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Research Paper

Effects of the hospital-community-family trinity cardiac rehabilitation on patients with acute myocardial infarction after percutaneous coronary intervention: A randomized trial

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ABSTRACT

Objectives: This study aimed to develop a hospital-community-family trinity cardiac rehabilitation (CR) intervention program and assess its' effects on patients with acute myocardial infarction (AMI) after percutaneous coronary intervention (PCI).

Methods: Between April 2022 and April 2023, patients who had experienced AMI after PCI were enrolled. These patients were randomly assigned to an intervention group (IG) or a control group (CG) in equal numbers. The CG received standard CR, while the IG participated in the advanced trinity CR program in addition to the standard CR. Key parameters measured included the anaerobic threshold (AT), maximum oxygen uptake (VO2max), maximum exercise load (MEL), metabolic equivalent (MET), left ventricular ejection fraction (LVEF), left ventricular end-systolic volume (LVESV), left ventricular end-diastolic volume (LVEDV), and quality of life (measured by the SF-36). These were assessed pre-intervention and at 3, 6, 9, and 12 months post-intervention. SPSS.26 was employed for data analysis, with statistical methods such as repeated measures analysis of variance (ANOVA), Chi-square tests, and independent sample *t*-tests.

Results: A total of 110 patients completed the intervention, 55 in each group. There was no significant difference in the scores of all indicators between the two groups before intervention ($P > 0.05$). However, at 3, 6, 9 and 12 months after intervention, the scores of AT, VO2max, MEL, MET, LVEDV, LVESV, LVEF, and quality of life in the intervention group were higher than those in the control group, there was statistical significance at four-time points, group, time, and interaction effect ($P < 0.05$).

Conclusions: The hospital-community-family trinity CR intervention program developted in this study significantly improved exercise endurance, cardiac function, and quality of life in patients with AMI after PCI.

What is know?

- Cardiac rehabilitation is considered a vital component of ongoing treatment for patients with cardiovascular diseases.
- Research focusing on hospital-community-family trinity cardiac rehabilitation for patients with acute myocardial infarction after percutaneous coronary intervention has not been reported.
- The main goal of cardiac rehabilitation is to restore patients' physiological and psychological functions, thereby improving their overall quality of life.

What is new?

- This study introduced a novel program of cardiac rehabilitation for patients with acute myocardial infarction after post-percutaneous coronary intervention, which is essential for developing and implementing rehabilitation interventions for those with coronary artery disease.
- The hospital-community-family trinity cardiac rehabilitation is safe, feasible, and effective, enhancing exercise endurance, cardiac function, and overall quality of life.

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1. Introduction

Acute myocardial infarction (AMI) is characterized by the necrosis of cardiomyocytes, a condition precipitated by inadequate coronary blood supply and subsequent ischemia of the heart muscle [1]. Recent studies have indicated an alarming trend towards younger populations being increasingly affected by AMI [2,3]. In China, AMI represents the predominant cause of mortality associated with coronary heart disease [4,5]. Percutaneous coronary intervention (PCI) is the treatment of choice for AMI, effectively removing obstructions in blood vessels to restore myocardial blood flow, thereby mitigating the damage to cardiomyocytes caused by ischemia and hypoxia [6,7]. However, the completion of PCI does not mark the cessation of treatment. In the post-acute phase, lifestyle factors and cardiovascular risk factors may expedite coronary restenosis, potentially precipitating recurrent angina or further myocardial infarctions, thus adversely impacting patient prognosis [8]. Therefore, cardiac rehabilitation (CR) is critical for the ongoing care of individuals with cardiovascular diseases.

CR encompasses various rehabilitative activities that draw upon multiple disciplines and methodologies. It offers sustained and personalized interventions for individuals diagnosed with cardiovascular disease, addressing cardiovascular risk factors, exercise therapy, pharmacological treatment, psychological support, patient education, and ongoing follow-up. The primary objectives of CR are to enhance both the physiological and psychological well-being of patients, mitigate cardiovascular morbidity and mortality, and ultimately improve the overall quality of life [9]. CR has demonstrated efficacy in managing risk factors linked to cardiovascular disease, improving patients' physical condition through behavioral changes, reducing the incidence of adverse events, and potentially slowing or reversing disease progression [10,11].

With a history extending over two centuries, CR has seen considerable advancement in the last fifty years. Around 54.7% of countries globally, predominantly middle- and high-income nations, have implemented CR programs. In the United States, CR has been incorporated into the clinical medical care quality evaluation system, and in Germany, health insurance policies require patient participation in CR. Multiple leading European and American cardiology organizations have also classified CR as a Class I recommendation for preventing and managing cardiovascular diseases [12].

The evolution of CR in China has been ongoing since its introduction in the early 1980s. At the dawn of the 21st century, Professor Hu [13] outlined the core components of CR, comprising five key prescriptions. Supported by relevant national policies and the concerted efforts of medical professionals, the guidelines for CR and secondary prevention were published in 2018 in China, laying a robust foundation for the implementation of CR [14]. The guidelines indicate that CR encompasses three phases: stage I (in-hospital rehabilitation), stage II (early rehabilitation outside the hospital or outpatient rehabilitation), and stage III (long-term community or family rehabilitation). In China, two prevalent models of CR are employed: regular outpatient CR and extended care beyond hospital settings. Nevertheless, ensuring the effectiveness and sustainability of CR programs poses challenges, primarily due to reliance on patient or caregiver initiative for follow-up. A lack of awareness about CR and insufficient social support are commonly cited barriers to participation in these programs [15]. To improve participation and adherence and to provide patients with professional rehabilitation plans, it is imperative that CR extends into community settings, involving families and caregivers.

Compared to traditional outpatient CR and extended care outside of the hospital, community-family CR transfers the rehabilitation process into the patients' living environments. This model reduces the demand for hospital-based rehabilitation services and bolsters the implementation of tiered diagnosis and treatment but also capitalizes on the accessibility of community health service centers. As a result, it enhances the delivery of CR and improves patients' capabilities in managing their health. Community-family CR is a hybrid approach synthesizing hospital-centered, community-based, and family-oriented care [16]. Patients receive initial evaluations and health education for CR while hospitalized, participate in early rehabilitation under professional supervision, and, following discharge, continue their rehabilitation within community and family settings under self-supervision. This model is distinguished by its convenient transportation, reduced medical costs, stable patient population, and simplified follow-up procedures. As a result, the coordination between hospitals, communities, and families is crucial for the CR of patients with coronary heart disease. This approach leverages the strengths of each setting, minimizes disruptions in patients' rehabilitation treatments, and enhances the long-term outcomes of CR.

Improving exercise tolerance is a fundamental goal of CR. Regular physical activity increases maximal oxygen uptake (VO2max) and muscular strength, which helps patients perform daily activities more efficiently and reduces the limitations imposed by cardiac conditions [17]. Through structured exercise training and risk factor management, CR can enhance cardiac function, decrease myocardial oxygen demands, improve endothelial function, and reduce cardiovascular risk [18]. Beyond physical improvements, CR also focuses on psychological and social support, helping patients achieve better mental health and emotional well-being, decrease anxiety and depression, enhance self-efficacy, and ultimately improve their quality of life [19]. Extensive clinical Research has shown that CR significantly enhances exercise tolerance, cardiac function, and overall quality of life [20].

This study aimed to develop a comprehensive hospital-community-home trinity CR intervention program and evaluated its effects on exercise endurance, cardiac function, and quality of life.

2. Methods

2.1. Study design

This study was a randomized parallel intervention trial that adhered to the Consolidated Standards of Reporting Trials (CONSORT) checklist [21].

2.2. Participants and settings

The participants were recruited from the Department of Cardiology at Xuzhou Central Hospital, Xuzhou, China, between April 2022 and April 2023 and they lived in the Taishan, Heping, and Yunlong communities, which are in cooperation with Xuzhou Central Hospital. The inclusion criteria were as follows: 1) $\geq$ 18 years old; 2) complying with the diagnostic criteria for AMI as defined by the American Heart Association [22]; 3) undergoing PCI for the first time; 4) Killip class $\leq$ III and a left ventricular ejection fraction (LVEF) of $\geq$ 40% after PCI; 5) possessing adequate understanding and communication skills; and 6) providing written informed consent. The exclusion criteria included: 1) incomplete medical records (such as treatment details or medical documentation); 2) coexisting conditions affecting vital organs (such as the liver, brain, lungs, or kidneys) or other significant chronic diseases; 3) a history of major complications (such as stroke, transient ischemic attack, cerebral hemorrhage, or idiopathic syncope); and 4) participation in other CR intervention studies.

2.3. Sample size, randomisation and blinding

Aerobic endurance, a critical cardiovascular health and function indicator, was used to determine the sample size [23]. VO2max, which indicates the maximum capacity of an individual's cardiovascular and respiratory systems to transport and utilize oxygen, is a reliable quantitative measure of aerobic endurance [24]. According to the sample size estimation method for the comparison of two sample means, we established the sample size of the intervention group (IG) and the control group (CG) to be equivalent, using the formula: $2\times[(Z_{\alpha/2}+Z_{\beta})\sigma/\delta]^2$. The Z_{β} value and $Z_{\alpha/2}$ value were 1.28 and 1.96, respectively. Based on a study evaluating the impact of CR on aerobic endurance in myocardial infarction patients in terms of VO2max, the σ/δ ratio was estimated at 1.5 [25]. The calculated sample size required for each group was 47. After accounting for a potential 15% dropout rate during follow-up, the adjusted sample size was approximately 109.

We utilized the Random Number Generator function in the Transform menu of SPSS version 26.0 for randomizing participants, setting a constant seed of 2,000,000 to generate random numbers. The Rv. Uniform function was adopted to yield each participant's random numbers. Subsequently, the participants were divided into two groups of equal size through the Visual Binning function in SPSS based on the generated random numbers. Grouping schemes were placed in opaque envelopes, each labeled with a code on the exterior, sealed, and handed to the researcher. Upon enrollment, participants were assigned sequential numbers. The envelopes corresponding to these numbers were opened, and participants were sorted according to the distribution scheme contained within. Participants were then randomized into either the IG or the CG on a 1:1 basis. Although participants knew their assigned numbers, they were not informed about the specifics of the grouping criteria. The data collection and analysis were conducted by staff who lacked clarity regarding the allocation specifics.

2.4. Interventions

2.4.1. The control group (routine cardiac rehabilitation)

The day after undergoing PCI, hospital nurses initiated CR files for the patients and provided consistent guidance on CR throughout their hospitalization. Evaluations of relevant items were completed on the day of discharge, and CR prescription reports, along with CR clock manuals, were issued. These manuals included schedules for follow-up visits, exercise plans, medication adherence, blood pressure monitoring, dietary advice, and other relevant information. Nurses trained the patients on how to use the CR clock system effectively. Family caregivers were also engaged in rehabilitation education to ensure patients and caregivers were proficient in CR techniques, including monitoring, documentation, and emergency response. The guidance provided during hospital follow-up visits for the CG is summarized in Appendix A.

2.4.2. The intervention group (hospital-community-family trinity cardiac rehabilitation)

Establishing an intervention team: the intervention team consisted of 12 members, including the director of the nursing department at the hospital, the chief nurse of the cardiology department, two cardiology physicians, two cardiology nurses from the hospital, three cardiology physicians from the community, and three community nurses. The director of the nursing department oversaw the project's implementation. The chief nurse coordinated nursing workflows and responsibilities across all nursing staff levels. The hospital's cardiology nurses were pivotal in designing and implementing the study, involving tasks such as literature review, CR program development and revision, organizing expert meetings, data collection, implementing the hospital-community-home CR programs, scheduling follow-up appointments, and conducting community health education. The hospital's cardiology physicians and nurses trained community medical staff, managed outpatient follow-ups, operated community expert workstations, and ensured rehabilitation quality. Community cardiology physicians handled outpatient follow-ups and CR program adjustments and provided medication therapy advice, while community nurses maintained patient records, monitored patients' diet and exercise, and tracked rehabilitation training plan implementation.

Literature review: research databases such as PubMed, Embase, the Cochrane Library, Web of Science, SinoMed, Wanfang, and the China National Knowledge Infrastructure (CNKI) database were employed to gather all pertinent articles using search terms such as "myocardial infarction," "percutaneous coronary intervention," "coronary heart disease," "cardiac rehabilitation," "community-based cardiac rehabilitation," and "home-based cardiac rehabilitation." The search covered the period from each database's inception until February 2022. The literature type is a clinical controlled trial. The literature was chosen and reviewed based on the research topic and category, including six articles [26–31]. A preliminary draft of the hospital-community-family trinity CR program was developed after a comprehensive literature review, relevant guidelines, and expert consensus.

Developing a hospital-community-family CR program: the criteria for expert inclusion were set as follows: 1) clinical, nursing, rehabilitation, psychological experts, and those with expertise in nursing management or education within cardiovascular disease; 2) a minimum of a bachelor's degree with an intermediate or higher professional title; 3) at least ten years of experience in clinical CR work. Twelve experts from relevant fields were invited to provide consultations and evaluate the program, ensuring its scientific validity and practicality. The general data of experts are shown in Appendix A. To test the program's feasibility, ten AMI after PCI patients hospitalized in the Department of Cardiology at Xuzhou Central Hospital were selected for pre-experiment. The inclusion and exclusion criteria used were the same as those above. These ten patients were excluded from the final count of 110 eligible patients. The general data of ten patients are shown in Appendix A. Feedback from these patients, their families, the intervention team, and the expert group led to further adjustments and improvements, culminating in the final draft of the program. The hospital-community-family trinity CR program consists of the following: 1) the intervention team underwent standardized training and evaluations. Subsequently, the team established CR clinics in multiple communities; 2) hospital nurses extended invitations to patients and their family caregivers to participate in the CR WeChat group and the Heals health education platform. On the day of patient discharge, hospital nurses communicated pertinent patient information to the intervention team's WeChat group and informed the associated communities. Community nurses provided patients with information regarding the timing of their follow-up appointments at CR clinics, and the schedule for community health education programs; 3) follow-up visits at the CR clinics were arranged every month over 12 months. Upon the patients' arrival at the CR clinics, community physicians provided medical directives following their consultations. Community nurses reviewed patients' CR clock manuals, recorded any adverse events, adjusted CR prescription reports, and provided health guidance to both patients and their family caregivers. After the follow-up visits, community nurses documented the visit information in the team WeChat group. The responsibility for data evaluation and statistical analysis was subsequently assigned to hospital nurses; 4) health education activities were conducted monthly in communities, consisting of lectures and communication meetings. Hospital nurses notified

patients about the content and schedule of these lectures through the WeChat group and the Heals health education platform one week in advance; 5) patients completed the family CR program according to the CR prescription reports and followed the daily routines outlined in the clock manuals; 6) patients were required to attend four follow-up visits at the hospital at 3, 6, 9, and 12 months following the intervention. Hospital nurses made a phone call one week in advance to prepare for the follow-up visit. As summarized in Appendix A, the IG implemented this refined hospital-community-family trinity CR program.

2.5. Measures

2.5.1. Sociodemographic and clinical data

The participants' sociodemographic and clinical data included age, gender, education level, marital status, household monthly income, smoking status, drinking status, history of diabetes, history of hypertension, and cardiac function classification.

2.5.2. Exercise tolerance

The exercise tolerance indicators include the aerobic threshold (AT), maximum oxygen uptake (VO2max), maximum exercise load (MEL), and metabolic equivalent (MET).

2.5.3. Cardiac function

The cardiac function indicators include left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), and left ventricular ejection fraction (LVEF).

2.5.4. Quality of life

The quality of life was assessed using the Short Form 36-Item Health Survey Questionnaire (SF-36), which includes domains such as physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH) [32]. Responses to inquiries within each dimension are aggregated and converted to produce dimension scores ranging from 0 to 100. A score of 0 signifies the lowest level of functioning, while a score of 100 represents the highest level of functioning, and a score of 50 denotes the average level of functioning. A higher score on the SF-36 indicates an improved quality of life. Cronbach's α coefficient was calculated to evaluate the internal consistency and reliability of the test scores, with values greater than 0.7 indicating good reliability. The SF-36 showed good reliability, as indicated by Cronbach's α coefficient in Appendix A.

2.6. Data collection

Cardiopulmonary exercise tests were administered to patients using the Scheler CARDIOV IT AT-104PC system, and measurements including the AT, VO2max, MEL, and MET, were recorded. Measurements of LVEDV, LVESV, and LVEF were conducted using a Philips GK5500 cardiac color Doppler ultrasound system (Philips Healthcare, Amsterdam, The Netherlands). The quality of life was assessed using the SF-36. All data before the intervention were collected before the discharge. Post-intervention data were gathered during four follow-up appointments at the hospital, occurring at 3, 6, 9, and 12 months after the intervention. Data was collected by the hospital's cardiology nurses, who were part of the intervention team. The hospital's cardiology nurses gathered the post-intervention data following the patient's arrival at the hospital to undergo the requisite testing. To ensure data quality, the data collectors (the hospital's cardiology nurses) were trained before data collection. Parallel double data entry was conducted to ensure accurate data entry, and matching would be conducted after inconsistent data had been reviewed.

2.7. Data analyses

Analyses were performed using IBM SPSS Statistics. The Kolmogorov-Smirnov test was applied to evaluate normality. Categorical data were expressed as number (n) and percentage (%), normally distributed continuous data as means and standard deviation (SD), and non-normally distributed as means and interquartile range (IQR). For normally distributed Categorical data that met the homogeneity of variances assumption, the t-test was employed. The Mann–Whitney U rank-sum test was utilized for non-normally distributed data. Comparisons of categorical data between groups were conducted using the chi-square (χ^2) test. Mauchly's sphericity test was performed for normally distributed continuous data that satisfied the homogeneity of variances assumption. Continuous data meeting the assumption of sphericity were analyzed using repeated-measures ANOVA to evaluate the main effects of the variables "group" and "time" (considering repeated measures), as well as their interaction (group×time). Where the assumption of sphericity was violated, the Greenhouse-Geisser correction was applied. Statistical tests were two-sided, with a significance threshold set at a $P < 0.05$.

2.8. Ethics considerations

This study received approval from the Ethics Committee of the Central Hospital of Xuzhou (No. XZXY-LJ-20220402-003), and all participants provided informed consent before their involvement.

3. Results

3.1. Recruitment and characteristics of the participants

The recruitment, allocation, and dropout processes for participants were documented in Appendix B. Amongst the 280 patients, 106 were not eligible, and 64 declined to participate. Ultimately, 110 eligible patients consented to participate and were randomly assigned to either the IG ($n = 55$) or the CG ($n = 55$). The intervention lasted 12 months, and no patients were lost to follow-up in each group. The IG included 18 women and 37 men, with an average age of 58.69 ± 9.46 years. The CG comprised 19 women and 36 men, with an average age of 59.52 ± 8.78 years. The sociodemographic and clinical data of the participants are shown in Appendix A. The differences in characteristics between groups were not statistically significant ($P > 0.05$).

3.2. Comparison of exercise tolerance and cardiac function between two groups

The independent t-test results demonstrate that the differences between the two groups in exercise tolerance and cardiac function indices were not statistically significant before intervention ($P > 0.05$). Still, at 3, 6, 9, and 12 months post-intervention were all statistically significant ($P < 0.05$). One-way repeated ANOVA showed a significant difference in AT, VO2max, MEL, MET, LVEDV, LVESV, and LVEF with intervention time for both groups ($P < 0.05$). The two-way repeated measures ANOVA results indicated statistically significant differences between the two groups over time, across groups, and in their interaction for the variables AT, VO2max, MEL, MET, LVEDV, LVESV, and LVEF ($P < 0.05$). The detailed results are presented in Table 1. Trend analyses of exercise tolerance and cardiac function indices before and after the intervention showed that AT, VO2max, MEL, MET, LVEDV, LVESV, and LVEF improved as the intervention duration increased (Appendix B).

Table 1
Comparison of the indicators of exercise tolerance and cardiac function between two groups ($n = 110$).

Variables	Group	Before intervention	After intervention				One-way repeated-measures ANOVA		Two-way repeated-measures ANOVA					
			3 months	6 months	9 months	12 months	*F*	*P*	Group		Time		Time×Group	
									F	*P*	*F*	*P*	*F*	*P*
AT (mL/kg/min)	CG	11.96 ± 2.49	13.25 ± 1.19	14.18 ± 1.30	15.08 ± 1.24	15.97 ± 1.34	375.763	<0.001	6.479	0.012	1,096.326	<0.001	31.905	<0.001
	IG	11.79 ± 2.51	13.76 ± 1.25	14.88 ± 1.22	16.15 ± 1.36	17.52 ± 1.37	754.890	<0.001						
	t	0.358	−2.195	−2.924	−4.327	−6.019								
	P	0.721	0.030	0.004	<0.001	<0.001								
VO2 max (mL/kg/min)	CG	14.75 ± 2.18	15.73 ± 2.20	16.54 ± 2.06	18.20 ± 2.27	19.24 ± 2.19	991.694	<0.001	23.611	<0.001	3,655.297	<0.001	270.255	<0.001
	IG	14.62 ± 2.20	16.93 ± 2.13	19.07 ± 2.10	20.94 ± 1.67	22.29 ± 1.52	2,992.959	<0.001						
	t	0.312	−2.912	−6.379	−7.228	−8.505								
	P	0.756	0.004	<0.001	<0.001	<0.001								
MEL (W)	CG	113.62 ± 21.64	118.47 ± 21.52	126.43 ± 22.24	131.46 ± 24.21	139.16 ± 24.34	289.522	<0.001	7.537	0.007	1,387.285	<0.001	93.870	<0.001
	IG	114.44 ± 21.56	128.55 ± 21.77	139.67 ± 23.30	148.81 ± 25.35	157.28 ± 23.97	1,709.059	<0.001						
	t	−0.199	−2.443	−3.049	−3.671	−3.935								
	P	0.843	0.016	0.003	<0.001	<0.001								
MET (mL/kg/min)	CG	6.86 ± 1.16	7.12 ± 1.46	7.65 ± 1.39	8.26 ± 1.28	9.07 ± 1.16	840.330	<0.001	70.989	<0.001	4,914.674	<0.001	923.965	<0.001
	IG	6.87 ± 1.28	8.69 ± 1.37	10.09 ± 1.29	11.24 ± 1.26	12.27 ± 1.21	5,187.040	<0.001						
	t	−0.044	−5.817	−9.576	−12.354	−14.217								
	P	0.965	<0.001	<0.001	<0.001	<0.001								
LVEDV (mL)	CG	104.63 ± 15.32	97.97 ± 19.21	96.34 ± 19.41	94.90 ± 17.07	93.35 ± 17.41	136.492	<0.001	4.759	0.031	422.485	<0.001	48.000	<0.001
	IG	105.11 ± 20.29	89.57 ± 20.10	87.17 ± 18.00	85.26 ± 15.99	83.58 ± 14.11	288.324	<0.001						
	t	−0.140	2.241	2.570	3.057	3.234								
	P	0.889	0.027	0.012	0.003	0.002								
LVESV (mL)	CG	51.72 ± 5.76	47.22 ± 5.08	46.47 ± 5.41	45.96 ± 5.12	45.35 ± 5.72	514.500	<0.001	6.366	0.013	1,420.435	<0.001	34.637	<0.001
	IG	51.59 ± 5.46	45.13 ± 5.16	44.28 ± 4.85	43.71 ± 4.98	43.01 ± 4.35	935.408	<0.001						
	t	0.122	2.143	2.237	2.339	2.417								
	P	0.903	0.034	0.027	0.021	0.017								
LVEF (%)	CG	49.64 ± 5.68	51.41 ± 4.89	52.37 ± 5.33	53.46 ± 5.11	55.14 ± 5.63	228.722	<0.001	9.345	0.003	1,173.840	<0.001	98.765	<0.001
	IG	50.06 ± 5.03	53.96 ± 4.77	55.66 ± 5.28	57.62 ± 5.06	59.88 ± 5.78	1,419.362	<0.001						
	t	−0.411	−2.771	−3.255	−4.294	−4.360								
	P	0.682	0.007	0.002	<0.001	<0.001								

Note: Data are *Mean* ± *SD*. AT = Aerobic threshold. VO2max = Maximum oxygen uptake. MEL = Maximum exercise load. MET = Metabolic equivalent. LVEDV = Left ventricular end-diastolic volume. LVESV = Left ventricular end-systolic volume. LVEF = Left ventricular ejection fraction. CG = Control group. IG = Intervention group.

3.3. Comparison of quality of life between two groups

The differences between the two groups in quality of life scores were not statistically significant before intervention ($P > 0.05$). However, at 3, 6, 9, and 12 months post-intervention were all statistically significant ($P < 0.05$). The two-way repeated measures ANOVA results revealed statistically significant differences in the PF, RP, BP, GH, VT, SF, RE, and MH scores between the two groups concerning time, group, and their interaction ($P < 0.05$). These results are presented in Table 2. Variation trends in quality of life scores between both groups before and after the intervention indicated an upward trend in scores for PF, RP, BP, GH, VT, SF, RE, and MH as the duration of the intervention increased (Appendix B).

4. Discussion

A systematic and scientific methodology marks the development of this intervention program, and its content is particularly comprehensive. This intervention program is categorized as a continuous care model, with the primary objective of aiding patients in reintegration into their communities or families while ensuring that they receive professional care post-discharge. This intervention program compensates for the disadvantages, such as the inadequate ability of family caregivers and simple regular follow-ups in hospitals. Consequently, it improved integration among hospitals, communities, and families, thereby providing standardized and professional rehabilitation guidance for patients. This intervention program is a research-based initiative to address home care requirements following hospital discharge.

4.1. Effects of the hospital-community-family trinity CR on exercise tolerance

The fundamental role of physical exercise involves the synergistic interaction between the cardiovascular and respiratory systems to accommodate the increased oxygen demands during muscular activity. These interactions can significantly impact exercise endurance, which is closely associated with cardiac function and the performance of the autonomic nervous system [33]. The cardiopulmonary exercise test, a diagnostic tool designed to evaluate the respiratory and cardiovascular responses to exercise, precisely measures a patient's exercise endurance [34]. Research conducted by Choi et al. [35] supports the notion that CR is both safe and crucial for patients with myocardial infarction, demonstrating that participants in CR programs exhibit enhanced cardiopulmonary fitness compared to non-participants. Our study observed similar trends in the indices of exercise tolerance, including AT, VO2max, MET, and MEL. These indices showed an upward trajectory as the intervention period progressed, aligning with the findings of Choi et al. Initially, the two groups had no significant differences in exercise tolerance. However, significant improvements were noted at 3, 6, 9, and 12 months post-intervention, with the IG showing superior AT, VO2max, MEL, and MET values compared to the CG. These results suggest that the enhancement in exercise tolerance observed in the IG was more pronounced than in the CG following the intervention. A key factor contributing to this outcome is the targeted exercise training within the hospital-community-family trinity CR framework, particularly under the guidance and supervision of specialized intervention personnel. This training facilitates the redistribution of blood throughout the body, enhances the relaxation of vascular endothelial cells, and modulates oxidase activity to improve cardiac

Table 2
Comparison of the scores for quality of life between groups ($n = 110$).

Variables	Group	Before intervention	After intervention				One-way repeated-measures ANOVA		Two-way repeated-measures ANOVA					
			3 months	6 months	9 months	12 months	*F*	*P*	Group		Time		Time×Group	
									F	*P*	*F*	*P*	*F*	*P*
PF	CG	66.67 ± 10.05	67.29 ± 10.33	58.56 ± 11.54	69.26 ± 9.56	69.73 ± 7.42	17.593	<0.001	7.180	0.009	155.939	<0.001	44.087	<0.001
	IG	67.47 ± 11.83	71.56 ± 10.60	73.13 ± 8.07	76.71 ± 8.26	77.55 ± 10.87	188.649	<0.001						
	t	−0.382	−2.141	−2.404	−4.376	−4.407								
	P	0.703	0.035	0.018	<0.001	<0.001								
RP	CG	51.21 ± 10.64	51.82 ± 10.96	53.75 ± 8.02	54.71 ± 9.11	55.91 ± 11.20	54.344	<0.001	6.002	0.016	296.333	<0.001	25.288	<0.001
	IG	53.42 ± 9.80	56.11 ± 10.56	58.93 ± 10.63	60.16 ± 10.01	62.33 ± 10.61	425.145	<0.001						
	t	−1.137	−2.091	−2.886	−2.988	−3.086								
	P	0.258	0.039	0.005	0.003	0.003								
BP	CG	56.44 ± 13.11	56.86 ± 11.79	57.44 ± 10.64	57.80 ± 9.58	58.62 ± 10.78	8.655	<0.001	4.405	0.038	156.61	<0.001	77.092	<0.001
	IG	54.77 ± 8.14	61.87 ± 10.22	62.82 ± 9.79	63.66 ± 9.17	64.49 ± 9.59	284.401	<0.001						
	t	0.804	−2.385	−2.760	−3.273	−3.019								
	P	0.424	0.019	0.007	0.001	0.003								
GH	CG	59.70 ± 10.43	60.51 ± 10.46	61.15 ± 10.81	61.64 ± 9.88	62.36 ± 9.19	22.568	<0.001	9.014	0.003	198.681	<0.001	63.745	<0.001
	IG	61.64 ± 9.84	65.31 ± 9.46	66.86 ± 9.83	68.67 ± 10.29	71.51 ± 10.93	208.925	<0.001						
	t	−1.006	−2.525	−2.898	−3.658	−4.749								
	P	0.317	0.013	0.005	<0.001	<0.001								
VT	CG	66.77 ± 10.63	67.55 ± 10.83	68.46 ± 10.87	69.02 ± 10.13	69.98 ± 10.20	33.788	<0.001	9.442	0.003	399.674	<0.001	135.347	<0.001
	IG	67.56 ± 9.87	72.76 ± 10.87	74.93 ± 10.04	76.98 ± 10.28	79.87 ± 10.73	538.974	<0.001						
	t	−0.409	−2.523	−3.245	−4.093	−4.955								
	P	0.683	0.013	0.002	<0.001	<0.001								
SF	CG	71.14 ± 6.11	71.06 ± 8.90	72.13 ± 9.59	73.66 ± 8.88	74.58 ± 11.97	22.554	<0.001	4.588	0.034	127.504	<0.001	35.336	<0.001
	IG	69.94 ± 6.53	75.42 ± 11.25	76.84 ± 8.78	78.62 ± 10.51	80.91 ± 12.07	130.016	<0.001						
	t	0.995	−2.256	−2.686	−2.675	−2.761								
	P	0.322	0.026	0.008	0.009	0.007								
RE	CG	71.94 ± 10.50	72.18 ± 9.13	72.82 ± 9.35	73.22 ± 9.65	74.33 ± 9.87	20.600	<0.001	4.308	0.040	223.919	<0.001	109.176	<0.001
	IG	69.95 ± 8.83	77.20 ± 9.39	77.98 ± 9.89	78.66 ± 9.14	79.71 ± 11.21	288.714	<0.001						
	t	1.071	−2.843	−2.813	−3.034	−2.672								
	P	0.286	0.005	0.006	0.003	0.009								
MH	CG	63.14 ± 10.47	63.86 ± 9.75	64.62 ± 9.30	65.71 ± 9.28	66.69 ± 8.95	29.983	<0.001	15.129	<0.001	579.777	<0.001	240.163	<0.001
	IG	64.09 ± 8.91	68.15 ± 9.65	70.67 ± 9.61	75.04 ± 9.73	81.09 ± 9.98	1,032.243	<0.001						
	t	−0.520	−2.320	−3.358	−5.144	−7.966								
	P	0.604	0.022	0.001	<0.001	<0.001								

Note: Data are *Mean* ± *SD*. PF = Physical functioning. RP = Role physical. BP = Bodily pain. GH = General health. VT = Vitality. SF = Social functioning. RE = Role emotional. MH = Mental health. CG = Control group. IG = Intervention group.

contractility. Additionally, it can augment oxygen uptake and the oxidative capacity of myocardial cells, thereby enhancing both oxygen acquisition and output capabilities [36,37]. Such improvements can alleviate stress on the sympathetic nervous system and enhance parasympathetic regulation of the heart. Ultimately, this leads to improved autonomic nerve function and motor capabilities [38].

4.2. Effects of the hospital-community-family trinity CR on cardiac function

Research conducted by Zhao et al. [39] demonstrated that a joint model of continuous care, incorporating family doctor involvement in in-home rehabilitation (termed the hospital-community-family trinity), led to superior outcomes in cardiac function recovery compared to routine CR. In our study, at 3, 6, 9, and 12 months post-intervention, indices such as LVEDV, LVESV, and LVEF in the IG were significantly better than those in the CG. These indices showed an upward trend with the duration of the intervention, suggesting that the hospital-community-family trinity CR effectively enhances cardiac function. This model extends nursing care continuously from the hospital to the patient's home, overcoming traditional limitations of nursing services. Medical and nursing personnel can closely monitor the patient's recovery progress through daily interactions, including follow-up visits and health education initiatives. They also promote physical activity, ensure adherence to a healthy diet, and address psychological concerns. Moreover, this approach encourages family members to participate actively in the daily care of patients, fostering a collaborative role in the recovery process. This multidimensional and multilevel approach to cardiac care facilitates the development of a disease knowledge framework for patients with AMI, enhances their awareness and focus regarding the condition, and fosters improved self-management capabilities through cognitive transformation [40]. Research indicates that the execution of CR's exercise regimen is significantly associated with individual self-management practices [41]. Enhancing self-management capabilities in patients with AMI can be achieved through cognitive modifications in conjunction with CR efforts, which can enhance systemic blood circulation and metabolism, increase coronary blood flow, inhibit the release of substances such as adrenaline and catecholamines, and reduce smooth muscle hyperplasia [42]. Consequently, this effectively dilates blood vessels, improves coronary collateral circulation, enhances endothelial function, increases cardiac reserve capacity, inhibits ventricular remodeling, and ultimately improves cardiac function [43].

4.3. Effects of the hospital-community-family trinity CR on quality of life

The notion of quality of life is fundamentally based on an individual's assessment of their health status and their standing within the sociocultural environment in which they reside. This assessment is influenced by their expectations and other dimensions of life that they deem significant [44]. The quality of life encompasses the effects of illness and therapeutic interventions on

an individual's physical, mental, social, and emotional health [45,46]. Numerous tools are available for assessing quality of life, which are commonly utilized in research [47]. CR's ultimate goal is restoring patients' physiological and psychological functions following PCI, enhancing their quality of life. Cao et al. confirmed that the hospital-community-family trinity linkage management model significantly improves patients' quality of life, as measured by the Seattle Angina Questionnaire, after one year of intervention [29]. Our study utilized the SF-36 instrument to evaluate patients' quality of life. PF, RP, BP, GH, VT, SF, RE, and MH scores in the IG were significantly higher than those in the CG after 3, 6, 9, and 12 months of intervention. This further demonstrates the effectiveness of the hospital-community-family trinity CR in enhancing quality of life. The hospital-community-family trinity CR capitalizes on tertiary hospitals' technical expertise while improving community healthcare personnel's CR knowledge and management skills through standardized training and technical assistance. This approach fosters greater trust among patients in community rehabilitation facilities [48]. The exchange of information and reciprocal referrals between tertiary hospitals and community health systems establishes a holistic model for prevention and treatment, offering comprehensive and ongoing management services for patients across various stages of their illnesses [49]. This holistic strategy enhances patients' self-management skills and compliance with treatment protocols, enabling them to more effectively manage their symptoms and regulate their conditions, thereby sustaining an improved quality of life [50,51].

5. Limitations

Firstly, the participants were restricted to one tertiary hospital and a small number of communities due to constraints in human, material, and financial resources, among other factors. Future Research should aim to expand the sample size to improve the representativeness and robustness of the findings. Secondly, the hospital-community-family trinity CR program used in this study is inherently complex, requiring effective integration across hospital, community, and family settings. Future efforts should focus on simplifying the model to improve its applicability and ease of implementation and promotion. Finally, medical staff from both the hospital and community sectors conducted training and follow-up during their rest periods, which may lead to fatigue and decreased enthusiasm. Furthermore, coordination between some patients and their primary caregivers was less than ideal, placing a significant burden on many caregivers. These challenges must be addressed in future applications of the hospital-community-family trinity CR. Plans are underway to enhance collaboration with multiple communities, establish a long-term mechanism, strengthen scientific training, and create opportunities for further research with larger and more diverse sample sizes.

6. Conclusions

Implementing this hospital-community-home trinity CR intervention program in patients with AMI post-PCI has effectively improved exercise endurance, cardiac function, and quality of life. The hospital-community-family trinity CR has demonstrated the potential to facilitate the vertical integration of medical resources and to establish an efficient hierarchical model for diagnosis and treatment. By leveraging tertiary hospitals' technical and managerial expertise, this model allows patients to access comprehensive chronic disease management and enhances healthcare providers' professional knowledge and skills in community settings.

CRediT authorship contribution statement

Ying Zhao: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Yanzhen Yang:** Methodology, Validation, Investigation, Resources, Data curation, Writing – original draft, Project administration. **Lina Chen:** Conceptualization, Formal analysis, Investigation, Resources, Data curation. **Hongxia Sun:** Conceptualization, Methodology, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing. **Jinjie Xia:** Conceptualization, Methodology, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2025.02.010.

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