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Original Article

The effects of CPET-guided cardiac rehabilitation on the cardiopulmonary function, the exercise endurance, and the NT-proBNP and hscTnT levels in CHF patients

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Abstract: Objective: To explore the effects of cardiopulmonary exercise testing (CPET) on the cardiopulmonary function, the exercise endurance, and the NT-proBNP and hscTnT levels in chronic heart failure (CHF) patients. Methods: Altogether 98 patients with CHF were randomly divided into a control group and a CPET group, with 49 cases in each group. The control group was administered routine treatment, and the CPET group was administered CPET cardiac rehabilitation training in addition to the routine treatment. Heart and lung function, exercise endurance, and the peripheral blood NTproBNP, hscTnT, and CRP levels were observed. The patients' quality of life, anxiety, and depression were observed using the scale. Results: After the treatment, the left ventricular end systolic diameters (LVESD) and the left ventricular end diastolic diameters (LVEDD) were significantly decreased, the left ventricular ejection fractions (LVEF), the stroke volumes (SV), and the CI levels were significantly increased, and there were significant differences in these indexes between the CPET group and the control group (all P<0.05). After the treatment, the carbon dioxide ventilation equivalent slope (VE/VCO_2slop) decreased significantly, the peak oxygen consumption (peakVO_2) and anaerobic threshold oxygen consumption (VO_2AT) levels increased significantly, and there were significant differences in these indicators between the CPET group and the control group (all P<0.05). Compared with the control group, the exercise endurance, the maximum oxygen uptake capacity (VO_2max), the maximum power, the exhaustion times, and the six-minute walking test (6MWT) levels in the CPET group increased significantly (all P<0.05). After the treatment, the N-terminal precursor brain natriuretic peptide (NTproBNP), the high sensitivity cardiac troponin (hscTnT), and the C-reactive protein (CRP) levels in the two groups were decreased compared with their pre-treatment levels, and there were significant differences in these indexes between the CPET group and the control group (all P<0.05). After the treatment, the Minnesota living with heart failure questionnaire (MLHFQ), the self-rating anxiety scale (SAS), and the self-rating depression scale (SDS) scores in the two groups were significantly lower than they were before the treatment, and there were significant differences in the two scores between the CPET group and the control group (all P<0.05). Conclusion: CPET for patients with CHF helps increase heart and lung function, improves exercise endurance, reduces the NT-proBNP and hscTnT levels, and improves patients' quality of life.

Keywords: Chronic heart failure, cardiopulmonary exercise testing, cardiopulmonary function, endurance test, N-terminal precursor brain natriuretic peptide (NTproBNP), high sensitivity cardiac troponin

Introduction

Chronic heart failure (CHF) is a pathological state in which the heart pumping function is reduced due to the original chronic heart disease, and the heartbeat cannot keep up with the body's metabolism [1]. CHF has become a global public health problem. Epidemiology shows that there are 4 million CHF patients in China, and there are local differences. The prevalence rates in the south and the north areas of China are 0.5% and 1.4% respectively [2]. At present, the causes of CHF include respiratory tract infections, basic heart diseases, long-term physical activity, and anemia. The clinical manifestations of CHF patients are dyspnea, epigastric pain, and liver tenderness. Heart and lung dysfunction also exist in CHF

patients. The six-minute walking test to test exercise endurance can evaluate patient prognosis, and the degree of heart failure in CHF patients can be evaluated by measuring a patient's walking distance. The expression of N-terminal pro-brain natriuretic peptide (NT-BNP) increases with an increase in the ventricular wall tension and the ventricular dilatation. Because of its long half-life, NT-BNP can be used as a marker for diagnosing heart injury, and it has high sensitivity [3]. For normal individuals, the serum content of high-sensitivity cardiac troponin (hscTnT) is extremely low. After a heart attack, free hscTnT quickly enters the blood from myocardial cytoplasms, resulting in a high serum concentration. The degree of myocardial injury can be judged by measuring the serum content of hscTnT, a highly sensitive and specific measure [4].

The principle of the cardiopulmonary exercise test (CPET) is to reflect the number of respiratory and circulatory indexes through treadmill activity and the power treadmill, as it can comprehensively evaluate the cardiopulmonary function of CHF patients [5]. CPET, as a non-invasive method, can continuously monitor the patient's condition and objectively reflect the clinical efficacy and the prognosis. The International Heart Failure Guidelines highly agree with the efficacy of exercise intervention for CHF patients, but there are still doubts about the efficacy and treatment of CHF patients in clinical treatment [6]. Based on this, this paper adopted CPET to guide cardiac rehabilitation training, and observed its influence on patients' cardiopulmonary function and serum indexes, so as to provide a theoretical basis for clinical practice. The details are as follows.

Materials and methods

General information

A prospective study was conducted on 98 patients with CHF from May 2019 to June 2020. The patients were randomly divided into a control group and a CPET group, with 49 cases in each group. The control group was administered routine treatment, and the CPET group was administered CPET cardiac rehabilitation training in addition to the routine treatment. Signed informed consent forms were obtained from the patients and their families, and the research was approved by the ethics committee of our hospital.

Inclusion criteria

(1) The research met the heart function classification (I-III) standard of the New York Heart Association (NYHA) [7]. (2) The stable times of the CHF patients' clinical symptoms were more than 30 days. (3) The patients had been administered anti-CHF drugs. (4) The left ventricular ejection fraction (LVEF) score was less than 45%. (5) The patients were confirmed to have CHF through ultrasounds and electrocardiograms.

Exclusion criteria

(1) Patients with severe myocardial ischemia, myocardial infarction, or cardiac pacemaker implantation. (2) Patients whose systolic blood pressure was ≥200 mmHg and whose diastolic blood pressure was ≥110 mmHg under a static state. (3) Patients with thrombosis and myocarditis. (4) Patients with pulmonary heart complication, pulmonary hypertension, or severe infections. (5) Patients with unstable diseases of the lower limbs. (6) Patients with cognitive insufficiency or mental illness. (7) Patients who participated in other clinical projects.

Methods

The control group was administered conventional anti-CHF treatment for 6 months, including oxygen inhalation, physical activity control, bed rest repair, sodium intake reduction, disease knowledge popularization, treatment confidence building, nutrition diet guarantee, and bad living habits improvement. Oral hydrochlorothiazide (Shanxi Yunpeng Pharmaceutical Co., Ltd., China, batch number: 60211) was administered to the patients, 25 mg/time and once a day. Captopril (Furen Pharmaceutical Group, China, batch number: 1508075) was also administered, 12.5 mg/time and once a day. Digoxin tablets (Shanghai Xinyi Pharmaceutical Factory Co., Ltd., China, batch number: 02015070) were administered, 25 mg/time and once a day. Metoprolol tartrate tablets (AstraZeneca (China) Pharmaceutical Co., Ltd., batch number: 000186) were also administered, 12.5-50 mg/time and once a day.

In addition to the above treatment, the patients in the CPET group underwent CPET sports rehabilitation training, and a targeted rehabilitation plan was carried out according to the objective and quantitative evaluation of CPET. The spe-

cific contents were as follows: (1) The patient data were collected, the management files were established according to the order of the visits, including the contact information. (2) An intervention group was set up. Standardized management was conducted for the CHF patients. Physical and psychological training, mastering disease knowledge, training methods and skills, 6-minute walking tests, planning rehabilitation plans, increasing entertainment facilities, and interaction were carried out to improve the CHF patients' quality of life. (3) The exercise methods included cycle ergometer and treadmill tests. The physical therapist guided the CHF patients to exercise according to their CPET evaluation results. (4) Exercise intensity: Each patient followed the individualized exercise method, and the training intensity ranged from light to strong (60%-85%). The intensity was adjusted according to each patient's heart rate and tolerance, and the endurance training was increased by 5% every time. The gradual progress in the process was followed to reduce the occurrence of adverse events. (5) Exercise frequency: The exercise duration started at 30 min, except those who could not bear it started at 20 min, and the longest time was no more than 60 min. If other sports were added in the later period, the rest interval between the individual sports was 5-10 min. (6) Exercise and monitoring: During the exercising, the patients were monitored using an ECG telemetry system, and they were fully warmed up before their exercise training. If discomfort such as chest pain occurred during the exercises, the exercise was stopped immediately. After recovery, the intensity was reduced in order to the continue training, and the causes were analyzed. If necessary, a new exercise plan was made. The exercise intervention lasted for six months.

Outcome measures

Main outcome measures

Heart function: Referring to the NYHA grading evaluation method in America, a G70 full-digital color Doppler ultrasound with a probe frequency of 7.0 Hz was used before and after the treatment [7]. The ultrasound doctors operated the device according to NYHA's recommended method, and the left ventricular ejection fraction (LVEF), the left ventricular end systolic diameter (LVESD), the left ventricular end diastolic diameter (LVEDD), the stroke volume (SV), and the heart index were measured respectively.

Cardiopulmonary function: Before and after the treatment, a Netherlands ENRAF rehabilitation cycle ergometer was used. According to the rehabilitation exercise method and each patient's condition, the test was carried out under the supervision of the medical staff. When the respiratory exchange rate was more than 1.05, the cardiopulmonary function indexes were recorded, including peak oxygen consumption (peakVO_2), the carbon dioxide ventilation equivalent slope (VE/VCO_2slop), and the anaerobic threshold oxygen consumption (VO_2AT).

Exercise endurance: Six-minute walking tests (6MWT) were administered to all the patients, and a corridor with a length of about 60 m was selected [8]. Seats were placed at both ends and in the middle, and rest was allowed if necessary. The best effort to walk back and forth in the corridor was tested, the patient's vital signs were recorded after 6 min, and the maximum oxygen uptake capacity (VO_2max), the maximum power, the exhaustion time, and the 6MWT were calculated.

Comparison of the peripheral blood NTproBNP, hscTnT, and C-reactive protein (CRP) levels: A 3 mL peripheral blood sample was collected from the elbow on an empty stomach, separated at 3000 r/min for 10 min using a TGL-15M desktop micro high-speed freezing centrifuge (Pingfan Science and Technology Company, Hunan Province, China). The serum was then obtained, and the hscTnT was tested using double antibody sandwich biotin-avidin ELISA. The CRP was measured using immunoturbidimetry, and the N-terminal precursor brain natriuretic peptides (NTproBNP) were measured using enzyme immunoadsorption (ELISA). All the kits were purchased from GuangZhou Jianlun Biology Technology Co., Ltd., China.

Secondary outcome measures

The Minnesota living with heart failure questionnaire (MLHFQ), self-rating anxiety scale (SAS) and self-rating depression scale (SDS) scores: The MLHFQ was used to evaluate the patients' quality of life, including 21 questions, and the scores from 0 (zero) to 5 points indi-

Table 1. Comparison of the baseline data between the two groups

Group	Control group (n=49)	CPET group (n=49)	χ^2/t	P
Gender (n)			0.169	0.919
Males	30	28		
Females	19	21		
Average age (years)	62.4±4.6	63.0±4.2	0.674	0.502
Average course of disease (years)	9.5±3.2	10.2±2.9	1.135	0.259
BMI (kg/m^2)	24.51±1.36	24.32±1.25	0.720	0.473
NYHA classification (n)			0.377	0.828
I-II	22	19		
III-IV	27	30		
Smoking (n)	28	26	0.055	0.973
Coronary heart disease (n)	19	20	0.021	0.990
Hypertension (n)	20	18	0.085	0.959
Diabetes (n)	17	15	0.104	0.949
Type of disease (n)			1.415	0.622
Expandability	29	34		
Ischemic	12	10		
Alcoholic	8	5		
Education (n)			4.064	0.255
Illiteracy	3	0		
Elementary and junior high	22	25		
High school and college	15	18		
University and above	9	6		
Economic income (yuan)			2.186	0.335
<1000	3	4		
1000-3000	25	31		
>3000	21	14		

Note: NYHA: New York Heart Association; BMI: Body mass index; CPET: cardiopulmonary exercise test.

cated the degree of heart failure from light to severe [9]. A higher score indicated a poorer quality of life. The SAS and SDS were used to evaluate the patients' psychological stress levels before and after the intervention [10]. Both the SAS and the SDS contain 20 items, with 4 grades. If the score exceeds 50, it will be classified as depression, and higher scores on the two scales indicate a more serious depression level.

Statistical analysis

GraphPad Prism 8 was used to analyze and process the data in this paper, and the count data were expressed as ($\bar{x}$±sd). The measurement data were expressed as (n, %) and analyzed using chi-square tests. Independent sample t tests were used for the comparisons between groups, and paired sample t tests were used for the comparisons within groups. A difference was statistically significant when P<0.05.

Results

Comparison of the baseline data

There were no significant differences in terms of gender, average age, average course of the disease, BIM, NYHA grade, smoking history, hypertension, diabetes, coronary heart disease, disease type, education, or monthly income between the two groups (all P>0.05), as shown in **Table 1**.

Comparison of the cardiac function

There were no significant differences in the LVEDD, LVESD, LVEF, SV, or CI levels between the two groups before the intervention (all

Table 2. Comparison of the cardiac function between the two groups of patients before and after the treatment

Factors	Control group (n=49)	CPET group (n=49)	t	P
LVEDD (mm)				
Before treatment	62.05±4.11	61.36±4.50	0.793	0.430
After treatment	58.60±4.33	55.20±3.66	4.198	<0.001
t	4.045	7.434		
P	<0.001	<0.001		
LVESD (mm)				
Before treatment	47.52±3.80	48.06±3.69	0.714	0.477
After treatment	44.12±3.51	41.06±3.37	4.402	<0.001
t	4.601	9.805		
P	0.001	<0.001		
LVEF (%)				
Before treatment	30.08±3.71	29.69±3.80	0.514	0.608
After treatment	33.18±2.69	39.04±2.34	11.510	<0.001
t	4.735	14.670		
P	<0.001	<0.001		
SV (mL/time)				
Before treatment	50.24±7.20	51.09±6.85	0.599	0.551
After treatment	56.33±5.74	61.25±7.60	3.616	0.001
t	4.630	6.951		
P	<0.001	<0.001		
CI (L/(min·m^2))				
Before treatment	3.58±1.17	3.64±1.01	0.272	0.786
After treatment	4.22±1.38	5.39±1.77	3.649	0.001
t	2.476	6.011		
P	0.015	<0.001		

Note: LVESD: left ventricular end systolic diameter; LVEDD: left ventricular end diastolic diameter; LVEF: left ventricular ejection fraction; SV: stroke volume; CI: heart index; CPET: cardiopulmonary exercise test.

P>0.05). After 6 months' treatment, the LVEDD and LVESD levels were significantly decreased, and the LVEF, SV, and CI levels were significantly increased in both groups compared with before the treatment, and there were significant differences between the CPET group and the control group after the treatment (all P<0.05), as shown in **Table 2**.

Comparison of the cardiopulmonary function

There were no significant differences in the PeakVO_2, VE/VCO_2slop, or VO_2AT levels between the two groups before the intervention (all P>0.05). After 6 months of treatment, the VE/VCO_2slop level decreased significantly, and the PeakVO_2 and VO_2AT levels increased significantly compared with before the treatment, and there were significant differences between the CPET group and the control group after the treatment (all P<0.05), as shown in **Table 3**.

Comparison of the exercise endurance

Compared with the control group after the treatment, the exercise endurance, VO_2max, maximum power, exhaustion time, and 6MWT in the CPET group increased significantly (all P<0.05), as shown in **Table 4**.

Comparison of the serum NTproBNP, hscTnT, and CRP levels

There were no significant differences in the serum NTproBNP, hscTnT, or CRP levels between the two groups before the intervention (all P>0.05). After 6 months of treatment, the serum NTproBNP, hscTnT, and CRP levels decreased significantly, and there were significant differences between the CPET group and

Table 3. Comparison of the cardiopulmonary function between the two groups

Factors	Control group (n=49)	CPET group (n=49)	t	P
PeakVO_2 (mL/min·kg)				
Before treatment	16.90±4.36	16.54±4.22	0.415	0.679
After treatment	19.16±4.90	21.33±5.41	2.081	0.040
t	2.412	4.887		
P	0.018	<0.001		
VE/VCO_2slop (mmoL/L)				
Before treatment	35.05±5.66	34.67±5.46	0.338	0.736
After treatment	32.11±4.85	29.28±4.60	2.964	0.004
t	2.761	5.285		
P	0.007	<0.001		
VO_2AT (mL/min·kg)				
Before treatment	10.15±2.69	9.69±2.77	0.934	0.406
After treatment	12.09±3.28	13.96±3.40	2.771	0.007
t	3.201	6.816		
P	0.002	<0.001		

Note: VE/VCO_2slop: carbon dioxide ventilation equivalent slope; peakVO_2: peak oxygen consumption; VO_2AT: anaerobic threshold oxygen consumption; CPET: cardiopulmonary exercise test.

Table 4. Comparison of the exercise endurance between the two groups after the treatment

Group	VO_2max (mL·Kg^{-1}·min^{-1})	Maximum power (W)	Exhaustion time (min)	6MWT (m)
Control group (n=49)	16.20±4.80	88.67±10.38	12.36±5.22	359.20±54.19
CPET group (n=49)	18.65±5.62	94.38±12.04	15.28±5.43	452.19±58.03
t	2.320	2.514	2.714	8.198
P	0.022	0.014	0.008	<0.001

Note: VO_2max: maximum oxygen uptake capacity; maximum power, 6MWT: six-minute walking test; CPET: cardiopulmonary exercise test.

the control group after the treatment (all P<0.05), as shown in **Table 5** and **Figure 1**.

Comparison of the MLHFQ, SAS, and SDS scores

There were no significant differences in the MLHFQ, SAS, or SDS scores between the two groups before the intervention (all P>0.05). After 6 months of treatment, the MLHFQ, SAS, and SDS scores were significantly lower than they were before the treatment, and there were significant differences between the CPET group and the control group after the treatment (all P<0.05), as shown in **Table 6**.

Discussion

CHF is a disease that causes changes in the heart function or structure, and it leads to complex conditions such as systemic congestion. As the terminal end of heart disease, CHF has a high morbidity and mortality, so it is very important to effectively control the development of the disease clinically. Conventional wisdom believed that CHF patients should reduce their activities to achieve the goal of reducing the heart load, but long-term activity restriction will increase the probability of thrombosis and affect patient prognosis. At present, there are many studies on the application of rehabilitation therapy in the cardiovascular field. CPET can prevent heart diseases, and international studies have reported that exercise for CHF patients can improve the patients' rehabilitation outcomes [11]. This study confirmed that CPET-guided rehabilitation training can improve CHF patients' cardiopulmonary functions and exercise endurance, reduce their inflammation indexes, and improve their quality of life.

Ultrasound is a non-invasive auxiliary examination for diagnosing CHF, and it can accurately

Table 5. Comparison of the serum NTproBNP, hscTnT, and CRP levels before and after the treatment in the two groups

Factors	Control group (n=49)	CPET group (n=49)	t	P
NTproBNP (pg/mL)				
Before treatment	2956.35±420.33	2896.36±485.23	0.654	0.515
After treatment	1852.74±254.17	1033.69±145.28	19.580	<0.001
t	15.730	25.740		
P	<0.001	<0.001		
hscTnT (mg/L)				
Before treatment	0.33±0.06	0.31±0.05	1.793	0.076
After treatment	0.14±0.03	0.07±0.01	15.500	<0.001
t	19.830	32.950		
P	0.007	<0.001		
CRP (mg/L)				
Before treatment	18.14±2.39	17.56±2.41	1.196	0.234
After treatment	14.62±2.04	11.69±1.89	7.375	<0.001
t	7.842	13.420		
P	0.002	<0.001		

Note: NTproBNP: N-terminal precursor brain natriuretic peptide; hscTnT: high sensitive cardiac troponin; CRP: C-reactive protein; CPET: cardiopulmonary exercise test.

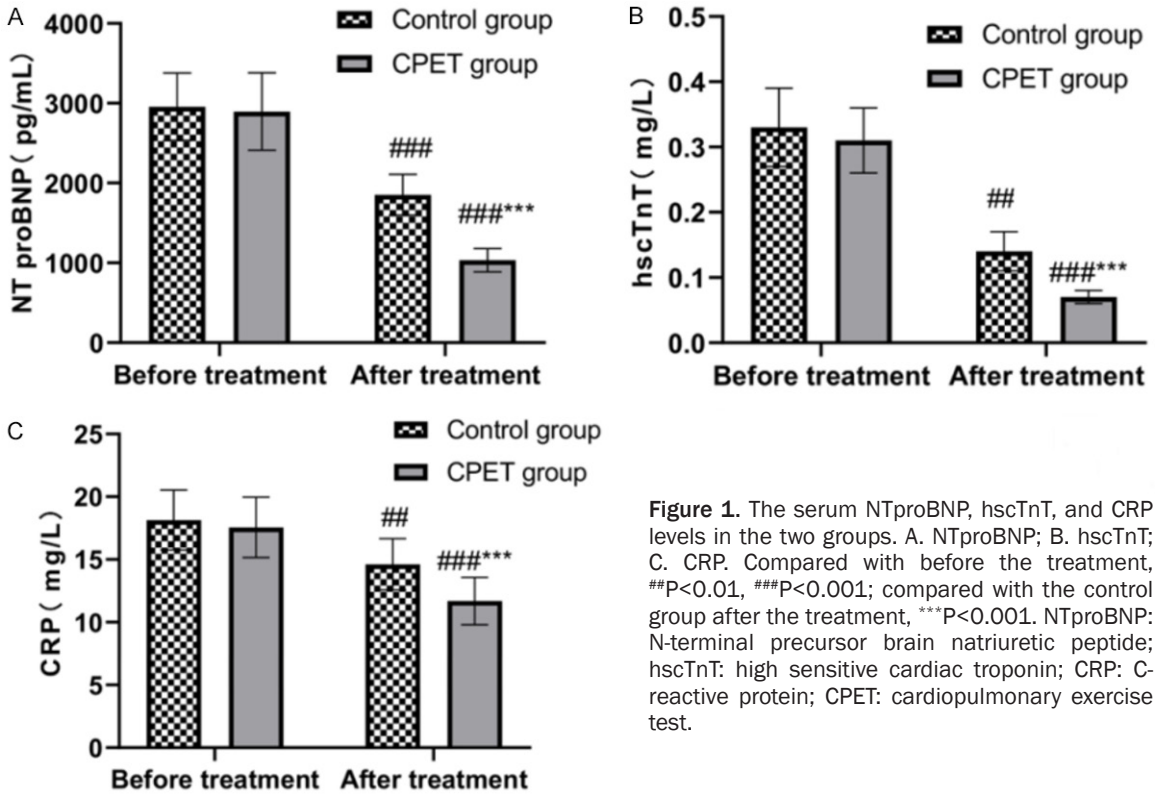

Figure 1. The serum NTproBNP, hscTnT, and CRP levels in the two groups. A. NTproBNP; B. hscTnT; C. CRP. Compared with before the treatment, ##P<0.01, ###P<0.001; compared with the control group after the treatment, ***P<0.001. NTproBNP: N-terminal precursor brain natriuretic peptide; hscTnT: high sensitive cardiac troponin; CRP: C-reactive protein; CPET: cardiopulmonary exercise test.

evaluate the changes in cardiac chamber size and cardiac function. In CHF patients, the heart volume decreased, the end diastolic volume increased, which increased the ventricular filling pressure, induced the elevation of heart pressure, and caused abnormal LVEF and LVESD levels. There are different degrees of ischemia in CHF patients' myocardial tissue,

Table 6. Comparison of the MLHFQ, SAS, and SDS scores in the two groups

Factors	Control group (n=49)	CPET group (n=49)	t	P
MLHFQ score (scores)				
Before treatment	46.50±17.02	45.55±20.01	0.253	0.801
After treatment	34.25±16.25	25.36±18.20	2.551	0.012
t	3.362	3.864		
P	<0.001	<0.001		
SAS score (scores)				
Before treatment	54.06±8.22	53.09±7.15	0.623	0.534
After treatment	39.25±7.10	35.02±5.23	3.358	0.001
t	9.544	14.280		
P	0.007	<0.001		
SDS score (scores)				
Before treatment	48.03±10.33	47.52±11.02	0.236	0.814
After treatment	37.25±8.69	31.08±8.22	3.611	0.001
t	5.590	8.371		
P	0.002	<0.001		

Note: MLHFQ: Minnesota living with heart failure questionnaire; SAS: self-rating anxiety scale; SDS: self-rating depression scale; CPET: cardiopulmonary exercise test.

thus leading to an asynchrony of ventricular contraction, limiting SV and CI, and affecting ventricular contraction function [12]. Therefore, in clinical treatment, improving heart function is important for the improvement of CHF. Clinical experiments show that rehabilitation exercise helps improve CHF patients' heart function, improves their exercise endurance, and reduces their chest pain. The cardiac function of the patients in the CPET group was better than the cardiac function in the control group, indicating that exercise training for CHF patients under CPET can enhance cardiac function and improve their conditions. CPET is a measurement method for evaluating the functions of multiple organs based on the holistic concept. It is mostly used in the study of heart diseases, and it can better reflect the functions of organs under exercise [13]. The rehabilitation plan for CHF patients varies with each individual and is conducted step by step. Cycle ergometer or treadmill tests can improve the coronary blood flow and the cardiac function storage, reduce myocardial oxygen consumption, further adjust myocardial tension and contraction intensity, and improve cardiac function. Previous studies have shown that CPET can improve patients' cardiac function injuries, guide rehabilitation exercises to improve the adaptability of cardiac function in CHF patients, and plays an important role in promoting the rehabilitation of CHF patients [14]. The results of this study are consistent with the results of the previous studies.

PeakVO_2, VE/VCO_2slop, and VO_2AT are indicators for measuring oxygen uptake. Heart function and stroke volume decrease in CHF patients, which leads to a decrease in the oxygen content in the peripheral muscles and a decrease in PeakVO_2 and VO_2AT [15]. PeakVO_2 refers to the circulatory ability of the body's heart function, and VO_2AT refers to the ventilation efficiency of the body. The elevation of VE/VCO_2slop in CHF patients indicates that increased anaerobic metabolism damages the cardiac function. Previous studies have shown that the heart function of CHF patients is decreased, and this is mainly related to a decrease in the vasodilation function and a decrease in the oxygen content in the lungs caused by a decrease in the blood oxygen carrying capacity [16]. The degree of improvement in the heart and lung function indexes in the CPET group was better than it was in the control group, indicating that CPET guiding cardiac rehabilitation helps increase CHF patients' heart and lung functions. The main research mechanism may be related to accelerating the whole body blood redistribution, up-regulating the vascular endothelial relaxation, and regulating the oxidase activity to strengthen the cardiac contractility during CPET guiding exercise. CPET exercise rehabilitation can increase the

oxygen uptake and the oxidase ability of the myocardial cells, enhance the oxygen acquisition and output abilities, and improve the heart and lung function. Guirgis et al. found that CPET rehabilitation exercises can improve the cardiopulmonary function of CHF patients, as this is mainly related to the increase in peak oxygen uptake [17]. This is consistent with our research results.

Patients with CHF can undergo skeletal muscle dysplasia in their respiratory and circulatory systems and suffer from limited airflow, which leads to limited respiratory function after exercise activities, thus reducing their exercise endurance. The 6MWT is a typical method used by The American Thoracic Society to evaluate patients' functional status and the decrease in exercise ability [18]. In this study, the exercise endurance of the CPET group was higher than it was in the control group, an indication that CPET can significantly increase the contraction ability of CHF patients' skeletal muscles. CPET cardiac rehabilitation training can improve the exercise intensity of CHF patients, and the exercise can adjust the microvasculature of the body to increase the muscle strength and endurance of the skeletal muscle, up-regulating the expression of oxidase in the skeletal muscle to increase the anti-inflammatory function. Gavotto et al. confirmed that aerobic exercise training for CHF patients can improve patients' exercise endurance by regulating the blood supply and mitochondrial function in the myocardium, which can improve cardiac remodeling to some extent [19].

Brain natriuretic peptide is produced when the ventricular volume expands and the ventricular pressure increases. NT proBNP is an N-terminal fragment produced after splitting the brain natriuretic peptide, and it is up-regulated in ventricular dysfunction. A higher level indicates more serious cardiac dysfunction [20]. The expression of hscTnT increases rapidly during myocardial injury, and it can better reflect the degree of myocardial injury and is a good diagnostic index for evaluating patients' condition. CRP is a symbolic inflammatory factor. Myocardial injury in CHF patients induces an expression of monocytes and macrophages to increase the expression of many inflammatory cytokines, which accelerates the occurrence of CRP and the injury of the vascular endothelium, thus affecting cardiac function. CPET can guide the cardiac rehabilitation of CHF patients, improve the blood circulation and lung ventilation, strengthen the self-repair of myocardial cells, and then reduce the ventricular volume expansion and pressure, and reduce the NT proBNP and hscTnT levels [21]. Some researchers believe that exercise training can reduce the expression of CRP in the serum inflammatory cells and is related to an increase in the anti-inflammatory factor ADP level. This study confirmed that CPET can reduce the split of brain natriuretic peptide and the content of inactive NT proBNP and hscTnT by improving heart and blood circulation and increasing heart function. The expression of serum NT proBNP, hscTnT and CRP in the CPET group was lower than it was in the control group, an indication that CPET guided exercise rehabilitation can reduce the expression of NT proBNP, hscTnT, and CRP. This was consistent with the research of Hein et al. [22]. Chronic CHF patients usually undergo a long period of treatment, including diet intervention and continuous drug treatment. In addition, the repeated attacks in some patients will reduce their treatment enthusiasm, foster a negative attitude, and reduce their quality of life and social function. CPET provides rehabilitation training for patients, regulates patients' neuro-immunity through exercise, improves anxiety and depression, increases self-confidence in the treatment and improves the quality of life. This is consistent with the research results of Rius-Suárez et al. [23].

Due to the limited time and cost, the samples and methods were unitary, which may have had an impact on the research results. In the later stage, we will strengthen our cooperation with other relevant research units, increase the sample size, refine the experimental content, and provide a clinical basis for the clinical treatment of patients with chronic CHF.

To sum up, CPET for patients with CHF helps to increase heart and lung function, improve exercise endurance, reduce the NT-proBNP and hscTnT levels, and improve the quality of life, so it is worthy of clinical promotion.

Disclosure of conflict of interest

None.

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