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Rehabilitation training effect guided by cardiopulmonary fitness assessment on NT-proBNP levels in patients with chronic heart failure.

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Keywords: cardiopulmonary fitness assessment; cardiopulmonary function; chronic heart failure; plasma N-terminal B-type pronatriuretic peptide; rehabilitation training.

Abstract. This study explored the impact of rehabilitation training guided by cardiopulmonary fitness assessment on NT-proBNP levels in patients with chronic heart failure (CHF). It was conducted on 220 chronic heart failure (CHF) patients from March 2020 to February 2022. They were divided into a control and observation group. The control group received routine nursing, while the an observation group underwent rehabilitation guided by a cardiopulmonary fitness assessment. Changes in NT-proBNP levels, vascular endothelial function, and cardiopulmonary function were compared between the groups at admission, eight, and 12 weeks later. Upon admission, the two groups had no statistically significant difference in NT-proBNP levels ($p>0.05$). However, after eight and 12 weeks of intervention, both groups showed decreased NT-proBNP levels, with the observation group exhibiting significantly lower levels than the control group ($p<0.05$). Similarly, there was no significant difference between the groups initially ($p>0.05$) in endothelial function comparison. However, after eight and 12 weeks, ET-1 and Ang-II levels decreased in both groups, with the observation group showing significantly lower levels than the control group ($p<0.05$). In terms of cardiopulmonary function, there was no significant difference initially. However, after eight and 12 weeks, Peak VO_2, VO_2 AT, and maximum exercise power increased in both groups compared to before the intervention, with the observation group showing significantly higher values than the control group ($p<0.05$). Additionally, the VE/VCO_2 slope decreased in both groups post-intervention, with the observation group having a lower slope than the control group ($p<0.05$). Cardiopulmonary fitness-guided rehabilitation objectively evaluates patients, formulates precise plans, reduces NT-proBNP levels and inflammation, improves vascular endothelial function, and is vital in secondary chronic heart failure prevention.

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Efecto del entrenamiento de rehabilitación guiado por la evaluación de la aptitud cardiorrespiratoria en los niveles de NT-proBNP en pacientes con insuficiencia cardíaca crónica.

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Palabras clave: evaluación de la aptitud cardiorrespiratoria; función cardiorrespiratoria; insuficiencia cardíaca crónica; péptido natriurético tipo B terminal plasmático; entrenamiento de rehabilitación.

Resumen. Este estudio tuvo como objetivo explorar el impacto del entrenamiento de rehabilitación guiado por la evaluación de la aptitud cardiorrespiratoria en los niveles de NT-proBNP en pacientes con insuficiencia cardíaca crónica (ICC). El estudio se llevó a cabo con 220 pacientes de ICC desde marzo de 2020 hasta febrero de 2022. Estos se dividieron en un grupo de control y un grupo de observación. El grupo de control recibió cuidados rutinarios, mientras que el grupo de observación se sometió a rehabilitación guiada por una evaluación de la aptitud cardiorrespiratoria. Se compararon los cambios en los niveles de NT-proBNP, la función endotelial vascular y la función cardiorrespiratoria entre los grupos al ingreso, a las 8 y a las 12 semanas. Al ingreso, no hubo diferencias estadísticamente significativas en el nivel de NT-proBNP entre los dos grupos ($p>0,05$). Sin embargo, después de 8 y 12 semanas de intervención, ambos grupos mostraron niveles disminuidos de NT-proBNP en comparación con antes de la intervención, con el grupo de observación exhibiendo niveles significativamente más bajos que el grupo de control ($p<0,05$). De manera similar, en la comparación de la función endotelial, no hubo diferencias significativas entre los grupos inicialmente ($p>0,05$), pero después de 8 y 12 semanas, los niveles tanto de ET-1 como de Ang-II disminuyeron en ambos grupos, con el grupo de observación mostrando niveles significativamente menores que el grupo de control ($p<0,05$). En términos de función cardiorrespiratoria, no hubo diferencia significativa inicialmente, pero después de 8 y 12 semanas, el pico de VO_2, VO_2 AT y la potencia máxima de ejercicio aumentaron en ambos grupos en comparación con antes de la intervención, con el grupo de observación mostrando valores significativamente más altos que el grupo de control ($p<0,05$). Además, la pendiente VE/VCO_2 disminuyó en ambos grupos después de la intervención, con el grupo de observación teniendo una pendiente más baja que el grupo de control ($p<0,05$). La rehabilitación guiada por la aptitud cardiorrespiratoria evalúa objetivamente a los pacientes, formula planes precisos, reduce los niveles de NT-proBNP y la inflamación, mejora la función endotelial vascular y es vital en la prevención secundaria de la insuficiencia cardíaca crónica.

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INTRODUCTION

Chronic heart failure (CHF) is a series of compensatory reactive diseases caused by weakened myocardial contraction caused by myocardial disease and the inability of cardiac output to meet the metabolic needs of the body [1, 2]. The prevalence of CHF varies globally, with an estimated 64 million people affected worldwide [3]. The condition is more

common in older adults, with a higher prevalence in men than women [4].

Patients with CHF typically present with signs and symptoms such as dyspnea, fatigue, reduced exercise tolerance, and fluid retention, manifesting as pulmonary congestion and peripheral edema. As the condition progresses, it can lead to a decline in quality of life and functional capacity [1].

The diagnosis of CHF relies on a combination of clinical assessment, biomarkers, and imaging techniques [5]. N-terminal pro-b-type natriuretic peptide (NT-proBNP) is an essential biomarker in the diagnosis and management of CHF, reflecting the degree of ventricular stress and providing prognostic information [6, 7]. Echocardiography remains the primary imaging modality for assessing cardiac function and structure [8].

Cardiopulmonary exercise testing (CPET) is valuable in evaluating cardiopulmonary fitness and functional capacity in CHF patients. It assists in the precise assessment of the severity of CHF, prognosis prediction, and tailoring individualized treatment strategies, including rehabilitation programs [9]. CPET measures various parameters, including oxygen consumption (VO_2), carbon dioxide production, and ventilatory efficiency, providing a comprehensive evaluation of the cardiovascular, pulmonary, and muscular systems during exercises [10, 11].

Rehabilitation training in the context of CHF has emerged as a necessary adjunctive therapy to improve functional capacity and quality of life, and potentially reduce hospital readmission rates. Rehabilitation programs are tailored to the individual and often involve aerobic exercise, resistance training, and respiratory exercises guided by cardiopulmonary fitness assessments [12]. These assessments, which include cardiopulmonary exercise testing (CPET), provide valuable information on the patient's functional limitations and responses to physical stress [13].

A study by Bozkurt *et al*. showed that cardiac rehabilitation (CR) is beneficial in patients with HF and is recommended as a Class 1A indication in HF practice guidelines [12] Another study conducted by Wang *et al*. showed that CPET for patients with CHF increases heart and lung function, improves exercise endurance, decreases NT-proBNP and hscTnT levels, and improves patients' quality of life [14].

The necessity of conducting the present study stems from the need to understand better the relationship between rehabilitation training and NT-proBNP levels in patients with CHF. Since few studies have been conducted in this field, it is necessary to conduct the present study to investigate the effect of rehabilitation exercise guided by assessment of cardiopulmonary fitness on NT-proBNP levels in patients with CHF.

MATERIALS AND METHODS

General information

Two hundred twenty patients with CHF treated in our hospital from March 2020 to February 2022 were chosen as samples. The sample size calculation formula is $n1=n2=2[(\mu_\alpha+\mu_\beta)\ \sigma/\delta]^2$, of which σ denotes the overall standard deviation, δ is the mean difference between the two samples, and n1=n2 represents the sample size of the control group (C) and the observation group (O), respectively, α= 0.05, β= 0.10. According to the t-limit table, $\mu_\alpha=1.96$, $\mu_\beta=1.28$, the sample size n1=n2=92 was calculated, taking into account the 20% loss of follow-up rate, and the required sample size was at least $(92+92)/(1+20\%)\approx220$. Finally, the sample size n1=n2=110 was determined. There were no statistically significant differences between the data in both groups of patients, as shown in Table 1. This study obtained the consent of patients and their families and was approved by the Ethics Committee.

Inclusion and exclusion criteria

Inclusion criteria: ① Patients meeting the relevant diagnostic criteria in the 2018 NICE Guidelines for the Diagnosis and Man-

Table 1
General information comparison.

Project	Gender		Age (Years)	Left ventricular Ejection Fraction (%)	Complications			New York Heart Function Classification	
	M	F			Hyperlipidemia	Diabetes	Hypertension	I	II
Group C (n=110)	61(55.45)	49(44.55)*	63.67±9.26**	42.79±2.09	26(23.64)	38(34.55)	46(41.82)	63(57.27)	47(42.73)
Group O (n=110)	65(59.09)	45(40.91)*	62.95±8.55**	43.14±2.36	22(20.00)	43(39.09)	45(40.91)	68(61.82)	42(38.18)
χ^2/t	0.297		0.641	1.181	0.653			0.472	
$p^{\#}$	0.586		0.522	0.239	0.721			0.492	

C: control group, O: observation group. Data are expressed as *frequency (%), ** mean ± SD: # p t-test (Independent Samples t-test) and chi-square χ^2.

agement of Adult Chronic Heart Failure[15]; ② Patients showing fatigue dyspnea, upright breathing, anorexia, epigastrium pain, pleural effusion or ascites in severe cases[16]; ③ New York Heart Association Cardiac Function Classification I-II; ④ Patients with stable condition for ≥ 1 month; ⑤ First onset; ⑥ Age from 30 to 85 years old.

Exclusion criteria: ① Patients having myocardial infarction, hypertrophic obstructive cardiomyopathy, aortic valve stenosis and acute myocarditis in recent three months; ② Patients with substantial lesions of essential organs, such as heart, lungs, and kidneys; ③ Patients with chronic obstructive pulmonary disease or pulmonary heart disease; ④ Patients with intermittent claudication, limb dysfunction, or inability to take care of themselves; ⑤ Patients with malignant arrhythmia and unstable angina pectoris; ⑥ Patients with electrolyte disorders; ⑦ Patients with a high degree of atrioventricular block. The two groups of general data were balanced with no statistically significant difference ($p>0.05$), as shown below.

Research method

Group C implemented routine nursing measures: (1) Exercise: The amount of exercise was determined based on the patient's heart function grading. It was generally recommended that patients with heart function level II should appropriately limit physical activity, not affect physical labor and household chores, and increase nap time. Strict physical activity restrictions were required for patients with heart function level III. Patients can get out of bed and move around, but general physical labor was limited. (2) Diet: Low salt and low-fat diet, with a sodium intake of less than 2.5 g/d, and strict restrictions on foods, such as sausages, canned goods, and seafood. Patients with severe heart failure had a daily fluid volume of 1.5-2.0 liters. (3) Medication care: When patients take diuretics, their blood potassium content should be monitored to avoid hypokalemia. For digitalis preparations, attention should be paid to observing the patient's appetite, palpitations, and vision. If the patient's pulse was less than 60 beats per minute, administration was discontinued and reported to the doctor. Group O implemented rehabilitation training under the guidance of cardiopulmonary fitness assessment with the following steps.

Cardiopulmonary fitness assessment

Cardiopulmonary function testing was performed using the MasterScreen CPX pulmonary function testing system (CEPT). The first choice was to complete a full set of static pulmonary function tests in the sitting position, guide the patient to sit on the power bike and record non-invasive blood, 12 lead ECG, oxygen saturation, gas exchange, and other indicators. Patients should rest for 3

minutes first, then warm up without load at a cycling rate of 60 r/min for 3 minutes. Based on the patient's gender, age, and functional status, the bicycle power increase rate was set to 20-30 W/min, so the patient could reach the symptom-limiting maximum exercise target within 10 minutes. The patient's maximum motor power and Peak VO2, VO2 AT, maximum exercise time, and VE/VCO2 sleep were recorded during the recovery period.

A high-load intensity exercise prescription was accurately formulated based on CEPT results: 50% power=[(anaerobic threshold measurement power - power increase rate) × 0.75)/2], and medical-grade precision power waste trucks were selected for training tools. (1) Stretching exercise: The patient performed muscle stretching exercises before using the bike trainer. Neck extension: Hands were placed on hips, waist and back were straightened, and the head was slightly extended upwards. Neck stretching left and right: Seated in a sitting position, the patient's head was tilted left and right to the left, repeated 3 times. Baby position: Assume a kneeling and standing position with legs spread wider than shoulder-width apart, then sit the hips towards the heels, lean the body forward, and touch the ground with their upper limbs from the front to the forehead. Maintain this stance for five seconds and repeat the exercise five times. Baby hugging posture: Patient sitting position: Keep the waist and back straight, stretch one thigh to the chest, keep the knee level with the same elbow socket, and the foot level with the opposite elbow socket. Maintain this position for 10 seconds and complete two sides into a group of 5 groups. (2) Car riding exercise: Warm up without power for 2 minutes, exercise for 30 minutes at 50% power intensity, with a speed of 60 revolutions per minute. If the speed cannot be maintained during the exercise, it is necessary to reverse without power and rest for 1 minute before continuing the exercise. After completing 30 minutes of exercise, enter the recovery period and run the car without power for 5 minutes. The exercise frequency is 5d/week for 8 weeks (2 months).

Exercise precautions: During exercise, relevant vital indicator monitoring instruments were equipped, such as blood pressure, heart rate, and pulse oxygen saturation.

Indication of exercise termination: ① The target heart rate was achieved; ② Patients having difficulty breathing, noticeable shortness of breath, pale complexion, as well as damp and cold skin; ③ Patients having central nervous system symptoms, such as dizziness, sensory abnormalities, ataxia, and visual impairments occur; ④ As the power increased, blood pressure decreased by>10mmHg or continuous baseline blood pressure or systolic blood pressure>220mmHg, diastolic blood pressure>115mmHg; ⑤ Patients having severe arrhythmia, persistent ventricular tachycardia, and rapid atrial fibrillation; ⑥ Patients requested to stop exercising.

Outcome measures

NT-proBNP: 5mL of patients' venous blood was collected upon admission, and after 8 weeks and 12 weeks. After centrifugation, serum was stored at -80°C, and the NT-proBNP level was determined by automatic electrochemiluminescence immunoassay. The reagent kits were all purchased from Shanghai Zhenma Industrial Co., Ltd., and the operation process was strictly carried out following the instructions.

Vascular endothelial function: 10mL of fasting venous blood was collected from patients upon admission, 8 weeks later, and 12 weeks later. After centrifugation, the serum was stored in a refrigerator at -80°C. The serum levels of endothelin-1 (ET-1) and angiopoietin-II (Ang-II) were measured using ELISA. The reagent kits were all purchased from Shanghai Hengyuan Biotechnology Co., Ltd, and the operation process followed the instructions.

Cardiopulmonary function: CPET was conducted using the MasterScreen CPX pulmonary function testing system produced by company Yeger (German) upon admission, 8

weeks later, and 12 weeks later. Basic patient information was collected, and the patient was asked to wear a mask after 5 minutes of rest. The electrocardiogram lead wire and electrode were connected, and the cuff was tied. Then, the patient started the measurement and the results were recorded. This included 50% peak oxygen consumption (Peak VO_2), anaerobic threshold oxygen consumption (VO_2 AT), maximum exercise power, and carbon dioxide ventilation equivalent slope (VE/VCO_2 slope) [17].

Statistical methods

EpiData software was applied to establish a database, and two people ensured the accuracy of data input through parallel input. The research collected data was statistically analyzed using the IBM® SPSS software (version 26.0), $\bar{x}\pm SD$ represents data, and inter-group comparisons were conducted using sample t-tests. The counting data is expressed as frequency or percentage, using c^2. Multiple data sets were analyzed using repeated variance measures, with $p<0.05$ indicating statistical differences.

Ethical considerations

Ethical approval was obtained before the commencement of the study. Informed consent was obtained from all participants before their inclusion in the study. The study protocol ensured the privacy and confidentiality of patient information. The study complied with relevant data protection regulations and the Declaration of Helsinki.

RESULTS

NT-proBNP comparison of two groups

Upon admission, there was no statistically significant difference in the levels of NT-proBNP between the two groups ($p>0.05$). After 8 and 12 weeks of intervention, the levels of NT-proBNP in the two groups were lower than those before the intervention, and those of the observation group were lower than those of the control group ($p<0.05$) (Table 2). The two groups' change curves of NT-proBNP levels showed a downward trend.

Endothelial function levels comparison between the two groups of blood vessels

Upon admission, there was no statistically significant difference in endothelial function levels between the two groups ($p>0.05$). After 8 and 12 weeks of intervention, the levels of ET-1 and Ang-II in both groups were lower than those before the intervention, and those of the observation group were lower than those of the control group ($p<0.05$) (Table 3). The levels of ET-1 and Ang-II in the two groups showed a downward trend.

Cardiopulmonary function comparison of the two groups

Upon admission, there was no statistically significant difference in cardiopulmonary function between the two groups ($p>0.05$). After 8 and 12 weeks of intervention, peak VO_2, VO_2 AT, and maximum exercise power in both groups were higher than those before the intervention, and those of the observation group were higher than those of the control group ($p<0.05$) (Table 4). The VE/VCO_2 slope in both groups was low-

Table 2
NT-proBNP Comparison of two groups.

Group	NT-proBNP(ng/mL)		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	380.41±39.56**	357.31±41.74	316.15±38.63
O* (n=110)	383.49±42.07	322.65±38.96	292.51±35.34
t	0.559	6.389	4.736
p#	0.577	<0.001	<0.001

N-terminal pro-b-type natriuretic peptide (NT-proBNP) *C: control group, O: observational group. **Mean±SD, # p t-test (Independent Samples t Test).

Table 3
Endothelial function levels comparison

Group	ET-1 (ng/L)		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	23.82±4.07**	22.18±3.44	19.77±4.23
O* (n=110)	23.92±3.99	20.28±4.05	18.03±3.49
t	0.184	3.750	3.328
pP#	0.854	<0.001	0.001
Group	Ang -II (ng/L)		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	109.70±12.24**	104.29±12.37	99.12±11.55
O* (n=110)	107.09±11.50	98.61±12.49	91.30±12.79
t	1.630	3.389	4.759
p#	0.105	0.001	<0.001

ET-1: endothelin-1 , Ang-II: angiotensin II *C: control group, O: observational group. **Mean±SD, # p t-test (Independent Samples t Test).

Table 4
Cardiopulmonary function comparison of the two groups.

Group	Peak VO_2[mL/(min·kg)]		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	17.24±1.34**	17.72±1.57	18.35±1.43
O* (n=110)	17.15±1.39	18.69±1.72	19.09±1.54
t	0.489	4.369	3.691
p#	0.625	0.001	<0.001
Group	VO_2 AT[mL/(min·kg)]		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	9.25±1.15**	9.90±1.37	10.47±1.49
O* (n=110)	9.45±1.47	10.47±1.25	11.09±1.68
t	1.124	3.224	2.896
p#	0.262	0.002	0.004

*C: control group, O: observational group. **Mean±SD, # p t-test (Independent Samples t Test).

er than that before the intervention, and that of the observation group was lower than that of the control group ($p<0.05$) (Table 5). The peak VO_2, VO_2 AT, and maximum exercise power of the two groups showed an upward trend, while the VE/VCO_2 slope showed a downward trend.

DISCUSSION

NT-proBNP, as an important biochemical CHF marker, predicts CFH development and progression and can accurately determine its severity [18]. Results showed no sta-

Table 5
Cardiopulmonary function comparison of the two groups.

Group	Maximum Motion Power		
	Upon admission	8 Weeks	12 Weeks
C* (n=110)	104.87±13.73**	108.84±13.49	112.64±12.92
O* (n=110)	103.83±13.26	113.94±12.19	120.34±12.28
t	0.572	2.942	4.531
$p^{\#}$	0.568	0.004	<0.001
Group	VE/VCO_2 slop (%)		
	Upon admission	8 Weeks	12 Weeks
C (n=110)	33.70±3.64**	31.23±3.53	30.32±3.37
O (n=110)	33.28±3.45	29.91±3.37	28.50±3.15
t	0.878	2.837	4.138
$p^{\#}$	0.381	0.005	<0.001

*C: control group, O: observational group. **Mean±SD, # p-value t test (Independent Samples t Test).

tistically significant difference in NT-proBNP level upon admission (p>0.05). After 8 and 12 weeks of intervention, NT-proBNP levels were lower than before and much lower in Group O (p<0.05). The repeated analysis of variance results showed group, time, and interaction effects between the two groups (p<0.05). Rehabilitation training guided by cardiopulmonary fitness assessment reduces NT-proBNP levels in CHF patients. The reason is that as an essential part of secondary prevention of heart failure, exercise rehabilitation is recommended as Class 1 in the management guidelines of the American Heart Association and is valued by patients and clinicians [19]. High-intensity exercise is the core of rehabilitation training, and exercise intensity is related to patient safety and treatment effects. The conventional exercise intensity system is determined based on the patient's heart rate; however, currently, the commonly used drugs in clinical practice for heart failure patients are β Receptor blockers. Therefore, determining exercise intensity based on heart rate poses significant safety risks, so it is imperative to develop reasonable intensity exercise rehabilitation training based on the patient's exercise endurance [20,21]. After the stimulation of the synthesis of brain natriuretic peptide precursor by myocardial cells, the brain natriuretic peptide precursor protease decomposes into NT-proBNP and the bioactive hormone brain natriuretic peptide, which then enters the bloodstream, leading to an increase in the content of NT-proBNP in the blood. Rehabilitation training guided by cardiopulmonary fitness assessment can increase glucose oxidation, improve substrate utilization and mitochondrial respiratory oxidation ability, reduce oxidative stress, delay myocardial fibrosis, stabilize myocardial cell contraction rhythm, reduce myocardial cell stimulation, and lower blood NT-proBNP levels.

Results showed no statistically significant difference in endothelial function level upon admission (p>0.05). After 8 and 12 weeks of intervention, the ET-1 and Ang II levels in both groups were lower than before the intervention and much lower in Group O (p<0.05). Repeated analysis of variance results showed group, time, and interaction effects between the two groups (p<0.05). This is similar to the research results of Papathanasiou *et al.* [22,23]. CHF may cause an increase in the excitability of renin-angiotensin-aldosterone and the sympathetic nervous system, stimulate inflammation and oxida-

tive stress reactions, and subsequently cause dysfunction of vascular endothelial function. Meanwhile, vascular endothelial dysfunction can lead to increased cardiac load, myocardial ischemia exacerbation, and vicious cycle formation [24,25]. ET-1 is mainly synthesized and secreted by endothelial cells. When myocardial cells are damaged, endothelial cells accelerate the synthesis of a large amount of ET-1. This may be related to the fact that rehabilitation training guided by cardiopulmonary fitness assessment can reduce the concentration of catecholamines in the blood, reduce the stimulation of inflammatory and oxidative stress reactions on vascular endothelium, and protect vascular endothelial function [26,27].

The research results also showed no statistically significant difference in cardiopulmonary function upon admission ($p>0.05$). After 8 and 12 weeks of intervention, Peak VO_2, VO_2 AT, and maximum exercise power in both groups were higher than before and much higher in Group O ($p<0.05$). The VE/VCO_2 slope was lower than before the intervention and much lower in Group O ($p<0.05$). Repeated analysis of variance results showed group, time, and interaction effects between the two groups ($p<0.05$). This is similar to the research results of Turri Silva and others [28]. Rehabilitation training guided by cardiopulmonary fitness assessment can help improve the cardiovascular function of CHF patients. CPET can accurately evaluate the exercise ability of subjects, objectively evaluate their exercise endurance and cardiac reserve function, and provide a reliable basis for developing rehabilitation training for heart failure patients. CPET evaluated this study, and a 50% anaerobic threshold exercise intensity was selected to avoid lactic acid accumulation caused by prolonged aerobic metabolism and systemic muscle soreness. Moderate and mild exercise can inhibit excessive vasoconstriction, improve the elastic reserve capacity of blood vessels, regulate myocardial metabolism, improve cardiac contractile function, and improve cardiopulmonary function.

In conclusion, the findings of this study demonstrate significant improvements in NT-proBNP levels, endothelial function, and cardiopulmonary function. The results revealed a notable decrease in NT-proBNP levels after 8 and 12 weeks of intervention, particularly in the observation group, indicating the effectiveness of rehabilitation training in reducing NT-proBNP levels in CHF patients. Furthermore, improvements in endothelial function, as evidenced by lower levels of ET-1 and Ang II after the intervention period, suggest that rehabilitation training guided by cardiopulmonary fitness assessment can mitigate vascular endothelial dysfunction associated with CHF. Additionally, enhancements in cardiopulmonary function, including increased Peak VO_2, VO_2 AT, maximum exercise power, and decreased VE/VCO_2 slope, highlight the positive impact of this intervention on cardiovascular function. These results underscore the importance of tailored rehabilitation programs based on cardiopulmonary fitness assessment for improving outcomes in CHF patients by enhancing NT-proBNP levels, endothelial function, and cardiopulmonary performance.

Limitations

The study encountered several limitations. Firstly, the sample size of 220 patients may not adequately represent the general population, potentially limiting the robustness of the results. Secondly, including patients with chronic heart failure could introduce selection bias, thus challenging the study's applicability to the broader population. Additionally, 8 to 12 weeks might not have been sufficiently long to observe significant changes in specific outcomes. Finally, the study focused on NT-proBNP levels, endothelial function, and cardiopulmonary function, but other relevant outcomes could have been included to provide a more comprehensive understanding of the effects of the intervention.

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The author was involved in data collection, article design, interpretation of results, review, and manuscript preparation.

Conflict of competence

The author declares no conflict of interest.

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