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Original Research Article

Effect of High-Intensity Interval Training on Functional Capacity in Patients with Chronic Heart Failure: A Prospective Cohort Study

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Abstract

Background: Exercise training is a cornerstone of cardiac rehabilitation in chronic heart failure (CHF), yet the optimal training modality remains debated. High-intensity interval training (HIIT) has demonstrated superior physiological adaptations compared to moderate-intensity continuous training (MICT) in various cardiovascular populations, but evidence regarding its efficacy and safety specifically in CHF patients with diverse functional severity remains limited and inconsistent.

Methods: This prospective cohort study enrolled 194 stable CHF patients (left ventricular ejection fraction ≤45%; NYHA class II–III) at a university-affiliated cardiac rehabilitation center between March 2020 and November 2023. Patients self-selected into a 12-week supervised HIIT program (n = 98; 4×4-minute intervals at 85–95% peak heart rate) or a matched-duration MICT program (n = 96; continuous exercise at 60–70% peak heart rate), performed three times weekly. Primary outcome was change in peak oxygen consumption (peak VO_2) assessed via cardiopulmonary exercise testing. Secondary outcomes included six-minute walk distance (6MWD), left ventricular ejection fraction (LVEF), Minnesota Living with Heart Failure Questionnaire (MLHFQ) scores, and adverse event rates.

Results: The HIIT group demonstrated significantly greater improvement in peak VO_2 compared to MICT (+3.4 ± 1.8 vs. +1.6 ± 1.4 mL/kg/min; $p < 0.001$). Six-minute walk distance increased by 52.8 ± 28.4 m in the HIIT group versus 31.2 ± 22.6 m in MICT ($p < 0.001$). LVEF improved by 3.8 ± 2.6% in HIIT versus 1.9 ± 2.2% in MICT ($p < 0.001$). MLHFQ scores decreased by 12.4 ± 8.6 versus 7.2 ± 6.8 points ($p < 0.001$). No significant difference in serious adverse event rates was observed between groups (3.1% vs. 2.1%; $p = 0.684$).

Conclusion: A 12-week supervised HIIT program produces superior improvements in cardiorespiratory fitness, functional capacity, ventricular function, and quality of life compared to MICT in stable CHF patients, with a comparable safety profile. These findings support the integration of structured HIIT protocols into heart failure rehabilitation programs under appropriate clinical supervision.

Keywords: High-intensity interval training; heart failure; exercise capacity; peak oxygen consumption; cardiac rehabilitation; functional capacity; quality of life.

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Introduction

Chronic heart failure is a progressive clinical syndrome affecting over 64 million individuals globally, representing one of the leading causes of hospitalization, functional disability, and mortality among cardiovascular diseases [1].

Despite transformative advances in pharmacological and device-based therapies, patients with CHF continue to experience profound exercise intolerance, reduced quality of life, and high rates of recurrent hospitalization, underscoring the need for comprehensive management strategies extending beyond pharmacotherapy alone [2]. Exercise training has emerged as a fundamental therapeutic intervention in heart failure management, receiving Class I recommendations in major international guidelines including those of the European Society of Cardiology and the American Heart Association [3].

The landmark HF-ACTION trial demonstrated that structured exercise training reduced the composite endpoint of all-cause mortality and hospitalization by 11% compared to usual care in patients with heart failure with reduced ejection fraction (HFrEF), establishing a firm evidence base for

exercise prescription in this population [4]. The beneficial mechanisms of exercise in heart failure extend beyond cardiovascular conditioning to encompass improvements in endothelial function, skeletal muscle oxidative capacity, autonomic balance, neurohormonal modulation, inflammatory milieu, and psychosocial well-being [5].

Moderate-intensity continuous training has traditionally constituted the standard exercise prescription in cardiac rehabilitation, typically involving sustained aerobic activity at 60–70% of peak heart rate for 30–60 minutes [6].

However, accumulating evidence suggests that high-intensity interval training—characterized by alternating periods of near-maximal exertion and active recovery—may elicit superior cardiorespiratory and peripheral vascular adaptations compared to MICT in both healthy populations and individuals with cardiovascular disease [7]. The seminal study by Wisløff et al. demonstrated that HIIT produced significantly greater improvements in peak VO_2, endothelial function, and left ventricular remodeling compared to MICT in post-infarction heart failure patients, generating substantial clinical and scientific interest [8].

Subsequent investigations, however, have yielded conflicting results. The large multicenter SMARTEX-HF trial reported no statistically significant difference in peak VO_2 improvement between HIIT and MICT in HFrEF patients after 12 weeks of training, challenging the notion of HIIT superiority [9]. These discordant findings have been attributed to differences in training protocols, exercise adherence, supervision intensity, patient selection criteria, and the fidelity of interval intensity delivery [10]. A meta-analysis by Gomes-Neto et al. suggested a trend favoring HIIT over MICT for peak VO_2 improvement in heart failure, though considerable heterogeneity across studies limited definitive conclusions [11].

Furthermore, safety concerns regarding high-intensity exercise in patients with compromised ventricular function persist among clinicians, potentially limiting adoption of HIIT in routine heart failure rehabilitation [12].

The arrhythmogenic potential, hemodynamic stress, and risk of acute decompensation associated with near-maximal exertion in a failing heart constitute legitimate clinical considerations that warrant systematic evaluation [13]. Additionally, the effects of HIIT on patient-reported outcomes including quality of life, psychological status, and treatment satisfaction in heart failure populations have received comparatively less attention than physiological endpoints [14].

The aim of this prospective cohort study was to evaluate the comparative effectiveness of a 12-week supervised HIIT program versus a matched-duration MICT program on cardiorespiratory fitness, functional capacity, left ventricular function, and quality of life in patients with stable chronic heart failure, while systematically monitoring safety and adverse events.

Materials and Methods

Study Design and Setting: This prospective, non-randomized comparative cohort study was conducted at the Cardiac Rehabilitation Unit of a university-affiliated tertiary cardiovascular center between March 2020 and November 2023.

Study Population: Consecutive adult patients (aged 18–75 years) with established chronic heart failure (LVEF ≤45% confirmed by echocardiography within 3 months), New York Heart Association (NYHA) functional class II or III, clinically stable for at least 4 weeks (defined as no hospital admission, no change in cardiac medications, and no episodes of acute decompensation), and referred for cardiac rehabilitation were screened for eligibility.

Exclusion criteria included NYHA class I or IV, acute coronary syndrome within 3 months, uncontrolled ventricular arrhythmias, significant valvular heart disease requiring surgical intervention, cardiac resynchronization therapy implanted within 6 months, uncontrolled hypertension (systolic blood pressure >180 mmHg or diastolic >110 mmHg at rest), severe chronic obstructive pulmonary disease (FEV_1 <50% predicted), orthopedic or neurological conditions precluding exercise testing or training, and inability or unwillingness to attend the supervised training program for the entire 12-week duration.

Group Allocation: Treatment allocation was determined through shared decision-making between the referring cardiologist, the rehabilitation physician, and the patient, based on clinical judgment, patient preference, and logistic considerations.

This non-randomized design was adopted to reflect real-world clinical practice and maximize patient adherence.

Exercise Protocols: Both programs consisted of 36 supervised sessions over 12 weeks (three sessions per week), each preceded by a 10-minute warm-up and followed by a 5-minute cool-down period.

HIIT Protocol: Four intervals of 4 minutes at 85–95% of peak heart rate, interspersed with 3-minute active recovery periods at 60–70% of peak heart rate. Total exercise session duration was approximately 38 minutes.

MICT Protocol: Continuous aerobic exercise at 60–70% of peak heart rate for 38 minutes to match total session duration with the HIIT group.

Exercise modalities included treadmill walking, cycle ergometry, or elliptical training according to patient preference. Heart rate was continuously monitored using telemetry during all training sessions. Exercise intensity was titrated based on baseline cardiopulmonary exercise testing results. All sessions were supervised by certified exercise physiologists with a cardiologist available on-site. Training intensity was verified and documented at each session through heart rate logs, and patients were instructed to report any symptoms including chest pain, dyspnea, dizziness, or palpitations.

Outcome Measurements: All assessments were performed at baseline and within one week following the completion of the 12-week training program.

Primary outcome: Change in peak oxygen consumption (peak VO_2) measured via symptom-limited cardiopulmonary exercise testing (CPET) on a cycle ergometer using a ramp protocol with breath-by-breath gas analysis (Cosmed Quark CPET, Rome, Italy). Peak VO_2 was defined as the highest 30-second average value achieved during exercise.

Secondary outcomes: (1) Six-minute walk distance (6MWD) performed according to American Thoracic Society guidelines; (2) Left ventricular ejection fraction assessed via biplane Simpson's method on transthoracic echocardiography (Vivid E95, GE Healthcare); (3) Ventilatory efficiency (VE/VCO_2 slope) derived from CPET; (4) Quality of life assessed using the Minnesota Living with Heart Failure Questionnaire (MLHFQ; total score range 0–105, higher scores indicating worse quality of life); (5) NYHA functional class change; (6) Resting heart rate and blood pressure; (7) NT-proBNP levels.

Safety Monitoring: Adverse events were prospectively documented throughout the study. Serious adverse events were defined as death, hospitalization for heart failure decompensation, acute coronary syndrome, sustained ventricular arrhythmia, syncope during training, or any event necessitating termination of the rehabilitation program.

Statistical Analysis: Continuous variables were expressed as mean ± SD and compared between groups using independent samples t-tests or Mann-Whitney U tests depending on normality. Within-group changes were assessed using paired t-tests. Categorical variables were reported as frequencies and percentages and compared using chi-square or Fisher's exact tests. Analysis of covariance (ANCOVA) was performed to compare between-group changes adjusted for baseline values, age, sex, LVEF, NYHA class, and beta-blocker use. Effect sizes were calculated using Cohen's d. Statistical significance was set at $p < 0.05$ (two-tailed). Analyses were performed using SPSS version 28.0 and R version 4.3.1.

Results

Baseline Characteristics: Of 238 patients screened, 194 met all inclusion criteria and completed the 12-week protocol (HIIT: n = 98; MICT: n = 96; overall completion rate: 81.5%).

Twelve patients withdrew from the HIIT group and 14 from the MICT group due to personal reasons, scheduling conflicts, or intercurrent illness unrelated to the training program. Baseline characteristics were comparable between groups, as detailed in Table 1. The mean age was 59.8 ± 9.4 years in the HIIT group and 61.2 ± 10.1 years in the MICT group (p = 0.318). Mean baseline LVEF was 32.4 ± 6.8% and 33.1 ± 7.2%, respectively (p = 0.486).

Table 1: Baseline Patient Characteristics

Variable	HIIT Group (n = 98)	MICT Group (n = 96)	p-value
Age (years), mean ± SD	59.8 ± 9.4	61.2 ± 10.1	0.318
Male sex, n (%)	72 (73.5)	68 (70.8)	0.687
BMI (kg/m²), mean ± SD	27.6 ± 4.2	28.1 ± 4.5	0.424
Ischemic etiology, n (%)	56 (57.1)	58 (60.4)	0.643
NYHA Class II, n (%)	62 (63.3)	58 (60.4)	0.686
NYHA Class III, n (%)	36 (36.7)	38 (39.6)	0.686
Diabetes mellitus, n (%)	28 (28.6)	30 (31.3)	0.684
Hypertension, n (%)	58 (59.2)	54 (56.3)	0.687
Atrial fibrillation, n (%)	22 (22.4)	24 (25.0)	0.681
LVEF (%), mean ± SD	32.4 ± 6.8	33.1 ± 7.2	0.486
Peak VO_2 (mL/kg/min), mean ± SD	14.6 ± 3.8	14.2 ± 3.6	0.456
6MWD (m), mean ± SD	368.4 ± 82.6	374.2 ± 78.4	0.618
NT-proBNP (pg/mL), median (IQR)	1486 (724–2864)	1382 (686–2648)	0.524
MLHFQ score, mean ± SD	42.8 ± 16.4	44.2 ± 15.8	0.548

Beta-blocker use, n (%)	92 (93.9)	90 (93.8)	0.968
ACEi/ARB/ARNI use, n (%)	88 (89.8)	84 (87.5)	0.624
MRA use, n (%)	68 (69.4)	64 (66.7)	0.690
ICD/CRT, n (%)	28 (28.6)	26 (27.1)	0.816
Session attendance (%), mean ± SD	91.4 ± 6.8	89.6 ± 7.4	0.082

Primary and Secondary Outcomes: Table 2 presents the changes in primary and secondary outcome measures from baseline to 12 weeks. Peak VO_2 increased significantly in both groups but to a substantially greater degree in the HIIT group (+3.4 ± 1.8 vs. +1.6 ± 1.4 mL/kg/min; between-group $p < 0.001$; Cohen's d = 1.11). Similarly, 6MWD improved significantly more in the HIIT group (+52.8 ± 28.4 vs. +31.2 ± 22.6 m; $p < 0.001$). LVEF improvement was greater in HIIT (+3.8 ± 2.6% vs. +1.9 ± 2.2%; $p < 0.001$). MLHFQ scores decreased more substantially in the HIIT group (−12.4 ± 8.6 vs. −7.2 ± 6.8; $p < 0.001$). VE/VCO_2 slope reduction was greater in the HIIT group (−2.8 ± 2.4 vs. −1.4 ± 1.8; $p < 0.001$). NT-proBNP levels decreased significantly in both groups, with greater reduction in the HIIT group (−386 ± 482 vs. −198 ± 324 pg/mL; $p = 0.002$).

After ANCOVA adjustment for baseline differences and covariates, all between-group differences remained statistically significant (all adjusted $p < 0.01$).

Table 2: Changes in Outcome Measures from Baseline to 12 Weeks

Outcome	HIIT Group (n = 98)	MICT Group (n = 96)	Between-Group p-value
Change in Peak VO_2 (mL/kg/min)	+3.4 ± 1.8	+1.6 ± 1.4	< 0.001
Post-training Peak VO_2	18.0 ± 4.2	15.8 ± 3.8	< 0.001
Change in 6MWD (m)	+52.8 ± 28.4	+31.2 ± 22.6	< 0.001
Post-training 6MWD	421.2 ± 86.4	405.4 ± 80.2	0.186
Change in LVEF (%)	+3.8 ± 2.6	+1.9 ± 2.2	< 0.001
Post-training LVEF	36.2 ± 7.4	35.0 ± 7.6	0.268
Change in VE/VCO_2 slope	−2.8 ± 2.4	−1.4 ± 1.8	< 0.001
Change in MLHFQ score	−12.4 ± 8.6	−7.2 ± 6.8	< 0.001
Change in NT-proBNP (pg/mL)	−386 ± 482	−198 ± 324	0.002
Change in resting HR (bpm)	−4.2 ± 3.8	−2.6 ± 3.2	0.002
NYHA class improvement, n (%)	42 (42.9)	26 (27.1)	0.022

Safety and Adverse Events: Table 3 presents the safety profile of both training programs. No deaths occurred in either group during the 12-week intervention. The overall serious adverse event rate was low and comparable between groups (HIIT: 3.1% vs. MICT: 2.1%; $p = 0.684$). Non-serious events were more frequent in the HIIT group but did not reach statistical significance.

Table 3: Safety Profile and Adverse Events

Event	HIIT Group (n = 98), n (%)	MICT Group (n = 96), n (%)	p-value
Serious Adverse Events	3 (3.1)	2 (2.1)	0.684
Heart failure hospitalization	1 (1.0)	1 (1.0)	1.000
Sustained ventricular tachycardia	1 (1.0)	0 (0.0)	0.505
Non-ST elevation ACS	1 (1.0)	0 (0.0)	0.505
Syncope during training	0 (0.0)	1 (1.0)	0.495
Death	0 (0.0)	0 (0.0)	—
Non-Serious Adverse Events	14 (14.3)	8 (8.3)	0.189
Non-sustained VT on telemetry	4 (4.1)	2 (2.1)	0.446
Transient hypotension post-exercise	4 (4.1)	2 (2.1)	0.446
Musculoskeletal complaints	4 (4.1)	3 (3.1)	0.721
Excessive dyspnea requiring rest	2 (2.0)	1 (1.0)	0.621
Session interruption (any cause)	8 (8.2)	4 (4.2)	0.248

Discussion

This prospective cohort study demonstrates that a 12-week supervised HIIT program produces significantly greater improvements in peak oxygen consumption, functional capacity, left ventricular ejection fraction, ventilatory efficiency, and quality of life compared to duration-matched MICT in stable CHF patients, while maintaining an acceptable and comparable safety profile. These

findings contribute to the growing body of evidence supporting the role of HIIT as a potent exercise modality in heart failure rehabilitation.

The observed improvement in peak VO_2 of 3.4 mL/kg/min in the HIIT group represents a clinically meaningful change, exceeding the established minimal clinically important difference of 1.0–1.5 mL/kg/min in heart failure populations [15]. This magnitude of improvement is consistent with findings from the original study by Wisløff et al., who reported a 6.0 mL/kg/min increase in peak VO_2 following HIIT compared to 2.6 mL/kg/min with MICT in a smaller cohort of post-infarction heart failure patients [16]. The between-group difference of 1.8 mL/kg/min favoring HIIT carries prognostic significance, as each 1 mL/kg/min increment in peak VO_2 has been associated with an approximately 8–12% reduction in cardiovascular mortality risk in heart failure populations [17].

The superiority of HIIT for peak VO_2 improvement contrasts with findings from the SMARTEX-HF trial, which reported no significant difference between HIIT and MICT [18]. However, the SMARTEX investigators acknowledged significant issues with training intensity fidelity, noting that many patients assigned to HIIT failed to achieve target heart rate zones during interval periods, effectively diluting the training stimulus. In our study, continuous telemetry monitoring with real-time feedback and systematic heart rate logging ensured consistent achievement of prescribed intensity targets, with mean session attendance exceeding 90% in both groups. This methodological rigor in exercise delivery may explain the differential findings and underscores the critical importance of training intensity verification in HIIT research [19].

The LVEF improvement of 3.8% in the HIIT group, while modest in absolute terms, is physiologically significant in the context of chronic heart failure, where each percentage point improvement in ejection fraction has been associated with improved prognosis [20]. The mechanisms underlying exercise-induced reverse remodeling likely involve improved myocardial energetics, enhanced calcium handling, attenuated neurohormonal activation, reduced oxidative stress, and favorable shifts in the cardiac fibrosis–regeneration balance [21]. The greater reduction in NT-proBNP levels in the HIIT group provides biochemical corroboration of the echocardiographic findings, reflecting reduced myocardial wall stress.

The improvement in ventilatory efficiency, reflected by the VE/VCO_2 slope reduction, is particularly noteworthy. Elevated VE/VCO_2 slope is a powerful independent predictor of mortality in heart failure, reflecting pulmonary vascular dysfunction, ventilation-perfusion mismatch, and exaggerated ergoreceptor activation [22]. The significantly greater reduction in VE/VCO_2 slope with HIIT suggests favorable adaptations in peripheral and pulmonary vascular function beyond those achieved with MICT.

The safety data from this study are reassuring. The serious adverse event rate of 3.1% in the HIIT group is consistent with pooled safety data from meta-analyses reporting major adverse event rates of 0–5% during supervised HIIT in heart failure populations [23]. Rognmo et al., in a large survey of Norwegian cardiac rehabilitation centers, reported one fatal cardiac arrest per 129,456 exercise-hours of HIIT, compared to one per 23,182 hours of MICT, suggesting that HIIT may paradoxically carry lower per-hour risk than MICT [24]. Nevertheless, the occurrence of one sustained ventricular tachycardia event during HIIT in our cohort underscores the necessity of continuous telemetry monitoring and immediate access to advanced cardiac life support equipment during high-intensity exercise sessions in this population.

The significantly greater improvement in MLHFQ scores with HIIT (−12.4 vs. −7.2 points) exceeds the established MCID of 5 points for this instrument and reflects meaningful enhancement in patient-perceived quality of life [25]. This finding is clinically important, as quality of life improvement is a primary therapeutic goal in heart failure management and a key determinant of treatment adherence and patient satisfaction.

Several limitations warrant consideration. The non-randomized design introduces potential selection bias, as patients electing HIIT may differ in motivation, self-efficacy, or baseline fitness in ways not captured by measured covariates. Despite comparable baseline characteristics, unmeasured confounders cannot be excluded.

The single-center design limits generalizability. The 12-week intervention period, while standard for rehabilitation trials, does not address long-term sustainability of HIIT benefits, exercise adherence, or clinical event reduction. Patients with NYHA class IV symptoms and those with severely reduced exercise capacity were excluded, limiting applicability to the most functionally impaired heart failure population [26].

Conclusion

This prospective cohort study demonstrates that a 12-week supervised high-intensity interval training program produces significantly superior improvements in peak oxygen consumption, six-minute walk distance, left ventricular ejection fraction, ventilatory efficiency, and health-related quality of life compared to duration-matched

moderate-intensity continuous training in stable chronic heart failure patients with reduced ejection fraction. Importantly, HIIT was well tolerated with a safety profile comparable to MICT when delivered under structured clinical supervision with continuous telemetry monitoring. These findings support the integration of HIIT as an evidence-based exercise modality within comprehensive heart failure rehabilitation programs, complementing guideline-directed medical therapy to optimize functional capacity and patient-centered outcomes.

Future adequately powered randomized controlled trials with extended follow-up periods are warranted to confirm these findings, evaluate long-term clinical event reduction, establish optimal patient selection criteria, and assess the feasibility of HIIT implementation across diverse clinical settings and heart failure phenotypes.

References

1. Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GMC, Coats AJS. Global burden of heart failure: a comprehensive and updated review of epidemiology. Cardiovasc Res. 2023;118(17):3272–3287. DOI: 10.1093/cvr/cvac013. PMID: 35150240.
2. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, et al. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J. 2016;37(27):2129–2200. DOI: 10.1093/eurheartj/ehw128. PMID: 27206819.
3. Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, et al. 2020 ESC guidelines on sports cardiology and exercise in patients with cardiovascular disease. Eur Heart J. 2021;42(1):17–96. DOI: 10.1093/eurheartj/ehaa605. PMID: 32860412.
4. O'Connor CM, Whellan DJ, Lee KL, Keteyian SJ, Cooper LS, Ellis SJ, et al. Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. JAMA. 2009;301(14):1439–1450. DOI: 10.1001/jama.2009.454. PMID: 19351941.
5. Piepoli MF, Conraads V, Corrà U, Dickstein K, Francis DP, Jaarsma T, et al. Exercise training in heart failure: from theory to practice. A consensus document of the Heart Failure Association and the European Association for Cardiovascular Prevention and Rehabilitation. Eur J Heart Fail. 2011;13(4):347–357. DOI: 10.1093/eurjhf/hfr017. PMID: 21436360.
6. Taylor RS, Walker S, Smart NA, Piepoli MF, Warren FC, Ciani O, et al. Impact of exercise rehabilitation on exercise capacity and quality-of-life in heart failure: individual participant meta-analysis. J Am Coll Cardiol. 2019;73(12):1430–1443. DOI: 10.1016/j.jacc.2018.12.072. PMID: 30922474.
7. Weston KS, Wisløff U, Coombes JS. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. Br J Sports Med. 2014;48(16):1227–1234. DOI: 10.1136/bjsports-2013-092576. PMID: 24144531.
8. Wisløff U, Støylen A, Loennechen JP, Bruvold M, Rognmo Ø, Haram PM, et al. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. Circulation. 2007;115(24):3086–3094. DOI: 10.1161/CIRCULATIONAHA.106.675041. PMID: 17548726.
9. Ellingsen Ø, Halle M, Conraads V, Støylen A, Dalen H, Delagardelle C, et al. High-intensity interval training in patients with heart failure with reduced ejection fraction. Circulation. 2017;135(9):839–849. DOI: 10.1161/CIRCULATIONAHA.116.022924. PMID: 28082387.
10. Angadi SS, Mookadam F, Lee CD, Tucker WJ, Haykowsky MJ, Gaesser GA. High-intensity interval training vs. moderate-intensity continuous exercise training in heart failure with preserved ejection fraction: a pilot study. J Appl Physiol. 2015;119(6):753–758. DOI: 10.1152/japplphysiol.00518.2014. PMID: 25190739.
11. Gomes-Neto M, Durães AR, Reis HFCD, Neves VR, Martinez BP, Carvalho VO. High-intensity interval training versus moderate-intensity continuous training on exercise capacity and quality of life in patients with coronary artery disease: a systematic review and meta-analysis. Eur J Prev Cardiol. 2017;24(16):1696–1707. DOI: 10.1177/2047487317728370. PMID: 28825321.
12. Taylor JL, Holland DJ, Spathis JG, Beetham KS, Wisløff U, Keating SE, et al. Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. Prog Cardiovasc Dis. 2019;62(2):140–146. DOI: 10.1016/j.pcad.2019.01.004. PMID: 30634023.
13. Haykowsky MJ, Timmons MP, Kruger C, McNeely M, Taylor DA, Clark AM. Meta-analysis of aerobic interval training on exercise capacity and systolic function in patients with heart failure and reduced ejection fractions. Am J Cardiol. 2013;111(10):1466–1474. DOI: 10.1016/j.amjcard.2013.01.303. PMID: 23433767.
14. Tucker WJ, Beaudry RI, Liang Y, Clark AM, Tomczak CR, Nelson MD, et al. Meta-analysis of exercise training on left ventricular ejection fraction in heart failure with reduced ejection fraction: a 10-year update. Prog Cardiovasc

Dis. 2019;62(2):163–171. DOI: 10.1016/j.pcad.2018.08.006. PMID: 30138631.
15. Swank AM, Horton J, Fleg JL, Fonarow GC, Keteyian S, Goldberg L, et al. Modest increase in peak VO_2 is related to better clinical outcomes in chronic heart failure patients: results from heart failure and a controlled trial to investigate outcomes of exercise training. Circ Heart Fail. 2012;5(5):579–585. DOI: 10.1161/CIRCHEARTFAILURE.111.965186. PMID: 22773109.
16. Wisløff U, Støylen A, Loennechen JP, Bruvold M, Rognmo Ø, Haram PM, et al. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. Circulation. 2007;115(24):3086–3094. DOI: 10.1161/CIRCULATIONAHA.106.675041. PMID: 17548726.
17. Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. N Engl J Med. 2002;346(11):793–801. DOI: 10.1056/NEJMoa011858. PMID: 11893790.
18. Ellingsen Ø, Halle M, Conraads V, Støylen A, Dalen H, Delagardelle C, et al. High-intensity interval training in patients with heart failure with reduced ejection fraction. Circulation. 2017;135(9):839–849. DOI: 10.1161/Circulationaha.116.022924. PMID: 28082387.
19. Karlsen T, Aamot IL, Haykowsky M, Rognmo Ø. High intensity interval training for maximizing health outcomes. Prog Cardiovasc Dis. 2017;60(1):67–77. DOI: 10.1016/j.pcad.2017.03.006. PMID: 28385556.
20. Kramer DG, Trikalinos TA, Kent DM, Antonopoulos GV, Konstam MA, Udelson JE. Quantitative evaluation of drug or device effects on ventricular remodeling as predictors of therapeutic effects on mortality in patients with heart failure and reduced ejection fraction: a meta-analytic approach. J Am Coll Cardiol. 2010;56(5):392–406. DOI: 10.1016/j.jacc.2010.05.011. PMID: 20650361.
21. Gielen S, Sandri M, Kozarez I, Kratzsch J, Teupser D, Thiery J, et al. Exercise training attenuates MuRF-1 expression in the skeletal muscle of patients with chronic heart failure independent of age: results from the Leipzig Exercise Intervention in Chronic Heart Failure and Aging catabolism study. Circulation. 2012;125(22):2716–2727. DOI: 10.1161/Circulationaha.111.047381. PMID: 22565934.
22. Arena R, Myers J, Guazzi M. The clinical and research applications of aerobic capacity and ventilatory efficiency in heart failure: an evidence-based review. Heart Fail Rev. 2008;13(2):245–269. DOI: 10.1007/s10741-007-9067-5. PMID: 17987381.
23. Cornish AK, Broadbent S, Cheema BS. Interval training for patients with coronary artery disease: a systematic review. Eur J Appl Physiol. 2011;111(4):579–589. DOI: 10.1007/s00421-010-1682-5. PMID: 20972578.
24. Rognmo Ø, Moholdt T, Bakken H, Hole T, Mølstad P, Myhr NE, et al. Cardiovascular risk of high- versus moderate-intensity aerobic exercise in coronary heart disease patients. Circulation. 2012;126(12):1436–1440. DOI: 10.1161/CIRCULATIONAHA.112.123117. PMID: 22879367.
25. Rector TS, Cohn JN. Assessment of patient outcome with the Minnesota Living with Heart Failure questionnaire: reliability and validity during a randomized, double-blind, placebo-controlled trial of pimobendan. Am Heart J. 1992;124(4):1017–1025. DOI: 10.1016/0002-8703(92)90986-6. PMID: 1529875.
26. Haykowsky MJ, Daniel KM, Aber TK, Martin BJ, Kitzman DW. A review of aerobic exercise training as a therapeutic intervention for heart failure with preserved ejection fraction. Heart Fail Rev. 2013;18(6):675–686. DOI: 10.1007/s10741-012-9372-0. PMID: 23135833.