy diet, which can help delay the progression of frailty. In this study, elderly individuals in the "Middle-Alleviation Group" post-PCI had lower levels of self-efficacy. Secondly, occupations involving manual labor may entail more physical exertion and less decision-making control, leading to higher levels of physical fatigue and psychological stress, thereby affecting frailty trajectories. Physical labor may become more challenging with age, and a lack of control over the pace of work can increase work-related stress. Therefore, it is recommended that healthcare professionals provide guidance to elderly individuals on how to manage chronic diseases through health education programs, workshops, or individual counseling, to enhance their confidence and ability in self-managed health. For elderly individuals with manual labor occupations, healthcare professionals should pay attention to their psychological health, offering necessary psychological assessments and support to alleviate psychological stress and improve frailty trajectories.

The results of this study show that, compared to the Low-Ascending Group trajectory, individuals with NYHA class III are more likely to enter the High-Fluctuating Group trajectory. This is inconsistent with the research findings of Gou et al[40] which indicated that a higher NYHA class is significantly associated with frailty trajectories in elderly patients with chronic heart failure. The discrepancy may be due to differences in study design, population selection, sample size, and other factors between this study and theirs. Different studies have varying inclusion and exclusion criteria, leading to inconsistencies in their results. Additionally, this study found that the type of medication is another factor affecting the trajectories of the Low-Ascending Group, Middle-Alleviation Group, and High-Fluctuating Group. Patients taking more than 7 medications constituted the highest-risk group for unfavorable frailty trajectories. This is consistent with previous research.[41] In the Middle-Alleviation Group and High-Fluctuating Group trajectories, the risk of frailty associated with the use of 5–7 medications is 0.17 and 0.14 times, respectively, compared to the risk associated with 3-<5 medications. Some studies have pointed out[41] that polypharmacy is significantly correlated with the degree of frailty. Elderly individuals using more than five medications are more likely to exhibit frailty symptoms, possibly because polypharmacy increases the risk of drug interactions, leading to adverse reactions and negative events such as falls, thereby promoting the development of frailty. As the number of medications increases, the difficulty for elderly individuals to correctly take all their medications also increases, which may lead to decreased medication adherence,[42,43] affecting treatment outcomes and thus influencing frailty trajectories. It is also possible that the use of multiple medications may bring economic burdens, affecting the quality of life and health behaviors of the elderly, and consequently influencing frailty trajectories. In conclusion, this study identified three distinct frailty trajectories and their determinants in older adults after PCI. Our findings extend beyond theoretical modeling to highlight actionable clinical targets. Specifically, the strong association of depression and low self-efficacy with unfavorable trajectories calls for the integration of routine psychological screening and self-management support into standard cardiac rehabilitation. Furthermore, the risk linked with polypharmacy underscores the critical need for proactive medication review. Such reviews, which should include direct discussions with patients, can identify opportunities for deprescribing and enhance medication adherence through personalized guidance.[44]

Limitations

The limitations of the study include a relatively small sample size and the use of convenience sampling, which may limit the representativeness of the sample and affect the generalizability and extrapolation of the results. Therefore, future research will require large-sample, multicenter longitudinal studies to further explore and verify the frailty trajectories of elderly people after PCI and their influencing factors.

Conclusion

This study found that there are three frailty trajectories among elderly people after PCI. Based on the Health Ecology Model, in addition to occupation, NYHA class, and types of medication, depression and self-efficacy are also significant factors affecting the frailty trajectories of elderly individuals post-PCI. This indicates that optimizing medication treatment plans for the elderly,

providing psychological support, and health management guidance for diseases are crucial for preventing frailty in the elderly. The results of this study offer insights for intervention strategies for frailty symptoms in elderly individuals after PCI.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

The research was supported by Ningxia Natural Science Foundation of China (2023AAC03526).

Disclosure

Rong Wang is now affiliated with The 942nd Hospital of PLA Joint Logistics Support Force. The authors report no conflicts of interest in this work.

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