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Research Paper

Associations between depression, resilience, and fatigue in patients with multivessel coronary disease: A cross-lag study

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ABSTRACT

Objectives: This study aimed to examine the associations between depression, resilience, and fatigue in patients with multivessel coronary disease and verify their causal relationships.
Methods: Between October 2023 and June 2024, 316 patients with multivessel coronary disease were recruited from three tertiary hospitals in Tangshan, China. The Patient Health Questionnaire, Connor-Davidson Resilience Scale, and the Multidimensional Fatigue Inventory were administered to the patients on the third day of admission (T1), one month after discharge (T2), and three months after discharge (T3). Pearson correlation analysis was conducted to examine the relationships among depression, resilience, and fatigue in patients with multivessel coronary disease, and cross-lagged analysis to explore the temporal causal relationships.
Results: In patients with multivessel coronary disease, levels of depression and fatigue decreased from T1 to T3, while resilience scores increased during the same period. The correlation analysis revealed significant relationships among depression, resilience, and fatigue at T1, T2, and T3 ($P < 0.01$). The autoregressive paths indicated high stability over time for depression, medium stability for resilience, and low stability for fatigue. Cross-lagged paths demonstrated that depression at T1 significantly predicted fatigue at T2 ($\beta = 0.461$, $P < 0.001$), and depression at T2 significantly predicted fatigue at T3 ($\beta = 0.957$, $P < 0.001$). And resilience at T1 significantly predicted fatigue at T2 ($\beta = -0.271$, $P < 0.001$), and resilience at T2 significantly predicted fatigue at T3 ($\beta = -0.176$, $P < 0.001$). Additionally, resilience had a moderating effect on the relationship between depression and fatigue ($\beta = -0.760$, $P < 0.001$).
Conclusions: Our study confirmed that depression and resilience predicted fatigue in patients with multivessel coronary disease. To prevent and mitigate fatigue, alleviating depressive symptoms and enhancing resilience levels in patients at an early stage is essential.

What is known?

- Patients with coronary heart disease are at risk of experiencing persistent fatigue, which can negatively impact their prognosis and quality of life.
- There was a significant positive correlation between depression and fatigue, while resilience exhibited a negative correlation with fatigue.
- Previous studies focused on the static correlation analysis of depression, resilience, and fatigue. However, this approach does not effectively clarify the causal relationships among these variables, thus providing limited clinical guidance.

What is new?

- We examined the temporal relationship between depression, resilience, and fatigue, and we verified the effectiveness of reducing depression and enhancing resilience as strategies for alleviating fatigue in patients with multivessel coronary disease.
- Resilience had a moderating effect on the relationship between depression and fatigue.

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1. Introduction

Coronary heart disease is the leading cause of death from cardiovascular diseases and a significant public health concern [1]. With advancements in diagnostic and treatment technologies, multivessel coronary disease is increasingly prevalent in coronary angiography, with an incidence ranging from 40% to 70% [2]. Multivessel coronary disease is characterized by coronary atherosclerosis affecting two or more of the three primary coronary arteries, with stenosis over 50%, significantly reducing blood flow to the heart [3]. This condition is associated with a higher risk of malignant arrhythmias, cardiogenic shock, and even sudden death, resulting in significant physical and psychological distress for patients, as well as contributing to physical and mental fatigue [4,5]. It has been reported that 73.6% of patients undergoing heart surgery experienced fatigue during hospitalization, and 53.6% continued to feel fatigued one month after discharge, with significant relief observed three months post-discharge [6]. The persistence of fatigue can lead to endocrine dysfunction, reduced bodily function, exacerbation of diseases, an increased risk of mortality, and a serious threat to the quality of life for patients [7,8]. To effectively manage and alleviate fatigue in patients with multivessel coronary disease, it is essential to understand the related predictive factors and the causal relationship between the factors.

A study has reported that fatigue in patients with coronary heart disease is influenced by both positive and negative psychological factors [9]. Meanwhile, several investigations have demonstrated a significant relationship between depressive symptoms and fatigue through cross-sectional studies [10,11]. Eckhardt et al. [12] examined 102 patients with coronary heart disease, and the results indicated that depressive symptoms were the sole predictor of fatigue intensity. Furthermore, depressive symptoms continue to impact the progression of fatigue. Gong [13] conducted a four-month survey of patients with acute myocardial infarction, revealing that higher depression scores were associated with an increased likelihood of patients experiencing persistent fatigue. In addition, a study has shown that positive psychological factors will have corresponding positive effects on relieving fatigue [10]. Resilience reflects an individual's physical and mental health, which can mitigate the impact of stress and improve adaptability [14]. Evidence demonstrated that patients with stroke in China exhibiting high levels of resilience are better able to cope with fatigue [15]. Moreover, resilience is negatively correlated with fatigue and is a crucial factor in alleviating fatigue among patients with lung cancer [16]. A previous study [17] has demonstrated that resilience mitigates the adverse effects of stress on physical health and lessens the impact of adverse mental states on fatigue. Resilience is considered a crucial buffer against depression [18]. Individuals with high resilience are better equipped to maintain mental equilibrium and prevent the exacerbation of depression when confronted with stressors [18]. Resilience decreases both the incidence and severity of depression by improving an individual's emotional regulation, increasing the utilization of social support, and enhancing problem-solving skills [19].

It is important to note that while studies have explored the relationships among depression, resilience, and fatigue, several limitations persist. Previous studies [9–11] have primarily demonstrated correlations among these variables through cross-sectional studies, lacking an investigation into their dynamic temporal associations. This limitation has hindered the elucidation of the causal relationships among depression, resilience, and fatigue, resulting in conclusions that cannot be generalized. Additionally, there may be a potential buffering effect of resilience in the relationship between depression and fatigue, which has yet to be investigated. Furthermore, the absence of a structural analysis method supported by a theoretical framework renders the relationships among these variables unclear.

Conservation of Resources (COR) model, first proposed by Hobfoll, emphasizes the dynamic flow of resources among individuals in stressful situations [20], which is closely related to the mechanisms of fatigue. Fatigue is not an isolated phenomenon and often arises from prolonged exposure to stress, leading to a depletion of personal resources that are hard to replenish [21]. COR focuses on the loss and protection of resources as key elements in how individuals cope with stress. It offers a robust theoretical framework for analyzing the causes of fatigue. This theory posits that individual resources are crucial in dealing with stress. Stressors can deplete these resources, and when individuals perceive a loss of resources, it can further intensify their feelings of stress, creating a negative loop. Individuals can enhance their adaptive capacity by accumulating resources, and psychological resources, such as resilience, can mitigate the effects of resource loss. Abundant psychological resources enable effective adaptation to stress through positive coping strategies [20].

As a common state of resource loss, depression not only directly depletes an individual's psychological resources but also further impedes the potential for resource gains through negative thought patterns and behavioral withdrawal, ultimately exacerbating feelings of fatigue [20]. Consequently, depression may have a direct positive correlation with fatigue. As a fundamental factor in resource protection, resilience is a crucial psychological resource that reflects individuals' adaptability in the face of stress. According to COR model, resilience directly alleviates fatigue by enhancing adaptive adjustment capabilities, and it enables individuals to effectively manage stressors, thereby reducing the loss of psychological resources caused by negative emotions and buffering the adverse effects of resource loss [14]. Consequently, resilience may exhibit a direct negative relationship with fatigue while mitigating resource loss induced by depression and further reducing fatigue. Drawing from existing literature and COR model, this study proposes the following hypothesis: 1) depression has a direct positive predictive effect on fatigue; 2) resilience has a direct negative predictive effect on fatigue; 3) resilience moderates the relationship between depression and fatigue.

Fatigue is a dynamic process that fluctuates in response to changes in individual resources (depression and resilience). COR model is a dynamic theory; the fluctuation of resources means that change is a natural part of the theory. It would be valuable to simultaneously examine the associations among depression, resilience, and fatigue in prospective studies to determine whether one or both variables can predict changes in fatigue over time, considering cross-sectional links, temporal stability, and variable causality. A cross-lagged model can reveal quasi-causal relationships, enhancing the findings' significance. Therefore, we analyzed longitudinal survey data using cross-lagged model analysis from patients with multivessel coronary disease within three months of discharge to investigate changes in depression, resilience, and fatigue, thereby deepening our understanding of their causal interactions.

2. Methods

2.1. Study design and participants

This longitudinal study was reported by Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and registered in the Chinese Clinical Registry Center (No. ChiCTR2300076995).

This study was conducted from October 2023 to June 2024 in three tertiary hospitals in Tangshan, China. Inclusion criteria were as follows: 1) 18–85 years old; 2) met the diagnostic criteria for coronary heart disease, and the first coronary angiography indicated multivessel coronary disease. Exclusion criteria included severe dysrhythmias (such as ventricular fibrillation or tachycardia and third-degree atrioventricular block), severe depression, and hearing or communication disabilities that hindered the successful completion of questionnaires.

2.2. Sample size

G*Power 3.1 software was utilized to estimate the sample size for this study [22]. Based on $\alpha = 0.05$ and a correlation effect size of $r = 0.20$, a minimum of 193 subjects was required to achieve 80% statistical power. Assuming 20% of questionnaires would be invalid, the final sample size needed at least 232.

2.3. Measures

2.3.1. Demographic and clinical characteristics

Electronic medical records were utilized to gather patient demographic characteristics and clinical data. The demographic characteristics included sex, age, education level, marital status, and place of residence. Clinical data included the treatment method, comorbidities, and disease lesions.

2.3.2. Depression

Depression was assessed using the Patient Health Questionnaire-9 (PHQ-9), a widely utilized screening tool for depressive symptoms [23]. The questionnaire was translated into Chinese in 2009 and demonstrated a Cronbach's α coefficient of 0.857 [24]. This questionnaire comprises nine items: little interest or pleasure in doing things; feeling down, depressed, or hopeless; trouble falling or staying asleep, or sleeping too much; feeling tired or having little energy; poor appetite or overeating; feeling bad about yourself—or that you are a failure or have let yourself or your family down; trouble concentrating on things, such as reading the newspaper or watching television; moving or speaking so slowly that others could have noticed? or the opposite—being so fidgety or restless that you have been moving around a lot more than usual; thoughts that you would be better off dead or of hurting yourself in some way. Each item was rated on a four-point Likert scale, ranging from "0" (not at all) to "3" (nearly every day). Total scores range from 0 to 27, with higher scores indicating a greater severity of depression. The total score was categorized into four severity groups: no (0–4), mild (5–9), moderate (10–14), and severe (15–27) symptoms of depression. In our study, the Cronbach's α coefficients for the PHQ-9 were 0.852, 0.815, and 0.772, respectively.

2.3.3. Resilience

Resilience was assessed using the 10-item Connor-Davidson Resilience Scale (CD-RISC). Developed by Campbell-Sills in 2007 [25] and translated into Chinese in 2018 [26], the Cronbach's α coefficient for the CD-RISC is 0.851. This scale comprises ten items: able to adapt to change; can deal with whatever comes; tries to see the humorous side of problems; coping with stress can strengthen me; tend to bounce back after illness or hardship; can achieve goals despite obstacles; can stay focused under pressure; not easily discouraged by failure; thinks of self as a strong person; can handle unpleasant feelings. Each item was rated on a five-point Likert scale, ranging from "0" (not true at all) to "4" (true nearly all of the time). Total scores range from 0 to 40, with higher scores indicating a greater level of resilience. In our study, the Cronbach's α coefficients for the CD-RISC were 0.900, 0.907, and 0.927, respectively.

2.3.4. Fatigue

Fatigue was assessed using the Multidimensional Fatigue Inventory-20 (MFI-20). It was developed by Smets in 1995 [27] and translated into Chinese in 2008 [28], the Cronbach's α coefficient is 0.882. This self-report instrument evaluates fatigue across five distinct dimensions: general fatigue (four items), physical fatigue (four items), reduced motivation (four items), reduced activity (four items), and mental fatigue (four items). Each item was rated on a five-point Likert scale, ranging from 1 to 5 (1 = completely inconsistent, 2 = somewhat consistent, 3 = neutral, 4 = mostly consistent, and 5 = completely consistent). The total score ranges from 20 to 100, with higher scores indicating greater fatigue severity. In our study, the Cronbach's α coefficients for the MFI-20 were 0.975, 0.973, and 0.973, respectively.

2.4. Data collection

The research team obtained permission from department heads at three hospitals before recruiting participants based on established inclusion and exclusion criteria. Trained and qualified researchers conducted the investigation. Before the investigation, the purpose, significance, and confidentiality measures were explained to the participants, and the investigation proceeded only after obtaining their informed consent. Data were collected on the third day of admission (T1), one month after discharge (T2), and three months after discharge (T3). The survey timing was based on consensus, guidelines [29,30], and previous studies [6,31]. Phase I cardiac rehabilitation should begin within 24 h of admission but may be delayed by three to seven days if the patient's condition is unstable [29]. We chose the third day after admission (T1) for the initial survey based on patients' conditions and clinical practices. Guidelines [30] recommend starting phase II rehabilitation one month after discharge, typically two to five weeks post-surgery. Research has demonstrated that emotional disorders in patients with coronary heart disease can persist for three months before stabilizing [31]. Consequently, we chose the second and third survey times to be one month (T2) and three months (T3) after discharge, respectively. Data were collected through face-to-face surveys. Patients completed the questionnaire themselves. If patients found it inconvenient to fill out the questionnaire, the investigator would read the questions and answer options, recording the patients' responses accordingly. Completed questionnaires were immediately checked for completeness and logical consistency. With patient and family consent, at least two commonly used telephone numbers were retained. Researchers were trained in telephone follow-up and conducted questionnaires at a specified time after discharge.

2.5. Data analysis

Statistical analysis was conducted using SPSS 22.0 and Mplus 8.3. Categorical variables were reported as number (n) and percentage (%), and numerical variables as mean and standard deviation (*SD*). Pearson correlation analysis examined the relationships among depression, resilience, and fatigue. We also explored potential causal relationships using cross-lagged panel model analysis to assess predictive relationships among these variables. Importantly, we aimed to analyze all three variables within the same cross-lagged model to estimate both cross-sectional and prospective relationships while simultaneously accounting for shared variance. Model fit was evaluated using the ratio of chi-square (χ^2) to degrees of freedom (df), the Tucker-Lewis Index (TLI), the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). A χ^2/df between 1 and 3 suggests a good fit, while values between 3 and 5 indicate an acceptable fit. A CFI and TLI greater than 0.90 indicate an acceptable model fit, while values exceeding 0.95 suggest a perfect fit. An SRMR value below 0.08 indicates a good fit to the data. An RMSEA of 0 signifies an exact fit; values between 0 and 0.05 suggest a close fit; values between 0.05 and 0.08 indicate a reasonable fit; values ranging from 0.08 to 0.10 suggest a mediocre fit; and an RMSEA greater than 0.10 indicates a bad fit [32,33]. When examining the causal relationship between variables A and B, if the correlation between the pretest variable A and the post-test variable B is stronger than the correlation between the pretest variable B and the post-test variable A, it can be inferred that a causal relationship exists between the pretest variable A and the post-test variable B. In this context, variable A is considered the causal variable for variable B [34]. Considering that the patients aged 18–85 years, exhibited significant age differences. To assess the robustness of the model, we included age as a control variable to evaluate its impact on the results.

2.6. Ethical considerations

The study was approved by the Human Ethics Committee of Tangshan Gongren Hospital (No. GRYY-2023-116). Written informed consent was obtained from each participant before the study.

3. Results

3.1. Characteristics of the participants

A total of 371 patients were enrolled in the study, and 55 were excluded for the following reasons: death ($n = 1$), worsening illness ($n = 12$), poor cooperation ($n = 19$), and loss of contact due to phone rejection or busy signals ($n = 23$). Ultimately, 316 patients were included in the analysis. Most participants (67.4%) were male, and the mean age was 62.11 ± 10.30 years. Most patients (94.3%) were married, and a significant portion (48.7%) had completed secondary education. The detailed sociodemographic and clinical characteristics of the participants are presented in Table 1.

Table 1
Characteristics of the participants ($n = 316$).

Characteristics	Categories	*n* (%)
Sex	Male	213 (67.4)
	Female	103 (32.6)
Age (years)	18–60	125 (39.6)
	61–69	123 (38.9)
	70–85	68 (21.5)
Education level (years)	Elementary (≤6)	83 (26.3)
	Secondary (7–9)	154 (48.7)
	Higher (>9)	79 (25.0)
Marital status	Married	298 (94.3)
	Single	18 (5.7)
Place of residence	Rural	135 (42.7)
	Urban	181 (57.3)
Treatment method	Medication alone	69 (21.8)
	PCI	236 (74.7)
	CABG	11 (3.5)
Comorbidities	0	96 (30.4)
	1	128 (40.5)
	2	78 (24.7)
	≥3	14 (4.4)
Lesions of disease	1	0 (0)
	2	181 (57.2)
	3	135 (42.8)

Note: PCI = percutaneous coronary intervention. CABG = coronary artery bypass graft.

3.2. Correlations among depression, resilience, and fatigue

In patients with multivessel coronary disease, levels of depression and fatigue decreased from T1 to T3, while resilience scores increased during the same period. Significant correlations were observed among depression, resilience, and fatigue at T1, T2, and T3 ($P < 0.01$), indicating a synchronous relationship among these variables. Additionally, the three variables demonstrated significant correlations between pretest and post-test measurements ($P < 0.01$), suggesting cross-time stability (Table 2). Overall, depression, resilience, and fatigue in patients with multivessel coronary disease exhibited both synchronous correlations and cross-time stability, fulfilling the conditions necessary for cross-lag analysis.

3.3. Cross-lag model

Fig. 1 shows the complete model of cross-lag paths and autoregressive paths. The model used all the data of the measured variables. The results showed that the model has good fitting indicators ($\chi^2/df = 2.659$, CFI = 0.991, TLI = 0.969, RMSEA = 0.072, and SRMR = 0.012).

3.3.1. Autoregressive paths

The results of autoregressive path analysis showed that T1 depression had significant effects on T2 depression ($\beta = 0.940$, $P < 0.001$), and T2 depression had significant effects on T3 depression ($\beta = 0.928$, $P < 0.001$). T1 resilience had a significant effect on T2 resilience ($\beta = 0.345$, $P < 0.001$), and T2 resilience had a significant effect on T3 resilience ($\beta = 0.859$, $P < 0.001$). T1 fatigue had significant effects on T2 fatigue ($\beta = 0.147$, $P < 0.001$), and T2 fatigue had a significant effect on T3 fatigue ($\beta = 0.230$, $P < 0.001$).

3.3.2. Cross-lag paths

The results of cross-lag path analysis showed that T1 depression had significant effects on T2 fatigue ($\beta = 0.461$, $P < 0.001$), and T2 depression had significant effects on T3 fatigue ($\beta = 0.957$, $P < 0.001$). T1 resilience had a significant effect on T2 fatigue ($\beta = -0.271$, $P < 0.001$), and T2 resilience had a significant effect on T3 fatigue ($\beta = -0.176$, $P < 0.001$). T1 fatigue had significant effects on T2 depression ($\beta = 0.078$, $P < 0.001$) and T2 resilience ($\beta = -0.148$, $P < 0.001$). T2 fatigue had no significant effect on T3 depression ($\beta = 0.013$, $P = 0.551$) and T3 resilience ($\beta = -0.050$, $P = 0.174$). T2 resilience had a moderating effect on the relationship between T1 depression and T3 fatigue ($\beta = -0.760$, $P < 0.001$).

In addition, after controlling for age (Appendix A), T1 depression had significant effects on T2 fatigue ($\beta = 0.436$, $P < 0.001$), and T2 depression had significant effects on T3 fatigue ($\beta = 0.956$, $P < 0.001$). T1 resilience had significant effects on T2 fatigue ($\beta = -0.282$, $P < 0.001$), and T2 resilience had significant effects on T3 fatigue ($\beta = -0.179$, $P = 0.001$). T1 fatigue had significant effects on T2 depression ($\beta = 0.077$, $P < 0.001$) and T2 resilience ($\beta = -0.148$, $P = 0.006$). T2 fatigue had no significant effect on T3 depression ($\beta = 0.004$, $P = 0.841$) and T3 resilience ($\beta = -0.033$, $P = 0.362$). T2 resilience exhibited a moderating effect on the relationship between T1 depression and T3 fatigue ($\beta = -0.762$, $P < 0.001$).

4. Discussion

4.1. Cross-lag autoregressive paths

The cross-lag autoregressive path revealed that the autoregressive coefficients for depression were significant, indicating that the depression level in patients with multivessel coronary disease

Table 2
Correlations between depression, resilience, and fatigue.

Variables	*Mean* ± *SD*	Depression^{T1}	Depression^{T2}	Depression^{T3}	Resilience^{T1}	Resilience^{T2}	Resilience^{T3}	Fatigue^{T1}	Fatigue^{T2}	Fatigue^{T3}
Depression^{T1}	6.85 ± 4.06	–	–	–	–	–	–	–	–	–
Depression^{T2}	4.94 ± 3.49	0.962*	–	–	–	–	–	–	–	–
Depression^{T3}	3.66 ± 2.87	0.888*	0.943*	–	–	–	–	–	–	–
Resilience^{T1}	22.57 ± 5.23	−0.391*	−0.368*	−0.324*	–	–	–	–	–	–
Resilience^{T2}	25.59 ± 6.50	−0.201*	−0.241*	−0.237*	0.398*	–	–	–	–	–
Resilience^{T3}	27.29 ± 5.39	−0.166*	−0.201*	−0.199*	0.332*	0.859*	–	–	–	–
Fatigue^{T1}	70.32 ± 18.70	0.335*	0.593*	0.560*	−0.316*	−0.244*	−0.240*	–	–	–
Fatigue^{T2}	59.11 ± 17.85	0.337*	0.402*	0.462*	−0.324*	−0.262*	−0.247*	0.402*	–	–
Fatigue^{T3}	47.97 ± 16.50	0.318*	0.391*	0.436*	−0.356*	−0.295*	−0.282*	0.380*	0.483*	–

Note: *P < 0.01. ^{T1} the third day after admission. ^{T2} one month after discharge. ^{T3} three months after discharge.

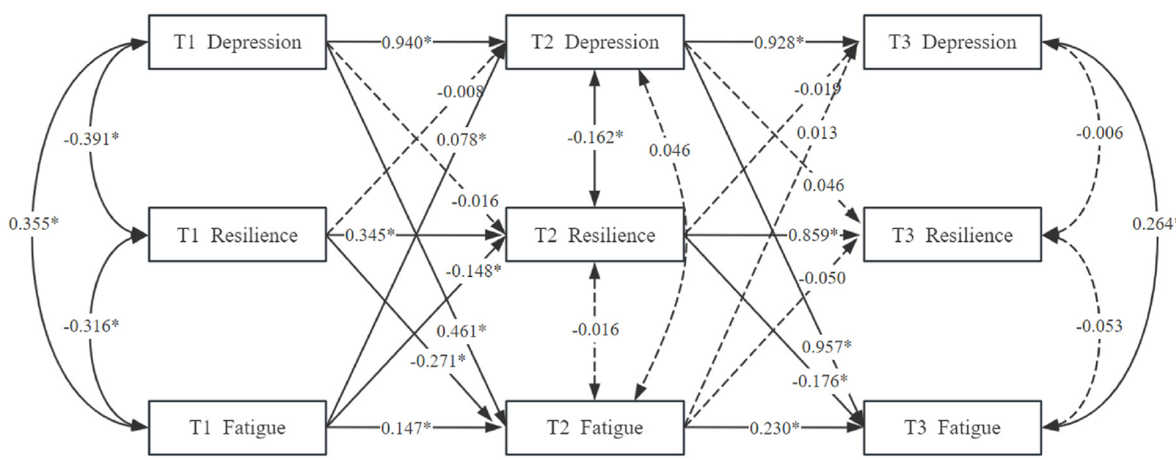

Fig. 1. Results of the cross-lag paths and autoregressive paths.
*P < 0.01. T1: the third day after admission. T2: one month after discharge. T3: three months after discharge.

exhibited minimal variation over time and demonstrated high stability. The high autoregressive coefficient indicates that the level of depression in the early stages can accurately predict the depressive state in subsequent stages. This suggests that once an individual experiences depression, the depressive state is likely to persist over an extended period [35]. Depression disorder is characterized by a high rate of recurrence and chronicity [36]. The coefficient results of this study quantitatively illustrate this trait at the individual level over time. This stability may be attributed to deeply ingrained negative cognition associated with depression. As outlined in Beck's cognitive theory, individuals with depression often interpret life events through a negative lens, which perpetuates feelings of self-denial and helplessness, thereby complicating the resolution of their depressive state [37]. Follow-up intervention plans should concentrate on disrupting this persistent stability and aim to reshape cognitive patterns while establishing support systems to assist patients in overcoming depression.

The autoregressive coefficients of resilience were significant, indicating moderate stability. An increase in these coefficients suggests that resilience among patients with multivessel coronary disease improves over time after discharge. Initially, resilience shows weak continuity, but stability increases in later stages, allowing individuals to maintain a stable state and reduce external interference. Bonanno et al. [38] identified four typical psychological reaction trajectories following trauma: chronic dysfunction, delay, resilience, and recovery. Our study found that resilience levels in patients with multivessel coronary disease increased post-discharge, aligning with the resilience and recovery trajectories. Specifically, the mental functioning of patients gradually improved and tended to reach a positive state; although their mental function was initially affected, it recovered to a normal level over time. When faced with significant adversities, like illness, internal and external resources are mobilized to enhance resilience and restore mental health [39]. In our study, the resilience of patients with multivessel coronary disease showed an exhibited notable increase was significant in the particularly early stages. The reason may be that individuals have accumulated certain coping experiences in the early stages. As the disease recovers, patients can gradually activate their internal positive resources, actively confront the illness's challenges, and steadily enhance their resilience.

In addition, the autoregressive coefficients for fatigue indicate that patients with multivessel coronary disease experience significant fluctuations in fatigue levels over time, indicating low stability. This suggests that fatigue is temporary and accumulates and transmits over time. If fatigue in the early stages is not properly addressed, it is highly likely to continue affecting individuals' subsequent states over time, thereby creating a vicious cycle. Furthermore, our study found that fatigue scores during hospitalization and up to three months post-discharge were significantly higher than in other studies [13], likely due to differences in population characteristics. Patients with multivessel coronary disease present greater complexity due to more significant vascular stenosis and blood flow obstruction, which is likely to lead to fatigue primarily caused by myocardial ischemia and hypoxia. Long-term fatigue can lead to elevated levels of stress hormones in the body, disrupt the normal functioning of the endocrine system, and weaken the body's self-repair capabilities [8]. Our study highlights the need for healthcare professionals to focus on patients with multivessel coronary disease. Early assessment of fatigue during hospitalization and monitoring post-discharge are crucial for identifying high-risk groups and implementing targeted interventions to alleviate symptoms.

4.2. Cross-lag regression paths

4.2.1. The pretest depression could positively predict post-test fatigue

While previous studies have shown a strong association between depression and fatigue, few have examined their causal relationship. Our study found that pretest depression in patients with multivessel coronary disease can positively predict post-test fatigue status; specifically, higher depression levels correlate with greater fatigue severity. This finding can guide healthcare professionals in preventing and managing fatigue. The theory of unpleasant symptoms suggests individuals may experience one or more symptoms simultaneously, each with varying degrees of severity. A single symptom may significantly impair an individual's functioning, and some symptoms may also serve as catalysts for the development and persistence of other symptoms [40]. Our study found that to prevent the exacerbation of fatigue, it is essential to address and reduce their levels of depression at an early stage. This proactive approach can help mitigate the compounded effects of both depression and fatigue, preventing depression from acting as a catalyst for the onset and persistence of fatigue symptoms. In addition, our findings align with Zhuang et al. [41], showing that pretest depression significantly and positively predicted post-test self-regulatory fatigue. Fatigue can hinder patients' ability to manage daily activities and may lead to feelings of powerlessness in their rehabilitation. This emotional state negatively affects mental health and daily life. Based on these findings, we recommend that healthcare professionals evaluate depressive symptoms upon hospitalization. For patients with significant depression, a psychological evaluation should confirm these symptoms, followed by targeted counseling and emotional support. Furthermore, educating patients on recognizing and managing depressive symptoms is essential, especially for those with multivessel coronary disease, as these symptoms can impact overall health. Early identification and treatment can help effectively manage and reduce fatigue.

4.2.2. The pretest resilience could negatively predict post-test fatigue

Our study demonstrated that the resilience levels of patients with multivessel coronary disease during a previous period can negatively predict their fatigue status in a subsequent period; specifically, a high level of resilience may mitigate the severity of fatigue. An individual's level of resilience may determine their experience of fatigue when confronted with the challenges posed by diseases. This finding aligns with the research conducted by Losoi et al. [42], which demonstrated that resilience is a significant predictor of changes in fatigue one to six months after discharge in patients with mild traumatic brain injury. Additionally, another cohort study indicated that low resilience is associated with an increased risk of persistent fatigue [43]. Patients with higher resilience can quickly adjust their mindset and use active coping strategies, reducing fatigue [44]. However, Our study revealed that while resilience in patients with multivessel coronary disease improved within three months post-discharge, it remained lower than in other studies [45]. This indicates that, despite recovery improvements, these patients did not achieve optimal resilience. Meanwhile, resilience remained stable one month after discharge, suggesting that healthcare professionals should focus on psychological well-being during early hospitalization. Implementing cognitive behavioral interventions, emotional regulation training, and other supportive measures can enhance patients' resilience [45], helping patients develop a positive outlook and improve coping abilities, ultimately reducing fatigue. Further research on resilience mechanisms in patients with multivessel coronary disease is crucial for effective nursing strategies.

4.2.3. Resilience moderates the relationship between depression and fatigue

Our study indicates that resilience plays a moderating role in the relationship between depression and fatigue in patients with multivessel disease. Specifically, higher resilience levels significantly reduce the negative impact of depression on fatigue, suggesting that resilience buffers these adverse effects. Resilience is regarded as a valuable coping resource that enables individuals to adapt effectively in the face of adversity and mitigate the impact of negative emotions on their health [46]. Those with higher resilience are better at regulating emotions and reducing emotional exhaustion associated with depression. Previous studies have demonstrated that highly resilient individuals exhibit positive cognitive and emotional regulation [47], which buffers negative risk factors and aids recovery from their effects [48]. High resilience in patients promotes the use of social support and health-promoting behaviors, mitigating fatigue from resource loss. It allows patients to confront stressors related to depression, transforming psychological burdens into motivation for personal growth and reducing fatigue. Furthermore, resilience may diminish the physiological and psychological effects of depression on fatigue by strengthening social support and coping resources. This finding underscores the pivotal role of resilience, indicating that fatigue can be alleviated by fostering and enhancing resilience among patients in nursing practice, particularly in high-risk groups exhibiting depressive symptoms. Healthcare professionals can implement targeted interventions, provide resilience training, and organize support groups to share coping experiences. These efforts can foster a positive environment for rehabilitation, further enhance patients' resilience, and alleviate fatigue.

4.3. Implication of nursing practice

Healthcare professionals should evaluate patients' mental states, emphasizing depression screening and resilience assessment to identify those at high risk for fatigue. Our study found that depression significantly predicts fatigue in patients with multivessel coronary disease, highlighting the necessity of addressing depression in fatigue interventions. Nursing staff should assist patients with depressive symptoms in managing negative emotions through cognitive behavioral therapy or supportive counseling, indirectly reducing fatigue. Furthermore, a multidisciplinary approach combining psychotherapy and pharmacotherapy can improve patients' psychological well-being and alleviate fatigue.

Resilience directly mitigates fatigue and moderates the adverse effects of depression on fatigue, suggesting new nursing intervention strategies. As a vital psychological resource, resilience helps patients cope with stress and negative emotions, alleviating fatigue symptoms. This can be achieved through mindfulness therapy, emotional regulation training, and participation in support groups or family activities. Strengthening psychological resources and adaptability to stress can reduce fatigue and enhance overall quality of life.

5. Study strengths and limitations

Our study presents several significant advantages. Firstly, it focuses on a cohort of patients with multivessel coronary disease, allowing us to understand both the positive and negative psychological changes experienced by this population. Secondly, we investigated the temporal causal relationships among depression, resilience, and fatigue, identifying a moderating effect of resilience on the relationship between depression and fatigue. However, there are limitations to consider when interpreting our findings and conducting further research. Firstly, the study relied entirely on self-reported measures, possibly leading to spurious associations. Future research should employ additional methods, such as clinical interviews, to assess key variables. Secondly, our small sample size was limited to hospitals in Tangshan, China. Future studies should include larger samples and a broader range of regions to validate our results. Thirdly, our study examined changes in depression, resilience, and fatigue only within three months post-discharge, limiting the ability to determine causal relationships accurately. Future research should extend the follow-up period to assess the stability of findings and identify trends. Most importantly, unmeasured confounding variables, such as sleep quality, social support, and illness severity, may influence these variables and were not controlled for in this study. Future research should incorporate these variables to explore the mechanisms underlying these relationships.

6. Conclusions

In conclusion, our study examined the prospective associations among depression, resilience, and fatigue in patients with multivessel coronary disease using cross-lag analysis. The results indicate that pretest depression and resilience significantly predict post-test fatigue severity, with resilience mediating the negative effects of depression on fatigue. These findings highlight the importance of reducing depressive symptoms and enhancing resilience early to prevent fatigue. Future research should extend follow-up periods and include diverse patient populations to enhance generalizability.

Data availability statement

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

CRediT authorship contribution statement

Binbin Sun: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing. **Jing Han:** Conceptualization, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Beibei Tian:** Conceptualization, Methodology, Validation, Investigation, Data curation, Writing - original draft. **Yuexuan Xu:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft. **Jin Wang:** Conceptualization, Methodology, Validation, Supervision, Writing - original draft, Writing - review & editing. **Jianhui Wang:** Conceptualization, Methodology, Validation, Supervision, Writing - original draft, Writing - review & editing, Project administration.

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Declaration of competing interest

The authors declare that they have no competing interests.

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2025.02.009.

References

[1] Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study. J Am Coll Cardiol 2020;76(25):2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010.

[2] He WF, Jiang L, Chen YY, Liu YH, Chen PY, Duan CY, et al. The association of baseline N-terminal pro-B-type natriuretic peptide with short and long-term prognosis following percutaneous coronary intervention in non-ST segment elevation acute coronary syndrome with multivessel coronary artery disease: a retrospective cohort study. BMC Cardiovasc Disord 2021;21(1):202. https://doi.org/10.1186/s12872-021-02010-9.

[3] Zimbardo G, Cialdella P, Di Fusco P, Donahue ME, D'Aquino UML, Paolucci L, et al. Acute coronary syndromes and multivessel coronary artery disease. Eur Heart J Suppl 2023;25(Suppl C):C74–8. https://doi.org/10.1093/eurheartj-supp/suad010.

[4] Mi Q, Wang JQ, Yan J. The role of two-dimensional speckle tracking echocardiography in evaluating left ventricular function of patients with multivessel coronary artery disease. J Chin Physician 2019;21(3):401–5. https://doi.org/10.3760/cma.j.issn.1008-1372.2019.03.020 [in Chinese].

[5] Walters SJ, Stern C, Stephenson M. Fatigue and measurement of fatigue: a scoping review protocol. JBI Database Syst Rev Implement Rep 2019;17(3):261–6. https://doi.org/10.11124/JBISRIR-2017-003699.

[6] Ai AL, Wink P, Shearer M. Fatigue of survivors following cardiac surgery: positive influences of preoperative prayer coping. Br J Health Psychol 2012;17(4):724–42. https://doi.org/10.1111/j.2044-8287.2012.02068.x.

[7] Gecaite-Stonciene J, Bunevicius A, Burkauskas J, Brozaitiene J, Neverauskas J, Mickuviene N, et al. Validation of the multidimensional fatigue inventory with coronary artery disease patients. Int J Environ Res Publ Health 2020;17(21):8003. https://doi.org/10.3390/ijerph17218003.

[8] Bansal R, Gubbi S, Koch CA. COVID-19 and chronic fatigue syndrome: an endocrine perspective. J Clin Transl Endocrinol 2022;27:100284. https://doi.org/10.1016/j.jcte.2021.100284.

[9] Li F, Wang R, Xia RN, Zhou JH, Xiao KJ, Li WH. Assessment tools and influencing factors in fatigue of the patients with coronary heart disease: a literature review of progress in research. Mod Clin Nurs 2022;21(12):82–6. https://doi.org/10.3969/j.issn.1671-8283.2022.12.013 [in Chinese].

[10] Kazukauskiene N, Bunevicius A, Gecaite-Stonciene J, Burkauskas J. Fatigue, social support, and depression in individuals with coronary artery disease. Front Psychol 2021;12:732795. https://doi.org/10.3389/fpsyg.2021.732795.

[11] Ayar K, Kasapoğlu Aksoy M, Dilara Hattatoğlu T, Yeşil B. Depression is the most significant independent predictor of fatigue in patients with primary Sjögren's syndrome. Arch Rheumatol 2022;38(3):375–86. https://doi.org/10.46497/ArchRheumatol.2023.9790.

[12] Eckhardt AL, Devon HA, Piano MR, Ryan CJ, Zerwic JJ. Fatigue in the presence of coronary heart disease. Nurs Res 2014;63(2):83–93. https://doi.org/10.1097/NNR.0000000000000019.

[13] Gong L. Research on predictors of fatigue trajectory in patients with acute myocardial infarction. Huzhou University; 2021 [in Chinese].

[14] Sisto A, Vicinanza F, Campanozzi LL, Ricci G, Tartaglini D, Tambone V. Towards a transversal definition of psychological resilience: a literature review. Medicina 2019;55(11):745. https://doi.org/10.3390/medicina55110745.

[15] Xu SX, Zhou WW, Wang LP, Huang CY. Analysis of situation and influencing factors of self-regulating fatigue in elderly stroke patients. J Nurs Train 2024;39(3):322–6. https://doi.org/10.16821/j.cnki.hsjx.2024.03.018 [in Chinese].

[16] Yuan YQ, Liu CP, Shi W, Wang Y, Chen LP. Trajectory patterns and predictors of cancer-related fatigue in postoperative lung cancer patients receiving chemotherapy. Support Care Cancer 2024;32(8):525. https://doi.org/10.1007/s00520-024-08715-9.

[17] Baattaiah BA, Alharbi MD, Aldhahi MI, Khan F. Factors associated with postpartum fatigue: an exploration of the moderating role of resilience. Front Public Health 2024;12:1394380. https://doi.org/10.3389/fpubh.2024.1394380.

[18] Bitsika V, Sharpley CF, Bell R. The buffering effect of resilience upon stress, anxiety and depression in parents of a child with an autism spectrum disorder. J Dev Phys Disabil 2013;25(5):533–43. https://doi.org/10.1007/s10882-013-9333-5.

[19] Jayakrishnan K, Baruah A, Kumar P, Javeth A. Scales and interventions for resilience among treatment-seeking patients with depression: a systematic review. J Caring Sci 2023;12(2):84–93. https://doi.org/10.34172/jcs.2023.31964.

[20] Hobfoll SE. Conservation of resources. A new attempt at conceptualizing stress. Am Psychol 1989;44(3):513–24. https://doi.org/10.1037//0003-066x.44.3.513.

[21] Abd-Elfattah HM, Abdelazeim FH, Elshennawy S. Physical and cognitive consequences of fatigue: a review. J Adv Res 2015;6(3):351–8. https://doi.org/10.1016/j.jare.2015.01.011.

[22] Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39(2):175–91. https://doi.org/10.3758/bf03193146.

[23] Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med 2001;16(9):606–13. https://doi.org/10.1046/j.1525-1497.2001.016009606.x.

[24] Bian CD, He XY, Qian J, Wu WY, Li CB. The reliability and validity of a modified patient health questionnaire for sereening depressive syndrome ingeneral hospital outpatients. J Tongji Univ 2009;30(5):136–40 [in Chinese].

[25] Campbell-Sills L, Stein MB. Psychometric analysis and refinement of the connor-Davidson resilience scale (CD-RISC): Validation of a 10-item measure of resilience. J Trauma Stress 2007;20(6):1019–28. https://doi.org/10.1002/jts.20271.

[26] Ye ZJ, Ruan XL, Zeng Z, Xie Q, Cheng MH, Peng CH, et al. Psychometric properties of 10-item connor-davidson resilience scale among nursing students. J Nurs 2016;23(21):9–13. https://doi.org/10.16460/j.issn1008-9969.2016.21.009 [in Chinese].

[27] Smets EM, Garssen B, Bonke B, De Haes JC. The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. J Psychosom Res 1995;39(3):315–25. https://doi.org/10.1016/0022-3999(94)00125-o.

[28] Miao Y, Liu XH, Liu ZW, Xie HB, Deng GH. Initial revision of the Chinese version of multidimensional fatigue inventory-20 in medical staff of military basic level. Chin Ment Health J 2008;(9):658–60. https://doi.org/10.3321/j.issn:1000-6729.2008.09.008 [in Chinese].

[29] Chen JY, Chen YD, Han YL. Expert consensus on exercise rehabilitation after percutaneous coronary intervention. Chin J Interventional Cardiol 2016;24(7):361–9. https://doi.org/10.3969/j.issn.1004-8812.2016.07.001 [in Chinese].

[30] Yuan LX, Ding RJ. Interpretation of guidelines for cardiac rehabilitation and secondary prevention in China. Chin Circulation J 2019;34(S1):86–90. https://doi.org/10.3969/j.issn.1000-3614 [in Chinese].

[31] Zhou YQ. The study of anxiety and/or depression before and after percutaneous coronary intervention following up twelve months. Hebei Med University; 2016 [in Chinese].

[32] McDonald RP, Ho MR. Principles and practice in reporting structural equation analyses. Psychol Methods 2002;7(1):64–82. https://doi.org/10.1037/1082-989x.7.1.64.

[33] Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model A Multidiscip J 1999;6(1):1–55. https://doi.org/10.1080/10705519909540118.

[34] Han SS, Li B, Meng SQ, Li YX, Tong WX. Bi-directionality between physical activity within school and fundamental movement skills in school-aged students: a cross-lagged study. Int J Environ Res Publ Health 2022;19(13):7624. https://doi.org/10.3390/ijerph19137624.

[35] Romens SE, Abramson LY, Alloy LB. High and low cognitive risk for depression: stability from late adolescence to early adulthood. Cognit Ther Res 2009;33(5):480–98. https://doi.org/10.1007/s10608-008-9219-5.

[36] Richards D. Prevalence and clinical course of depression: a review. Clin Psychol Rev 2011;31(7):1117–25. https://doi.org/10.1016/j.cpr.2011.07.004.

[37] Beck AT. The evolution of the cognitive model of depression and its neurobiological correlates. Am J Psychiatr 2008;165(8):969–77. https://doi.org/10.1176/appi.ajp.2008.08050721.

[38] Bonanno GA, Wortman CB, Lehman DR, Tweed RG, Haring M, Sonnega J, et al. Resilience to loss and chronic grief: a prospective study from preloss to 18-months postloss. J Pers Soc Psychol 2002;83(5):1150–64. https://doi.org/10.1037//0022-3514.83.5.1150.

[39] Sihvola S, Kuosmanen L, Kvist T. Resilience and related factors in colorectal cancer patients: a systematic review. Eur J Oncol Nurs 2022;56:102079. https://doi.org/10.1016/j.ejon.2021.102079.

[40] Lee SE, Vincent C, Finnegan L. An analysis and evaluation of the theory of unpleasant symptoms. ANS Adv Nurs Sci 2017;40(1):E16–39. https://doi.org/10.1097/ANS.0000000000000141.

[41] Zhuang AX, Liu ML. Cross-lag study of self-regulated fatigue, depression and short video use among left-behind children in rural middle schools. Chin J Health Psychol 2024;32(1):92–6. https://doi.org/10.13342/j.cnki.cjhp.2024.01.017 [in Chinese].

[42] Losoi H, Wäljas M, Turunen S, Brander A, Helminen M, Luoto TM, et al. Resilience is associated with fatigue after mild traumatic brain injury. J Head Trauma Rehabil 2015;30(3):E24–32. https://doi.org/10.1097/HTR.0000000000000055.

[43] König BH, van Jaarsveld CH, Bischoff EW, Schers HJ, Lucassen PL, Olde Hartman TC. Prognostic factors for persistent fatigue after COVID-19: a prospective matched cohort study in primary care. Br J Gen Pract 2023;73(730):e340–7. https://doi.org/10.3399/BJGP.2022.0158.

[44] Heathcote K, Sun J, Horn Z, Gardiner P, Haigh R, Wake E, et al. Caregiver resilience and patients with severe musculoskeletal traumatic injuries. Disabil Rehabil 2021;43(16):2320–31. https://doi.org/10.1080/09638288.2019.1698662.

[45] Cardi V, Albano G, Gentili C, Sudulich L. The impact of emotion regulation and mental health difficulties on health behaviours during COVID-19. J Psychiatr Res 2021;143:409–15. https://doi.org/10.1016/j.jpsychires.2021.10.001.

[46] Gill W. What is resilience? A review and concept analysis. Rev Clin Gerontol 2011;21(2):152–69. https://doi.org/10.1017/s0959259810000420.

[47] Min JA, Yu JJ, Lee CU, Chae JH. Cognitive emotion regulation strategies contributing to resilience in patients with depression and/or anxiety disorders. Compr Psychiatry 2013;54(8):1190–7. https://doi.org/10.1016/j.comppsych.2013.05.008.

[48] Masten AS. Resilience in children threatened by extreme adversity: frameworks for research, practice, and translational synergy. Dev Psychopathol 2011;23(2):493–506. https://doi.org/10.1017/S0954579411000198.