Journal of Biosciences and Medicines, 2026, 14(5), 414-435
https://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

A Randomized Controlled Trial to Explore the Effectiveness and Safety of Ba Duan Jin in Elderly Patients with HFpEF and Sarcopenia

Rui Li[1], Rosnani Hashim[1*], Shairyzah Ahmad Hisham[2]

[1]Faculty of Pharmacy, University of Cyberjaya, Cyberjaya, Selangor, Malaysia
[2]Department Faculty of Pharmacy, University of Nottingham Malaysia, Semenyih, Selangor, Malaysia
Email: *rosnani@cyberjaya.edu.my

How to cite this paper: Li, R., Hashim, R. and Hisham, S.A. (2026) A Randomized Controlled Trial to Explore the Effectiveness and Safety of Ba Duan Jin in Elderly Patients with HFpEF and Sarcopenia. *Journal of Biosciences and Medicines*, **14**, 414-435.
https://doi.org/10.4236/jbm.2026.145028

Received: March 31, 2026
Accepted: May 24, 2026
Published: May 27, 2026

Abstract

Background: Impaired exercise tolerance has become one of the key factors affecting the quality of life in elderly patients with heart failure. The presence of sarcopenia not only further reduces quality of life but also increases mortality. Ba Duan Jin has significant benefits in elderly patients with HFpEF and also has positive effects on patients with sarcopenia. However, few studies have examined the safety and efficacy of Ba Duan Jin in elderly patients with HFpEF and sarcopenia. **Objective:** To explore the effectiveness and safety of Ba Duan Jin in elderly patients with HFpEF and sarcopenia. **Study Design:** A target population was recruited and divided into a control group and an experimental group. The experimental group received Ba Duan Jin exercise and was compared with the control group after the exercise in terms of cardiopulmonary exercise testing, six-minute walk distance, the Minnesota Life Quality of Heart Failure Questionnaire, and the Short Physical Performance Battery. **Results:** Compared with the control group, the experimental group showed statistically significant improvements ($P < 0.05$) in exercise endurance parameters, including peak VO_2, anaerobic threshold, six-minute walk distance, the Minnesota Life Quality of Heart Failure Questionnaire, and the Short Physical Performance Board. No adverse events were observed. **Conclusion:** Ba Duan Jin is safe and effective for the target population and is an effective and practical exercise modality.

Keywords

Ba Duan Jin, Elderly, HFpEF, Sarcopenia, Safety

1. Introduction

1.1. Heart Failure (HF)

HF, a clinical syndrome resulting from structural or functional cardiac abnormalities, is commonly characterized by elevated natriuretic peptide levels and/or objective evidence of pulmonary or systemic congestion. Based on left ventricular ejection fraction (LVEF), HF is classified into four categories: HF with reduced ejection fraction (HFrEF, LVEF ≤ 40%), HF with improved ejection fraction (HFimpEF, previous LVEF ≤ 40% and a follow-up measurement of LVEF > 40%), HF with mildly reduced ejection fraction (HFmrEF, LVEF 41% - 49%), and HF with preserved ejection fraction (HFpEF, LVEF ≥ 50%) [1] (**Table 1**).

Table 1. Classification of heart failure.

Type of HF according to LVEF	Criteria
HFrEF (HF with Reduced EF)	LVEF ≤ 40%
HFimpEF (HF with Improved EF)	Previous LVEF ≤ 40% and a Follow-Up Measurement of LVEF > 40%
HFmrEF (HF with Mildly Reduced EF)	LVEF 41% - 49%
HFpEF (HF with Preserved EF)	LVEF ≥ 50%

https://www.acc.org/Latest-in-Cardiology/ten-points-to-remember/2022/03/29/19/53/2022-AHA-ACC-HFSA-Heart-Failure-Guideline-gl-hf

1.2. Sarcopenia

Sarcopenia is commonly observed in elderly patients with heart failure [2]. It is a geriatric clinical syndrome characterized by progressive, age-related loss of systemic muscle mass, accompanied by reduced muscle strength and impaired physiological muscle function [3]. Primarily affecting skeletal muscles, sarcopenia has been found to interact bidirectionally with cardiac function, contributing to the progression of heart failure. In patients with HFpEF, skeletal muscle loss often precedes noticeable weight loss [4]. HFpEF primarily impairs oxygen supply and vasodilation through vascular endothelial damage and dysfunction, which subsequently alters skeletal muscle structure and function, disrupting metabolic balance and oxygen supply, and ultimately leading to exercise intolerance [5]. Current evidence highlights the SARC-CalF scale as the most effective screening tool for sarcopenia, offering enhanced accuracy in identifying patients with this condition [6] [7].

1.3. Epidemiology

With the development of population aging, muscle mass decreases by 1% - 2% per

year after the age of 50, and muscle strength decreases by about 1.5%; after the age of 60, this process accelerates to 3% per year. The European Society of Cardiology's 2016 HF Guidelines consider sarcopenia as an important complication of HF, which requires special attention. In chronic diseases, including HF, it accelerates the process of muscle atrophy [8]-[10]. Heart failure with preserved ejection fraction (HFpEF) is a common HF classification. Its clinical manifestations are often accompanied by frailty. However, frail HFpEF patients are often accompanied by sarcopenia. Sarcopenia may lead to cardiovascular remodeling and dysfunction, and lead to the development of HFpEF through various metabolic and endocrine abnormalities, ultimately leading to a significant increase in the mortality rate of HFpEF patients. Studies have shown [11] that sarcopenia affects the clinical manifestations and clinical endpoints of some HFpEF patients.

1.4. Mechanisms of Sarcopenia and Heart Failure

Heart failure and sarcopenia are inextricably linked. Although the mechanism of sarcopenia in CHF remains unclear, studies have linked it to multiple factors, including angiotensin, proinflammatory cytokines, and myostatin. The main mechanism is summarized as follows: chronic heart failure (HF) is a systemic inflammatory state that produces proinflammatory cytokines. These cytokines activate signaling pathways that stimulate muscle protein degradation through the ubiquitin-proteasome system (UPS) and autophagy-lysosome pathways. This cytokine production stimulates muscle protein degradation by interfering with the insulin-like growth factor-1 (IGF-1)/phosphatidylinositol 3-kinase (PI3K)/protein kinase B (Akt) pathway, inhibiting muscle protein synthesis and promoting myocyte apoptosis, leading to sarcopenia. Furthermore, activation of the renin-angiotensin-aldosterone system (RAAS) increases angiotensin II secretion, directly inducing oxidative stress and upregulating MuRF-1 expression, leading to proteolysis. Angiotensin II can also cause endothelial dysfunction, hindering the delivery of nutrients to muscle, and aldosterone can promote insulin resistance and directly affect muscle catabolism [12] [13]. Due to pathophysiological changes such as increased skeletal muscle protein degradation, decreased synthesis, skeletal muscle fiber transformation, decreased capillary density, impaired blood supply, and decreased mitochondrial function in CHF patients [14], skeletal muscle mass can also be reduced in CHF patients, leading to sarcopenia. In addition, impaired endothelial function in CHF patients can cause pathological changes such as coronary atherosclerosis [15] [16], further leading to the development of sarcopenia.

1.5. Benefits of Aerobic Exercise Training

Aerobic exercise training is not only one of the most effective ways to combat sarcopenia, but also one of the ways to improve exercise endurance in elderly patients with HFpEF. Aerobic exercise can enhance muscle endurance and promote the conversion of myosin heavy chains from fast to slow, which is beneficial for

maintaining muscle function and improving muscle contraction capacity [17]. Studies have found that aerobic exercise can effectively inhibit the expression of apoptotic factors in aging muscle atrophy, improve cell mitochondrial quality, enhance the activity of metabolic enzymes, and thus improve skeletal muscle function [18]. However, considering the physical characteristics of the elderly, the available exercise programs are limited.

1.6. Ba Duan Jin—Aerobic Exercise Suitable for the Elderly

Ba Duan Jin is a traditional Chinese medical and health exercise with gentle stretching movements and is also a meditation exercise that can maximize physical and mental health [19]. Because Ba Duan Jin emphasizes the unity of body and mind, it can convey the concept of traditional Chinese medicine and has advantages in promoting overall personal recovery. Ba Duan Jin does not require specific equipment or venues, nor does it require too many body balance postures. It is easy to learn and has a relatively low tolerance to physical exercise intensity and temperature changes [20]-[22]. To further investigate its effects, we will conduct a randomized controlled trial to evaluate the impact of Ba Duan Jin exercise on elderly patients with HFpEF and sarcopenia, as well as its potential underlying mechanisms.

2. Methods

2.1. Research Objectives

This study aims to investigate the safety and efficacy of the Ba Duan Jin exercise intervention in older adults with sarcopenia and HFpEF.

2.2. Research Procedures

This randomized controlled trial (RCT) was conducted from June to August 2024. All participants provided written informed consent before enrollment. A total of 102 elderly patients with HFpEF were recruited and randomly assigned to two groups in a 1:1 ratio using a computer-generated randomization program. One group served as the experimental group, while the other functioned as the control group. The study design is illustrated in **Figure 1**.

2.3. Diagnostic Criteria

HFpEF diagnostic criteria applied at enrollment included: 1) Signs and symptoms of heart failure; 2) LVEF ≥ 50% by echocardiography; 3) Objective evidence of left ventricular diastolic dysfunction, defined as E/e' ratio ≥ 15 or E/e' ratio 8 - 14 plus NT-proBNP > 220 pg/mL (or BNP > 80 pg/mL), consistent with current guidelines [23]. Sarcopenia risk was identified using the SARC-CalF questionnaire [24], with a score ≥ 11 indicating high risk (**Figure 2**). Comprehensive sarcopenia diagnosis (e.g., muscle mass measurement) was not performed due to equipment limitations, as acknowledged in the Limitations section (**Table 2**).

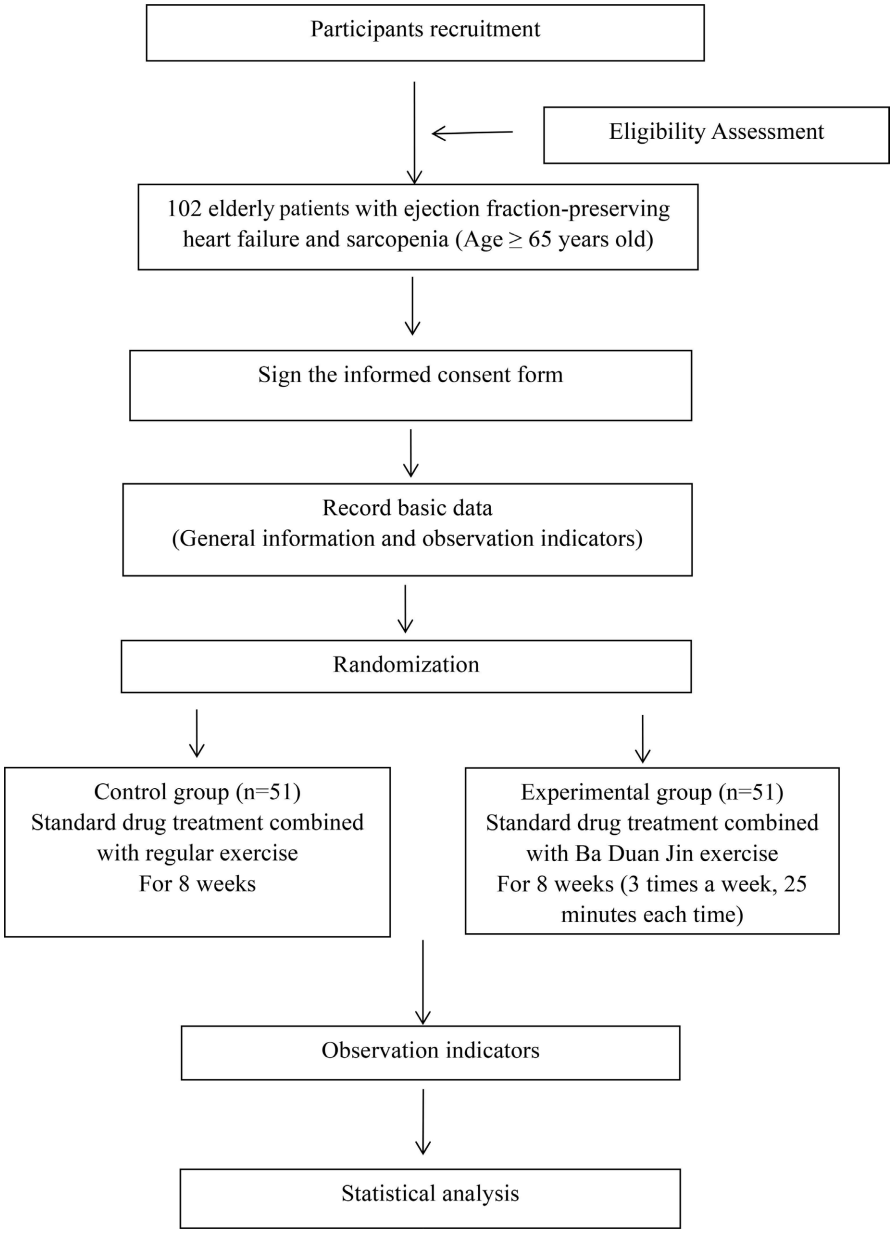

Figure 1. Study of a flow chart.

Table 2. SARC-CalF questionnaire and scoring.

Criteria	Questions	Score
Strength	How much is the difficulty to lift/carry 10 pounds (4.5 kilograms) weight?	0 = no difficulty 1 = some difficulty 2 = a lot of difficulty
Assistance	How much is the difficulty of walking across a room, and whether the use of aid or help is needed?	0 = no difficulty 1 = some difficulty 2 = a lot of difficulty, use aids, or unable to do without personal help

Continued

Rise	How much is the difficulty to transfer from a chair or bed, and whether the use of aid or help is needed?	0 = no difficulty 1 = some difficulty 2 = a lot of difficulty, use aids, or unable to do without personal help
Climb	How much is the difficulty of climbing a flight of 10 steps?	0 = no difficulty 1 = some difficulty 2 = a lot of difficulty
Falls	How many falls have been experienced in the past year?	0 = no fall 1 = 1 - 3 times falls 2 ≥ 3 times falls
Calf Circumference	What is the measurement of the right calf circumference while the legs are relaxed and the feet are 20 cm apart?	Male < 34 cm = 10 points Male ≥ 34 cm = 0 point Female < 33 cm = 10 points Female ≥ 34 m = 0 point

SARC-CalF questionnaire and scoring assessment of the AWGS; A score ≥ 11 points indicates a risk of sarcopenia; From: https://www.researchgate.net/figure/SARC-CalF-questionnaire-and-scoring-assessment-of-the-AWGS_tbl3_366151405.

2.4. Inclusion Criteria

- Elderly patients aged ≥ 65 years with a confirmed diagnosis of HFpEF.
- Screening positive on the SARC-CalF scale with a score of ≥11 points.
- Ability to independently complete the questionnaire survey.
- The capability to walk unaided without any limb disability.
- Physical capacity to perform the full set of Ba Duan Jin exercises.
- Willingness to participate in the study, comply with the intervention plan, and provide signed informed consent.

2.5. Exclusion Criteria

- Patients with serious diseases, such as malignant tumors, cerebrovascular accidents, severe liver disease, severe kidney disease, severe diabetes, thyroid disease, parathyroid disease, etc., have serious negative effects on muscle and bone metabolism.
- Patients with severe heart disease, especially those in the acute stage, are unstable and difficult to move.
- Patients with severe spinal diseases and joint diseases of the limbs.
- Patients with hearing impairment.
- Patients with severe cognitive impairment.

2.6. Main Population

The study population was recruited from outpatient clinics at Kunming Puji Hos-

pital through poster advertisements and health education lectures. The initial target population consisted of elderly patients (aged ≥ 65 years) diagnosed with HFpEF who may also have chronic medical conditions such as hypertension, diabetes, or coronary artery disease, and sarcopenia. Participant eligibility was further assessed based on inclusion and exclusion criteria. All eligible participants received detailed information about the study and signed informed consent before enrollment.

2.7. Randomization, Allocation Concealment, and Blinding

Following the baseline evaluation and informed consent process, eligible participants were randomly assigned to either the control group or the experimental group (Ba Duan Jin exercise group). The random allocation was conducted by a statistician with a mathematics background using a random number generator. The allocation sequence was implemented by a dedicated nurse who was not involved in participant recruitment or intervention activities.

Although blinding the participants and exercise coaches was not feasible, several measures were implemented to ensure blinding of statistical analysts and outcome assessors. Two independent evaluators, not involved in the intervention or allocation process, assessed the participants' outcomes. To minimize bias, participants, exercise coaches, and researchers were instructed not to disclose allocation details. Statistical analysis was conducted by personnel not involved in the trial's execution, and group allocation data were safeguarded with a blind code. The blind code was only revealed after completing the statistical analysis.

No statistically significant differences were observed between the control and experimental groups in baseline characteristics, including age, diastolic blood pressure, systolic blood pressure, and heart rate ($P > 0.05$). Details of baseline characteristics are provided in Table 2.

2.8. Interventions

2.8.1. Control Group

Participants in the control group maintained their usual lifestyle and daily routines throughout the 8-week intervention period. They were instructed not to engage in any structured exercise training beyond their routine activities. To maintain engagement and compliance, regular follow-up calls were made, and small gifts were distributed at study visits. They did not attend the hospital for group exercise sessions.

2.8.2. Experimental Group (Ba Duan Jin)

Ba Duan Jin exercises were conducted in accordance with the "Health Qigong Ba Duan Jin Standards" (General Administration of Sport of China, 2003). Training sessions were held at the hospital's rehabilitation center three times weekly (Monday, Wednesday, Friday) for eight weeks. Each session lasted 40 minutes: 10-minute warm-up, 25 minutes of Ba Duan Jin practice (eight movements, each repeated 6 - 8 times), and 5-minute cool-down. The daily training period was from

09:30 to 10:10 AM, not lasting until 12:00 as previously misstated. Two to three certified instructors supervised each session to ensure correct technique. The training process is detailed in Figure 2.

Figure 2. Eight movements of Ba Duan Jin (Source: created by the authors).

2.8.3. Confounding Bias

To control confounding factors: 1) Control group participants received regular follow-up calls to answer health questions and were given small gifts as incentives, but did not attend exercise sessions. 2) All participants were advised to maintain their usual eating habits and avoid irritating foods. 3) All participants were asked to ensure 6 hours of sleep daily. 4) Experimental group participants completed all Ba Duan Jin sessions as required; control group participants were instructed to avoid moderate- to high-intensity activities and unsafe activities.

2.9. Concomitant Treatment

Participants in both the experimental and control groups maintained their regular medications throughout the study, such as antiplatelet and statin drugs, angiotensin-converting enzyme inhibitors (ACEI), or beta-blockers, and the date and reason for any medication changes were recorded in the case report form (CRF).

2.10. Observation Indicators

2.10.1. Exercise Endurance Index

1) CPET (Cardiopulmonary Exercise Testing)

The evaluation of cardiopulmonary reserve and functional impairment was conducted using the CORTEX METACONTROL 3000 CPET system, providing a com-

prehensive and objective assessment. The test protocol began with a 3-minute resting phase followed by 3 minutes of unloaded cycling. Participants then performed a ramp protocol with incremental workload increases at a rate of 25 W/min.

The test was terminated based on the Borg fatigue scale, as its scores are strongly correlated with cardiopulmonary parameters [25]. Key metrics recorded during the test included peak VO_2 and anaerobic threshold (AT), which are recognized as accurate indicators of exercise capacity [26]. The testing process is depicted in Figure 3.

Figure 3. CORTEX META CONTROL 3000 CPET.
(From: https://www.rhcqmu.com/pc/lists/detail/s/id/1562)

2) Six-Minute Walking Distance (6 MWD)

The six-minute walk distance (6 MWD) test is a straightforward and practical assessment tool used to comprehensively evaluate exercise response and objectively measure cardiopulmonary function and potential injury. The test was conducted in accordance with the guidelines established by the American Thoracic Society [27].

2.10.2. Quality of Life Evaluation Index

1) Minnesota Living with Heart Failure Quality Score (MLHFQ)

The Minnesota Living with Heart Failure Questionnaire (MLHFQ) is a widely utilized tool for the systematic and comprehensive assessment of the condition and quality of life in heart failure patients. It evaluates outcomes across three key domains: physical, emotional, and total score. A higher score indicates a poorer quality of life, while a lower score reflects an improved quality of life. This scale is considered one of the most reliable instruments for assessing the impact of heart failure on patients' daily lives.

2) SPPB

The Short Physical Performance Battery (SPPB) test is recommended for diagnosing decreased exercise capacity, with a score of <10 points serving as the diagnostic threshold. This makes the SPPB a valuable tool for assessing recovery in exercise endurance [28]. The evaluation process is illustrated in Figure 4.

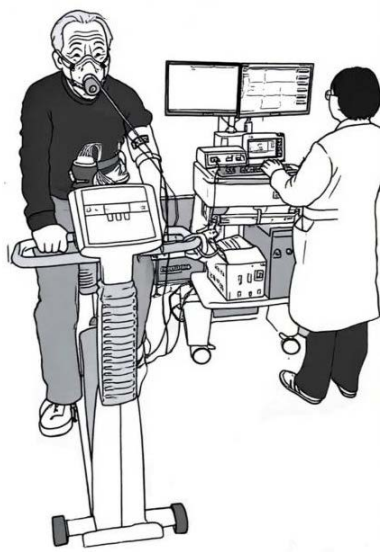

Figure 4. Short Physical Performance Battery (SPPB), including balance test, gait speed test, and chair stand test. From: multi-domain lifestyle intervention in older adults after myocardial infarction: rationale and design of the PIpELINe randomized clinical trial.

2.11. Adverse Events (AEs)

All clinical trials may experience adverse events (AEs). AEs are classified as serious or non-serious, expected or unexpected, study-related, possibly study-related, or unrelated [29] (**Table 3**).

Table 3. Definitions of adverse events and serious adverse events.

Term	Definition
Adverse Event (AE)	Any untoward medical occurrence in a patient or clinical investigation subject administered a pharmaceutical product, which does not necessarily have to have a causal relationship with this treatment.
Serious Adverse Event (SAE)	Any untoward medical occurrence that at any dose: a) Results in death b) Is life-threatening c) Requires inpatient hospitalisation or prolongation of existing hospitalisation d) Results in persistent or significant disability/incapacity e) ls a congenital anomaly/birth defect (SAEs will be a subset of AEs)

Definitions as described by the International Council for Harmonisation (ICH). From: https://link.springer.com/article/10.1186/s13063-020-04718-z/tables/1.

In this study, researchers prepared case report forms. If an adverse event occurred, the researchers filled it out according to the International Council for Harmonisation (ICH) adverse event classification criteria and notified the ethics com-

mittee, which evaluated the situation and decided whether the participant should be withdrawn from the trial.

2.12. Data Collection

Researchers will collect participants' demographic characteristics at the time of recruitment. Additionally, data on quality of life and exercise tolerance will be gathered at both the baseline and the conclusion of the intervention period to assess changes and outcomes.

2.13. Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. The significance level was set at 0.05. The obtained data were carefully verified, cleaned, and correctly entered into SPSS. Exploratory data analysis was performed to ensure correct data entry and detect outliers and missing data. For all continuous variables, normality was tested using graphical methods (histograms, normal QQ plots, stem-and-leaf plots, and boxplots) and other statistical methods (skewness and kurtosis ratios). Descriptive statistics were used to analyze the means and standard deviations of the demographics. Data were analyzed using paired-sample t-tests and repeated-measures analysis of variance (ANOVA). The P-values of the analyses were compared with a significance level of $\alpha = 0.05$ (95% confidence interval), providing 8% power to detect the effect of the intervention. The outcome variables were analyzed using intention-to-treat (ITT) analysis.

The normality of the data distribution ($P > 0.05$) will be assessed using the Shapiro-Wilk test. For qualitative variables, exact tests will be used to determine mean differences between two groups (dichotomous data). If the data follow a normal distribution, a paired sample t-test will be employed to compare differences between two samples. For data that do not conform to a normal distribution, the nonparametric Mann-Whitney U test will be applied. A P-value of less than 0.05 will be considered statistically significant.

3. Result

3.1. Baseline Characteristics

A total of 102 participants were enrolled and randomized to the Ba Duan Jin group (n = 51) or the control group (n = 51). Baseline demographic and clinical characteristics were comparable between the two groups, with no significant differences in age, sex distribution, comorbidities, or baseline outcome measures (Table 4).

Table 4. Comparison of two groups demographics.

Category	Control (N = 51)	Experiment (N = 51)	P Value
Sex (female)	21	19	>0.05
Age (y)	69 ± 3.6	70.1 ± 3.6	

Continued

SBP (mmHg)	130.36 ± 11.25	126.25 ± 6.98
DBP (mmHg)	72.50 ± 8.20	71.20 ± 8.10
HR (bpm)	82.61 ± 6.83	77.26 ± 8.71
History		
CAD	23	28
T_2DM	18	22
HBP	48	49
Stroke	30	32
COPD	28	31
Smoking		
Ex-Smoker	5	5
Current Smoker	25	27
Medicine		
ACEI	26	15
ARB	27	36
β-Blocker	33	39
CCB	13	16
Anti-Platelet Drugs	47	49
Statin Drugs	49	50
Diabetes Medication	12	10
Insulin	6	12
NYHA Classification		
II	36	33
III	15	18

3.2. Comparison of the Main Exercise Endurance Results between the Two Groups

3.2.1. 6-Minute Walking Distance

No statistically significant difference in the 6-minute walking distance between the control group and the experimental group before the intervention; after 8 weeks, the 6-minute walking distance of the experimental group was significantly improved compared with that before the intervention ($P < 0.05$), and was higher than that of the control group ($P < 0.05$); there was no statistically significant difference in the control group before and after the intervention ($P > 0.05$) in Table 5.

3.2.2. Cardiopulmonary Exercise Testing

At baseline, there was no significant difference in peak VO_2 and AT between the control group and the experimental group before intervention. After 8 weeks,

peak VO_2 and AT were significantly improved compared with those before intervention ($P < 0.05$), and exceeded those of the control group ($P < 0.05$). Before and after the intervention, there was no discernible change in the control group ($P > 0.05$). Details are presented in Table 6 & Table 7.

Table 5. Comparison of AT between two groups before and after Ba Duan Jin intervention [$\overline{\chi} \pm S$, mL/min/kg].

Category	Sample	Anaerobic Threshold, mL/min/kg		t	P
		Before	After		
Control	51	7.52 ± 1.15	7.65 ± 1.12	0.57	0.56
Experiment	51	7.48 ± 1.01	12.77 ± 1.11	20.4	<0.05
t		−0.38	−23.13		
P		0.70	<0.05		

Table 6. Comparison of peak VO_2 between two groups before and after Ba Duan Jin intervention [$\overline{\chi} \pm S$, mL/min/kg].

Category	Sample	Peak VO_2, mL/min/kg		t	P
		Before	After		
Control	51	12.39 ± 1.38	12.66 ± 1.31	2.15	0.36
Experiment	51	13.22 ± 1.34	15.04 ± 1.25	7.45	<0.05
t		−1.02	−7.06		
P		0.30	<0.05		

Table 7. Comparison emotional domain of MLHFQ between the two groups before and after Ba Duan Jin intervention [$\overline{\chi} \pm S$].

Category	Sample	Emotional Domain		t	P
		Before	After		
Control	51	16.56 ± 3.03	16.96 ± 2.92	−2.21	0.32
Experiment	51	15.78 ± 3.06	12.13 ± 2.39	13.74	<0.05
t		1.46	9.06		
P		>0.05	<0.05		

3.2.3. Minnesota Living with Heart Failure Quality Score

There was no significant difference in the Minnesota Heart Failure Quality Index between the control group and the experimental group before the intervention. After 8 weeks of intervention, the Physical domain, Emotional domain, and Overall score of the experimental group showed a downward trend compared with the baseline ($P < 0.05$), and were greater than the control group ($P < 0.05$). Before and after the intervention, there was no discernible change in the control group ($P > 0.05$) (Tables 8-10).

3.2.4. SPPB

After 8 weeks, SPPB (including balance test, gait speed test, chair stand test) was significantly improved compared with those before intervention ($P < 0.05$). Details are presented in Table 9.

Table 8. Comparison of the physical domain of MLHFQ between two groups before and after Ba Duan Jin intervention [$\overline{\chi} \pm S$].

Category	Sample	Physical Domain		t	P
		Before	After		
Control	51	19.45 ± 3.11	19.90 ± 3.23	−0.110	0.27
Experiment	51	19.94 ± 2.96	17.29 ± 3.43	5.23	<0.05
t		−0.68	3.95		
P		>0.05	<0.05		

Table 9. Comparison of the overall score of MLHFQ between two groups before and after Ba Duan Jin intervention [$\overline{\chi} \pm S$].

Category	Sample	Overall Score		t	P
		Before	After		
Control	51	43.86 ± 6.43	45.45 ± 6.76	−2.57	0.13
Experiment	51	42.11 ± 5.54	30.92 ± 5.45	14.95	<0.05
t		1.47	11.96		
P		0.144	<0.05		

Table 10. Comparison of SPPB (three physical fitness parameters) between two groups before and after Ba Duan Jin intervention (after 8 weeks).

Characteristics	Control (N = 51)		Experiment (N = 51)		Z	P
	Before	After	Before	After		
Balance Test	2.5 (2, 4)	2.4 (2, 4)	2.6 (2, 3)	2.3 (1, 4)	−2.97*	0.03
Gait Speed Test	2.7 (2, 4)	2.5 (1, 4)	3.0 (2, 4)	3.4 (2, 4)	−3.19*	0.01
Chair Stand Test	3.1 (2, 4)	3.1 (2, 4)	2.9 (2, 4)	3.4 (2, 4)	−3.54***	<0.001

*P < 0.05, **P < 0.01, ***P < 0.001.

4. Discussion

Heart failure with preserved ejection fraction (HFpEF) is a type of heart failure that is becoming increasingly common, especially among the elderly. HFpEF is often associated with multiple risk factors such as hypertension, diabetes, obesity, and atrial fibrillation. From the perspective of the pathophysiology of HFpEF, these factors will promote systemic inflammatory response, cause mitochondrial function decline, lead to endothelial dysfunction, and thus cause changes in myocardial structure and function. At the same time, the decline of mitochondria will

also lead to skeletal muscle dysfunction and then cause a decrease in exercise endurance Despite significant advances and ongoing innovations in the pharmacotherapy of HF such as conventional drugs, Mineralocorticoid receptor antagonists (MRAs), sodium-glucose cotransporter2 (SGLT-2) inhibitors, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), angiotensin receptor-neprilysin inhibitors (ARNIs) and β-blockers and sodium-glucose cotransporter2 (SGLT-2) inhibitors, these drugs have already made significant progress in treating heart failure and have been proven to reduce morbidity and mortality in a wide range of HF patients [30]. Due to the complex pathophysiology of HFpEF, although many studies have focused on finding effective drugs for HFpEF, no drug treatment in HFpEF trials can prove to reduce all-cause or cardiovascular mortality [31].

Clinical investigations have indicated that while therapies such as angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), and aldosterone receptor antagonists are effective for heart failure with reduced ejection fraction (HFrEF), their therapeutic efficacy is less satisfactory in patients with HFpEF. Conversely, exercise rehabilitation has been demonstrated to enhance exercise endurance, improve clinical condition, and positively impact prognosis in HFpEF patients. The 2023 Chinese Expert Consensus on the Diagnosis and Treatment of Heart Failure with Preserved Ejection Fraction recommends exercise rehabilitation therapy as an effective strategy to improve exercise tolerance and quality of life in patients with HFpEF [32].

A growing body of research highlights three primary physiological mechanisms underlying exercise limitation in HFpEF: 1) the impact of cardiac function on exercise capacity, 2) the influence of vascular function, and 3) the role of skeletal muscle dysfunction [33] [34]. These findings underscore that the pathophysiological manifestations of HFpEF are primarily attributed to impaired exercise function.

Research has highlighted the significant benefits of Ba duan jin for HFpEF patients through extensive experimental studies and analyses. Results indicate that exercise rehabilitation enhances exercise endurance, improves endothelial function, reduces sympathetic nerve tone, and strengthens skeletal muscle endurance and functionality [35]. The main reasons are:

1) Skeletal Muscle

a) Exercise training can activate the AMPK/PGC-1α signaling pathway in skeletal muscle, increase mitochondrial density and oxidase activity in skeletal muscle, thereby improving fatty acid oxidation capacity and directly increasing AT [36].

b) Exercise can induce the expression of vascular endothelial growth factor (VEGF), promote skeletal muscle capillary angiogenesis, shorten oxygen diffusion distance, improve oxygen uptake efficiency, and ultimately increase Peak VO_2 [37].

2) Endothelial Function

Exercise can increase endothelial nitric oxide synthase (eNOS) activity, reduce the inactivation of NO by reactive oxygen species (ROS), improve peripheral vas-

cular resistance, reduce cardiac afterload, improve the role of endothelial function in promoting oxygen transport, and increase cardiac output (CO) and oxygen delivery (DO_2) simultaneously, promoting the increase of Peak VO_2.

3) Reduced Sympathetic Tone and Optimized Cardiopulmonary Efficiency

a) Enhanced baroreflex sensitivity: Exercise training inhibits central sympathetic nerve activity (such as regulating the excitability of neurons in the RVLM area), reduces resting heart rate and plasma norepinephrine levels, and reduces myocardial oxygen consumption (MVO_2), thereby improving cardiopulmonary reserve during exercise [38].

b) Improved ventricular-vascular coupling: Reduced sympathetic tone can reduce arterial stiffness (by inhibiting the RAAS system), optimize ventricular contraction-diastole coordination, indirectly increase stroke volume, and thus increase Peak VO_2.

In this study, after 8 weeks of Ba Duan Jin exercise, the experimental group demonstrated substantial improvements in exercise endurance indicators: six-minute walk distance (6 MWD) increased from 223.38 ± 16.05 pre-intervention to 262.13 ± 12.10 post-intervention ($P < 0.05$); peak VO_2 improved from 13.22 ± 1.34 to 15.04 ± 1.25 ($P < 0.05$); and anaerobic threshold (AT) rose from 8.48 ± 1.01 to 12.77 ± 1.11 ($P < 0.05$).

Furthermore, sarcopenia is increasingly recognized as a prevalent comorbidity among the elderly. Epidemiological studies report that approximately 10% of individuals aged ≥ 65 years in the general population are affected by sarcopenia, with prevalence rates rising to 25% - 50% among those aged ≥ 85 years [39]. International studies also reveal a strong association between sarcopenia and heart failure, with 30% - 52% of patients with chronic heart failure diagnosed with sarcopenia. These patients tend to be older, exhibit more comorbidities, and have elevated levels of B-type natriuretic peptide (BNP) [40].

The association between sarcopenia and heart failure with preserved ejection fraction (HFpEF) in the elderly is complex and multifactorial. Sarcopenia and HFpEF share several common risk factors, such as aging, sedentary lifestyle, and other comorbidities. The main causes of sarcopenia in HFpEF are: 1) Chronic systemic inflammation and muscle catabolism, 2) Metabolic disturbances and inhibition of synthesis, 3) Decreased exercise tolerance and deconditioning effects, 4) Neurohormonal activation and muscle sympathetic hyperexcitability. These causes contribute to the development and progression of both diseases.

The main causes of sarcopenia in HFpEF are [41] [42]: 1) Chronic systemic inflammation and muscle catabolism, 2) Metabolic disorders and synthesis inhibition, 3) Decreased exercise tolerance and deconditioning effects, 4) Neurohormonal activation and overexcitation of muscle sympathetic nerves.

Research indicates that exercise training is currently the most effective intervention for addressing sarcopenia in patients with chronic heart failure [43]. A meta-analysis by Keteyian [43]. Demonstrated that exercise training enhances exercise endurance, improves vascular endothelial function, reduces sympathetic

nerve tension, increases skeletal muscle strength and endurance, and boosts skeletal muscle oxidase activity.

Decreased exercise tolerance, a hallmark of sarcopenia in the elderly, has been formally recognized in the Chinese Expert Consensus on the Multidisciplinary Decision-Making Model for addressing reduced exercise capacity in the elderly [44]. This consensus recommends the Short Physical Performance Battery (SPPB) as a screening tool for diminished exercise tolerance, with an SPPB score < 10 points serving as the diagnostic threshold for reduced exercise capacity (recommendation level: A).

Ba Duan Jin, an ancient form of Chinese Qigong, is gaining attention as a novel, low-intensity exercise method suitable for older adults and individuals with chronic medical conditions, including cardiovascular diseases. Combining body movement, controlled breathing, and mental focus, Ba Duan Jin has been shown to enhance exercise tolerance and physical performance.

The results of this study showed that after 8 weeks of Ba Duan Jin training, we could find that the SPPB (including balance test, gait speed test, chair stand test) exercise capacity of the experimental group was significantly improved compared with the pre-intervention level ($P < 0.05$). This highlights the potential of Ba Duan Jin as an effective rehabilitation exercise for elderly patients with sarcopenia and HFpEF.

In addition to its physical benefits, Ba Duan Jin integrates meditative elements and mindful breathing, which play a crucial role in promoting mental health and addressing psychological issues. Previous studies have demonstrated that Ba Duan Jin significantly improves quality of life [45], aligning with the findings of this study. After 8 weeks of Ba Duan Jin practice, the experimental group exhibited a marked reduction in the total score on the Minnesota Living with Heart Failure Questionnaire (MLHFQ), indicating improved quality of life (Overall score, 43.86 ± 6.43 before intervention vs. Overall score 30.92 ± 5.45 after intervention, $P < 0.05$).

Furthermore, no adverse events were reported during the 8-week follow-up period, underscoring the high safety profile of Ba Duan Jin as an exercise intervention.

5. Limitation

We acknowledge several limitations in our study. First, as the research was conducted in a primary medical institution with limited equipment, sarcopenia was only screened rather than comprehensively diagnosed. The study relied on the Short Physical Performance Battery (SPPB) as the sole observation metric, without incorporating diagnostic criteria established by the Asian Working Group for Sarcopenia (AWGS). This limitation may have influenced the trial outcomes to some extent. Second, the sample size was relatively small, which may limit the generalizability of the findings and prevent the results from fully representing broader population characteristics. Future studies should aim to include larger sample sizes

to enhance representativeness and statistical power.

6. Conclusions

Ba Duan Jin has been demonstrated to be a safe and effective intervention for elderly patients with heart failure with preserved ejection fraction (HFpEF) and sarcopenia. This traditional Chinese exercise not only significantly improves exercise tolerance, physical performance, and quality of life but also incorporates meditative and mindful breathing components that enhance mental health and psychological well-being. Importantly, no adverse events were reported during the study, underscoring its high safety profile.

Given its accessibility, low physical intensity, and adaptability to varying fitness levels, Ba Duan Jin is particularly suitable for elderly populations. It offers a holistic approach that addresses both the physical and mental health challenges associated with HFpEF and sarcopenia. As a cost-effective, low-risk intervention, Ba Duan Jin is highly recommended for broader implementation in clinical and community settings to improve the overall well-being of older adults.

Ethics Statement

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Kunming Puji Hospital. The study was registered prospectively in the ISRCTN registry (ISRCTN16443494). The present article was based on data collected as part of the registered study protocol.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Heidenreich, P.A., Bozkurt, B., Aguilar, D., *et al.* (2022) 2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure: Executive Summary: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*, **145**, e876-e894.

[2] Boureau, A., Annweiler, C., Belmin, J., Bouleti, C., Chacornac, M., Chuzeville, M., *et al.* (2022) Practical Management of Frailty in Older Patients with Heart Failure. *ESC Heart Failure*, **9**, 4053-4063. https://doi.org/10.1002/ehf2.14040

[3] Emami, A., Saitoh, M., Valentova, M., Sandek, A., Evertz, R., Ebner, N., *et al.* (2018) Comparison of Sarcopenia and Cachexia in Men with Chronic Heart Failure: Results from the Studies Investigating Co-Morbidities Aggravating Heart Failure (SICA-HF). *European Journal of Heart Failure*, **20**, 1580-1587. https://doi.org/10.1002/ejhf.1304

[4] Kim, S., Kim, T. and Hwang, H. (2013) The Relationship of Physical Activity (PA) and Walking with Sarcopenia in Korean Males Aged 60 Years and Older Using the Fourth Korean National Health and Nutrition Examination Survey (KNHANES IV-2, 3), 2008-2009. *Archives of Gerontology and Geriatrics*, **56**, 472-477. https://doi.org/10.1016/j.archger.2012.12.009

[5] Ryu, M., Jo, J., Lee, Y., *et al.* (2013) Association of Physical Activity with Sarcopenia and Sarcopenic Obesity in Community-Dwelling Older Adults: The Fourth Korea

National Health and Nutrition Examination Survey. *Age and Ageing*, **42**, 734-740. https://doi.org/10.1093/ageing/aft063

[6] Deng, X.T. (2023) A Systematic Review of Risk Screening and Assessment Tools for Sarcopenia in the Elderly. *Journal of Nursing Continuing Education*, **38**, 145-150.

[7] Chen, L., Liu, L., Woo, J., Assantachai, P., Auyeung, T., Bahyah, K.S., *et al.* (2014) Sarcopenia in Asia: Consensus Report of the Asian Working Group for Sarcopenia. *Journal of the American Medical Directors Association*, **15**, 95-101. https://doi.org/10.1016/j.jamda.2013.11.025

[8] Pellicori, P., Kallvikbacka-Bennett, A., Khaleva, O., Carubelli, V., Costanzo, P., Castiello, T., *et al.* (2014) Global Longitudinal Strain in Patients with Suspected Heart Failure and a Normal Ejection Fraction: Does It Improve Diagnosis and Risk Stratification? *The International Journal of Cardiovascular Imaging*, **30**, 69-79. https://doi.org/10.1007/s10554-013-0310-y

[9] von Haehling, S., Morley, J.E. and Anker, S.D. (2010) An Overview of Sarcopenia: Facts and Numbers on Prevalence and Clinical Impact. *Journal of Cachexia, Sarcopenia and Muscle*, **1**, 129-133. https://doi.org/10.1007/s13539-010-0014-2

[10] Borlaug, B.A., Melenovsky, V., Russell, S.D., Kessler, K., Pacak, K., Becker, L.C., *et al.* (2006) Impaired Chronotropic and Vasodilator Reserves Limit Exercise Capacity in Patients with Heart Failure and a Preserved Ejection Fraction. *Circulation*, **114**, 2138-2147. https://doi.org/10.1161/circulationaha.106.632745

[11] Bekfani, T., Pellicori, P., Morris, D.A., Ebner, N., Valentova, M., Steinbeck, L., *et al.* (2016) Sarcopenia in Patients with Heart Failure with Preserved Ejection Fraction: Impact on Muscle Strength, Exercise Capacity and Quality of Life. *International Journal of Cardiology*, **222**, 41-46. https://doi.org/10.1016/j.ijcard.2016.07.135

[12] Meier, N.F. and Lee, D.C. (2020) Physical Activity and Sarcopenia in Older Adults. *Aging Clinical and Experimental Research*, **32**, 1675-1687. https://doi.org/10.1007/s40520-019-01371-8

[13] Fauzi, A., Idrial, D. and Asdi, A.R.B. (2022) Clinical Importance of Sarcopenia and How It Impacts Orthopaedic-Trauma Patients and the Surgical Outcomes. *Folia Medica Indonesiana*, **58**, 355-363. https://doi.org/10.20473/fmi.v58i4.35971

[14] Loncar, G., Fülster, S., von Haehling, S. and Popovic, V. (2013) Metabolism and the Heart: An Overview of Muscle, Fat, and Bone Metabolism in Heart Failure. *International Journal of Cardiology*, **162**, 77-85. https://doi.org/10.1016/j.ijcard.2011.09.079

[15] Pugliese, N.R., Fabiani, I., Mandoli, G.E., Guarini, G., Galeotti, G.G., Miccoli, M., *et al.* (2018) Echo-Derived Peak Cardiac Power Output-to-Left Ventricular Mass with Cardiopulmonary Exercise Testing Predicts Outcome in Patients with Heart Failure and Depressed Systolic Function. *European Heart Journal—Cardiovascular Imaging*, **20**, 700-708. https://doi.org/10.1093/ehjci/jey172

[16] Ziaaldini, M.M., Marzetti, E., Picca, A. and Murlasits, Z. (2017) Biochemical Pathways of Sarcopenia and Their Modulation by Physical Exercise: A Narrative Review. *Frontiers in Medicine*, **4**, Article 167. https://doi.org/10.3389/fmed.2017.00167

[17] Liao, Z., Chen, J., Xiao, M., Sun, Y., Zhao, Y., Pu, D., *et al.* (2017) The Effect of Exercise, Resveratrol or Their Combination on Sarcopenia in Aged Rats via Regulation of AMPK/Sirt1 Pathway. *Experimental Gerontology*, **98**, 177-183. https://doi.org/10.1016/j.exger.2017.08.032

[18] Zou, L., Pan, Z., Yeung, A., Talwar, S., Wang, C., Liu, Y., *et al.* (2018) A Review Study on the Beneficial Effects of Baduanjin. *The Journal of Alternative and Complementary Medicine*, **24**, 324-335. https://doi.org/10.1089/acm.2017.0241

[19] Xia, R., Qiu, P., Lin, H., Ye, B., Wan, M., Li, M., *et al.* (2019) The Effect of Traditional

Chinese Mind-Body Exercise (Baduanjin) and Brisk Walking on the Dorsal Attention Network in Older Adults with Mild Cognitive Impairment. *Frontiers in Psychology*, **10**, Article 2075. https://doi.org/10.3389/fpsyg.2019.02075

[20] Fang, J., Zhang, L., Wu, F., Ye, J., Cai, S. and Lian, X. (2021) The Safety of Baduanjin Exercise: A Systematic Review. *Evidence-Based Complementary and Alternative Medicine*, **2021**, 1-11. https://doi.org/10.1155/2021/8867098

[21] Ding, W., You, T., Gona, P.N. and Milliken, L.A. (2020) Validity and Reliability of a Chinese Rating of Perceived Exertion Scale in Young Mandarin Speaking Adults. *Sports Medicine and Health Science*, **2**, 153-158. https://doi.org/10.1016/j.smhs.2020.08.001

[22] Borlaug, B.A., Sharma, K., Shah, S.J. and Ho, J.E. (2023) Heart Failure with Preserved Ejection Fraction. *Journal of the American College of Cardiology*, **81**, 1810-1834. https://doi.org/10.1016/j.jacc.2023.01.049

[23] Kerminen, H., Jyväkorpi, S., Urtamo, A., Huhtala, H., Öhman, H., Calvani, R., *et al.* (2024) Performance of the SARC-F, SARC-CalF, and Calf Circumference for Sarcopenia Case Finding in Community-Dwelling Older Adults. *European Geriatric Medicine*, **15**, 1817-1826. https://doi.org/10.1007/s41999-024-01060-4

[24] Morishita, S., Tsubaki, A., Hotta, K., Kojima, S., Sato, D., Shirayama, A., *et al.* (2021) Relationship between the Borg Scale Rating of Perceived Exertion and Leg-Muscle Deoxygenation during Incremental Exercise in Healthy Adults. In: *Advances in Experimental Medicine and Biology*, Springer, 95-99. https://doi.org/10.1007/978-3-030-48238-1_15

[25] Albouaini, K., Egred, M., Alahmar, A., *et al.* (2007) Cardiopulmonary Exercise Testing and Its Application. *Heart*, **93**, 1285-1292.

[26] ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories (2002) ATS Statement: Guidelines for the Six-Minute Walk Test. *American Journal of Respiratory and Critical Care Medicine*, **166**, 111-117.

[27] Xiang, B., Zhang, R., Wu, X. and Zhou, X. (2022) Optimal Pharmacologic Treatment of Heart Failure with Preserved and Mildly Reduced Ejection Fraction: A Meta-Analysis. *JAMA Network Open*, **5**, e2231963. https://doi.org/10.1001/jamanetworkopen.2022.31963

[28] Amalberti, R., Benhamou, D., Auroy, Y. and Degos, L. (2011) Adverse Events in Medicine: Easy to Count, Complicated to Understand, and Complex to Prevent. *Journal of Biomedical Informatics*, **44**, 390-394. https://doi.org/10.1016/j.jbi.2009.06.004

[29] Chinese Medical Association Geriatrics Branch (2024) Chinese Expert Consensus on Multidisciplinary Decision-Making Model for Decreased Exercise Capacity in the Elderly (2024 Edition). *Chinese Medical Journal*, **104**, 893-905.

[30] Tucker, W.J., Angadi, S.S., Haykowsky, M.J., Nelson, M.D., Sarma, S. and Tomczak, C.R. (2020) Pathophysiology of Exercise Intolerance and Its Treatment with Exercise-Based Cardiac Rehabilitation in Heart Failure with Preserved Ejection Fraction. *Journal of Cardiopulmonary Rehabilitation and Prevention*, **40**, 9-16. https://doi.org/10.1097/hcr.0000000000000481

[31] Miranda-Silva, D., Lima, T., Rodrigues, P., Leite-Moreira, A. and Falcão-Pires, I. (2021) Mechanisms Underlying the Pathophysiology of Heart Failure with Preserved Ejection Fraction: The Tip of the Iceberg. *Heart Failure Reviews*, **26**, 453-478. https://doi.org/10.1007/s10741-020-10042-0

[32] Ma, L.Y. (2022) Summary of "China Cardiovascular Health and Disease Report 2021." *Chinese Journal of Interventional Cardiology*, **30**, 481-496.

[33] Krieger, J., McCann, N., Bluhm, M. and Zuhl, M. (2022) Exercise Prescription and

Progression Practices among US Cardiac Rehabilitation Clinics. *Clinics and Practice*, **12**, 194-203. https://doi.org/10.3390/clinpract12020023

[34] Keteyian, S.J., Leifer, E.S., Houston-Miller, N., Kraus, W.E., Brawner, C.A., O'Connor, C.M., *et al.* (2012) Relation between Volume of Exercise and Clinical Outcomes in Patients with Heart Failure. *Journal of the American College of Cardiology*, **60**, 1899-1905. https://doi.org/10.1016/j.jacc.2012.08.958

[35] Liang, J., Zhang, H., Zeng, Z., Wu, L., Zhang, Y., Guo, Y., *et al.* (2021) Lifelong Aerobic Exercise Alleviates Sarcopenia by Activating Autophagy and Inhibiting Protein Degradation via the AMPK/PGC-1α Signaling Pathway. *Metabolites*, **11**, Article 323. https://doi.org/10.3390/metabo11050323

[36] Hendrickse, P. and Degens, H. (2019) The Role of the Microcirculation in Muscle Function and Plasticity. *Journal of Muscle Research and Cell Motility*, **40**, 127-140. https://doi.org/10.1007/s10974-019-09520-2

[37] Haitsma, D., Merkus, D., Boomsma, F., *et al.* (2003) Alterations in Hemodynamic and Neurohumoral Responses to Exercise in Swine with Left Ventricular Remodeling Early after Myocardial Infarction: Role of Blunted NO Bioavailability. *Cardiac Remodeling and Failure*, **26**, 205-230.

[38] Fuertes-Kenneally, L., Manresa-Rocamora, A., Blasco-Peris, C., Ribeiro, F., Sempere-Ruiz, N., Sarabia, J.M., *et al.* (2023) Effects and Optimal Dose of Exercise on Endothelial Function in Patients with Heart Failure: A Systematic Review and Meta-Analysis. *Sports Medicine—Open*, **9**, Article No. 8. https://doi.org/10.1186/s40798-023-00553-z

[39] Chen, D., Yu, W., Hung, H., Tsai, J., Wu, H. and Chiou, A. (2017) The Effects of Baduanjin Exercise on Fatigue and Quality of Life in Patients with Heart Failure: A Randomized Controlled Trial. *European Journal of Cardiovascular Nursing*, **17**, 456-466. https://doi.org/10.1177/1474515117744770

[40] Ratchford, S.M., Lee, J.F., Bunsawat, K., Alpenglow, J.K., Zhao, J., Ma, C.L., *et al.* (2022) The Impact of Obesity on the Regulation of Muscle Blood Flow during Exercise in Patients with Heart Failure with a Preserved Ejection Fraction. *Journal of Applied Physiology*, **132**, 1240-1249. https://doi.org/10.1152/japplphysiol.00833.2021

[41] Kumar, A.A., Kelly, D.P. and Chirinos, J.A. (2019) Mitochondrial Dysfunction in Heart Failure with Preserved Ejection Fraction. *Circulation*, **139**, 1435-1450. https://doi.org/10.1161/circulationaha.118.036259

[42] Takeyoshi, M., Togami, W., Hiyama, K., Takashio, S., Arima, Y., Tsujita, K., *et al.* (2023) Investigating Gait Speed as the Index of Exercise Tolerance in Heart Failure with Preserved Ejection Fraction. *Journal of Modern Rehabilitation*, **18**, 93-105. https://doi.org/10.18502/jmr.v18i1.14734

[43] Wang, R., Duan, J., Liu, W., Huang, K., Chen, Z., Yang, C., *et al.* (2022) The Role of Sarcopenia in Heart Failure with Depression. *Reviews in Cardiovascular Medicine*, **23**, 296. https://doi.org/10.31083/j.rcm2309296

[44] Yin, J., Lu, X., Qian, Z., Xu, W. and Zhou, X. (2019) New Insights into the Pathogenesis and Treatment of Sarcopenia in Chronic Heart Failure. *Theranostics*, **9**, 4019-4029. https://doi.org/10.7150/thno.33000

[45] Lenk, K., Erbs, S., Höllriegel, R., Beck, E., Linke, A., Gielen, S., *et al.* (2012) Exercise Training Leads to a Reduction of Elevated Myostatin Levels in Patients with Chronic Heart Failure. *European Journal of Preventive Cardiology*, **19**, 404-411. https://doi.org/10.1177/1741826711402735

List of Abbreviations

Abbreviations	Definition
ACEI	Angiotensin-Converting Enzyme Inhibitors
AEs	Adverse Events
ACE	Angiotensin-Converting Enzyme
ARBs	Angiotensin Receptor Blockers
ARNIs	Angiotensin Receptor-Neprilysin Inhibitors
AT	Anaerobic Threshold
AWGS	Asian Working Group for Sarcopenia
CHF	Chronic Heart failure
CRF	Case Report Form
CO	Cardiac Output
CPET	Cardiopulmonary Exercise Testing
DO_2	Oxygen Delivery
eNOS	Endothelial Nitric Oxide Synthase
HF	Heart Failure
HFrEF	HF with Reduced Ejection Fraction
HFmrEF	HF with Mildly Reduced Ejection Fraction
HFpEF	HF with Preserved Ejection Fraction
HFimpEF	HF with Improved EF
LVEF	Left Ventricular Ejection Fraction
MLHFQ	Minnesota Living with Heart Failure Quality Score
MVO_2	Myocardial Oxygen Consumption
MRAs	Mineralocorticoid Receptor Antagonists
ROS	Reactive Oxygen Species
RAAS	Renin-Angiotensin-Aldosterone System
RCT	Randomized Controlled Trial
SARC-Calf	SARC-F Combined with Calf Circumference
SPPB	Short Physical Performance Battery
SGLT-2	Sodium-Glucose Cotransporter-2
6 MWD	Six-Minute Walk Distance
VEGF	Vascular Endothelial Growth Factor