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Practical guidelines for exercise prescription in patients with chronic heart failure

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Abstract
Chronic heart failure (HF) is a major cause of morbidity, mortality, disability, and health care costs. A hallmark feature of HF is severe exercise intolerance, which is multifactorial and stems from central and peripheral pathophysiological mechanisms. Exercise training is internationally recognized as a Class 1 recommendation for patients with HF, regardless of whether ejection fraction is reduced or preserved. Optimal exercise prescription has been shown to enhance exercise capacity, improve quality of life, and reduce hospitalizations and mortality in patients with HF. This article will review the rationale and current recommendations for aerobic training, resistance training, and inspiratory muscle training in patients with HF. Furthermore, the review provides practical guidelines for optimizing exercise prescription according to the principles of frequency, intensity, time (duration), type, volume, and progression. Finally, the review addresses common clinical considerations and strategies when prescribing exercise in patients with HF, including considerations for medications, implantable devices, exercise-induced ischemia, and/or frailty.

Keywords Cardiac rehabilitation · Aerobic training · Resistance training · Inspiratory muscle training · Cardiorespiratory fitness · Physical therapy

Introduction

Chronic heart failure is a major global public health problem affecting over 64 million people worldwide and over 6 million in the USA [1, 2]. Heart failure (HF) is associated with significant morbidity, mortality, and health care costs [1]. Additionally, the prevalence of HF is projected to increase due to the aging of the population and improved survival due to improved treatment of ischemic heart disease and evidence-based treatments including guideline-directed medical therapy [1]. The phenotype of HF has expanded to HF with preserved ejection fraction (HFpEF), HF with mildly reduced ejection fraction (HFmrEF) along with HF with reduced ejection fraction (HFrEF), classified according to ejection fraction ranges [3]. Approximately 50% of patients have HFrEF with a relatively stable prevalence compared to the rapidly increasing prevalence of HFpEF which is projected to become the most common form of HF [1]. HFpEF is more likely to affect older individuals as well as women with significant and severe comorbidities, and to date, there are no effective treatments for HFpEF, which contributes to its high morbidity and mortality [4, 5]. HF is defined as a clinical syndrome encompassing structural and functional abnormalities, elevated brain natriuretic peptide, and pulmonary or systemic congestion [3]. The hallmark symptom of HFrEF and HFpEF phenotypes is severe exercise intolerance, which is multifactorial and stems from central and peripheral pathophysiological mechanisms such as impaired cardiac and pulmonary reserve, excessive systemic vascular resistance and impaired vasodilatory capacity, abnormal redistribution of blood flow and muscle perfusion, and reduced mitochondrial density/volume and skeletal muscle function [6, 7]. Fortunately, the body of evidence to date demonstrates improvements in exercise capacity following exercise training programs as well as attenuation of left ventricular remodeling, improvements in quality of life, and reductions in cardiovascular and all-cause hospitalizations

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[8–13]. Exercise training also improves exercise capacity and quality of life for patients with HFpEF, although the impact on or improvement in diastolic function has yet to be demonstrated [14]. Herein, we provide guidance and rationale for prescribing exercise in patients with HF.

Commencing an exercise program

Guidelines for the management of patients with HF recommend exercise training for clinically stable patients, regardless of whether ejection fraction is reduced or preserved [15, 16]. However, the term "stable" HF can be ambiguous without a universal consensus on the definition, making it challenging to determine the appropriate timeframe for when patients with HF can commence an exercise program. The American Heart Association (AHA) and American College of Cardiology (ACC) guidelines recommend exercise training as a Class 1 indication for HF patients who are stable and on optimal guideline-directed medical therapy [15]. The Centers for Medicare & Medicaid Services (CMS) in the USA define "stable" as "patients who have not had recent (≤ 6 weeks) or planned (≤ 6 months) major cardiovascular hospitalizations or procedures" [17]. This timeframe was based on criteria from the HF-Action Trial [18], and therefore, patients with HF in the USA undergo a 6-week clinical stabilization period before coverage for exercise-based cardiac rehabilitation is available. The European Society of Cardiology (ESC) guidelines recommend exercise training for stable HF patients, where stable is defined as symptoms and signs remaining generally unchanged for at least 1 month [16]. A randomized controlled trial by Australian researchers [19] found exercise training as part of a multidisciplinary HF disease management program soon after hospital discharge (commenced within 4–8 weeks) to be feasible and safe, including both supervised exercise intervention and home-based exercise control groups. There were no adverse events related to exercise training in 178 patients with either HFrEF or HFpEF, despite patients being recently hospitalized and having high rates of comorbidities (diabetes, chronic lung disease, and musculoskeletal disorders). The study found no difference in the primary outcome (death and hospital readmissions) between supervised and home-based control exercise groups, although patients meeting exercise guidelines of 150 min/week (supervised or home-based) had significantly lower rates of death or hospital readmissions at 3 months and 6 months than patients who did not meet exercise guidelines. Therefore, instead of determining whether patients are clinically stable to commence exercise training, it would be more pragmatic to individually assess patients for any contraindications to exercise training and signs or symptoms of decompensated HF (Table 1) [20]. A recent international report designed to establish universal definitions and classifications of HF proposes that decompensated HF represents both acute decompensation due to an inciting event, or chronic/progressive worsening of HF signs and symptoms despite ongoing therapy, which requires urgent intervention, hospitalization, or rapid escalation of therapies including advanced therapies [3].

While acute decompensated HF (ADHF) is currently recognized as a contraindication to exercise training, the Rehabilitation Therapy in Older Acute HF Patients (REHAB-HF) Trial is currently investigating whether exercise-based rehabilitation (focusing on improved balance, strength, mobility, and endurance) commenced during an admission for ADHF, may improve physical function and reduce future re-hospitalizations in older patients (> 60 years) [23]. The REHAB-HF pilot study demonstrated the feasibility and safety of rehabilitation compared with usual care and a trend toward improved physical function and decreased hospitalizations [23]. Moreover, a recent study by Delgado et al. [24] found early exercise therapy for inpatients recovering from acutely decompensated HF to be safe and efficacious for improvements in functional capacity compared with usual care. This study employed careful screening criteria prior to exercise training, excluding patients from their scheduled exercise session if they had ongoing intravenous infusion of inotropic medications, continuous oxygen therapy > 3 L/min, systolic blood pressure > 180 mmHg or < 80 mmHg, dysrhythmias and/or precordial pain in the prior 24 h, acute pulmonary edema or glycemic decompensation within the prior 12 h, or osteoarticular pathology impairing exercise performance [24]. Exercise training was supervised, and physiological responses were routinely measured, with exercise termination criteria in line with that of the American College of Sports Medicine (Table 2) [21].

Exercise assessment and programming

Prior to starting exercise or sports participation, it is important to review the patient's medical history and medications, assess for exercise contraindications, encourage optimization and adherence of medical therapy, and perform baseline assessments [16, 18, 25–27]. Conducting baseline exercise assessment is valuable for determining risk and prognosis, optimal training intensity, and effectiveness of an exercise training program. A symptom-limited cardiopulmonary exercise test (CPET) is the gold standard assessment for patients with HF, to provide information regarding the degree of cardiac and/or pulmonary impairment in addition to an objective measure of cardiorespiratory fitness expressed as peak oxygen uptake (VO_2peak) and other prognostic markers such as ventilatory efficiency (VE/VCO2 slope) and oscillatory ventilation [26]. Importantly, a CPET can also identify chronotropic incompetence

Table 1 Contraindications to exercise testing and training in patients with stable heart failure

Absolute contraindications
Early phase after acute coronary syndrome (within 2 days)
Ongoing unstable angina
Uncompensated heart failure
Acute thrombophlebitis or recent embolism (pulmonary or systemic)
Active endocarditis
Acute myocarditis or pericarditis
Acute aortic dissection
Symptomatic severe aortic stenosis
Acute systemic illness or fever
Uncontrolled hypertension (≥ 180 mmHg systolic or ≥ 110 mmHg diastolic blood pressure at rest)
Uncontrolled sinus tachycardiac (resting heart rate > 120 beats.min^{-1})
Uncontrolled or life-threatening atrial or ventricular dysrhythmias (including new onset atrial fibrillation/flutter)
Third-degree atrioventricular block without pacemaker
Uncontrolled diabetes mellitus
Orthostatic drop in blood pressure (> 20 mmHg) with symptoms
Progressive worsening of exercise tolerance or dyspnea at rest or on exertion over previous 3–5 days
Significant ischemia at low work rates (< 2 METs or 50 Watts)
Relative contraindications (increased risk)
≥ 1.8 kg or 3 lbs increase in body mass over previous 1–3 days
Concurrent continuous or intermittent dobutamine therapy
Decrease in systolic blood pressure with exercise
New York Heart Association Functional Class IV
Complex ventricular arrhythmias at rest or appearing with exertion
Supine resting heart rate ≥ 100 beats.min^{-1}
Pre-existing comorbidities limiting exercise tolerance
Severe hypertrophic obstructive cardiomyopathy
Symptoms or indications of worsening heart failure
≥ 1.8 kg or 3 lbs increase in body mass over previous 1–3 days
Worsening dyspnea (on exertion or rest)
Excessive fatigue, lack of energy
Swelling of legs, abdomen
Productive cough
Increased urination, particularly at night (nocturia)
Difficulty sleeping due to breathing problems (orthopnea)
Difficulty concentrating
Shock from an implantable cardiac defibrillator

Adapted from American College of Sports Medicine [21], Piepoli et al. [20], Keteyian et al. [22], and Myers [7]

METs metabolic equivalents

(i.e., insufficient heart rate response to exercise), which is highly prevalent in patients with HFrEF and HFpEF and can significantly affect exercise capacity and prescription [28]. Although CPET is not routinely available for many cardiac rehabilitation programs, standard graded maximal or submaximal exercise testing without gas exchange measurements can still be valuable to provide an estimate of cardiorespiratory fitness, assess physiological responses to exercise (e.g., symptoms, heart rate, blood pressure, cardiac rhythm), and to guide exercise prescription [22]. The 6-min walk test is widely used within cardiac rehabilitation programs and has been shown to have similar prognostic utility to CPET for all-cause mortality and hospitalization [29]. However, as the 6-min walk test is self-paced and does not rigorously evaluate the cardiorespiratory system, its use for establishing the optimal training intensity can be limited and may result in under-prescription of exercise intensity [30, 31]. Muscle strength can be assessed as a measure of physical function (e.g., handgrip, quadriceps) to determine the effectiveness of an exercise training program, as well as quantification for the basis of resistance training prescription [32]. For exercise prescription, the 1-repetition maximum

Table 2 Signs and symptoms for stopping exercise testing or setting upper limit of exercise training

Onset of angina or other symptoms of cardiac insufficiency
≥ 1.0 mm ST-segment depression (horizontal or downsloping)
Systolic blood pressure ≥ 250 mmHg or diastolic blood pressure ≥ 115 mmHg
Decrease in systolic blood pressure > 10 mmHg during exercise with increasing workload
Increased frequency of ventricular dysrhythmias
Other significant electrocardiogram disturbances (e.g., second- or third-degree atrioventricular block, atrial fibrillation, supraventricular tachycardia, complex ventricular ectopy)
Other signs/symptoms of exercise intolerance (e.g., light-headedness, cyanosis, shortness of breath, plateau of heart rate with increasing workload)

Adapted from the American College of Sports Medicine [21] and Myers [7]

(1RM) or estimated 1RM (from < 10RM test) is the most practical method for determining the resistance training load, ideally performed for each targeted muscle group [22, 32]. Identification of frailty can be accomplished through scales such as the Fried, Edmonton, or Clinical Frailty Scale [33–35]. 5-m gait speed is a physical and objective test that measures functional mobility, and in older adults, an improvement of 0.1 m/s in gait speed predicted a substantial reduction in mortality compared with other measures of physical function (including the Short Physical Performance Battery) [36].

Contraindications to exercise

Overall risk of exercise is low when pre-participation assessment and risk factor management are done properly, even for exercise at higher intensities and in more severe cases of HF [37, 38]. Prior to commencing an exercise training program, patients should be assessed for exercise contraindications (Table 1). Furthermore, ongoing assessment for signs of clinical instability or decompensated HF (e.g., weight gain, resting heart rate > 100 bpm, sudden worsening of symptoms, or exercise intolerance) should be conducted throughout an exercise program with immediate referral to the patient's primary physician if identified [7].

Cardiovascular signs and symptoms that should be used to guide exercise intensity limits are outlined in Table 2. For low-risk patients, monitoring of heart rate, cardiac rhythm, and blood pressure is appropriate for initial sessions at the commencement of exercise training, while educating patients about how to self-monitor exercise intensity and recognize signs and symptoms of exercise limits (e.g., excessive fatigue, angina, or light-headedness) [21]. Perspectives on the need for continuous telemetry during exercise-based cardiac rehabilitation have changed within the past few decades. It was previously recommended by the American College of Cardiology and other guidelines that patients undertaking cardiac rehabilitation should have ECG monitoring for the first 6–12 sessions; however, it is now recognized that most patients can exercise safely without continuous telemetry [7]. Minimizing the use of telemetry for low-risk patients can help reduce costs for cardiac rehabilitation programs, reduce time burden for cardiac rehabilitation staff, and encourage patients that they can exercise independently and safely without specialized monitoring. However, HF patients with a higher risk profile that should be considered for longer ECG monitoring include survivors of sudden cardiac death, patients with an implantable cardiac defibrillator (ICD), severely depressed left ventricular function (ejection fraction < 25%), severe coronary artery disease (CAD), or abnormal hemodynamic responses to exercise (e.g., exercise-induced hypotension) [7].

Importance of exercise intensity

In the HF-Action Trial, the magnitude of improvement in VO_2peak with exercise training was a strong, independent predictor of prognosis with each 6% increase in VO_2peak associated with a 7% reduction in all-cause mortality and an 8% reduction in cardiovascular mortality or hospitalization [39]. Furthermore, the HF-Action Trial showed that during a baseline CPET, VO_2peak (ml.kg.min^{-1}), percentage of predicted VO_2peak, and exercise duration were the strongest predictors of mortality in patients with HFrEF [40]. Several studies have demonstrated the importance of exercise training intensity for improving VO_2peak in patients with HF [41–43]. In a large meta-regression analysis of studies involving patients with HF or CAD, Uddin et al. [42] demonstrated that each 10% increase in exercise intensity as a percentage of VO_2peak (%VO_2peak) or percentage of heart rate peak (%HRpeak) was associated with a 1.0 ml.kg.min^{-1} increase in VO_2peak following CR. Specifically, in patients with HFrEF, Ismail et al. [41] found that exercise interventions of high intensity improved VO_2peak by 23% compared with exercise interventions of vigorous intensity (8% improvement), moderate intensity (13% improvement), or low intensity (3% improvement).

Since high-intensity exercise cannot be sustained continuously for long periods, high-intensity interval training (HIIT), also referred to as aerobic interval training, involves alternating bouts of high-intensity exercise interspersed with lower-intensity recovery exercise. The optimal HIIT protocol for patients with HF, regarding interval duration and intensity, remains equivocal [44, 45]. A common protocol is the 4 × 4 Norwegian model, involving four bouts of 4-min high-intensity intervals (90–95% HRpeak) interspersed with 3-min active recovery intervals (50–70% HRpeak) [46]. In patients with HFrEF, Wisløff et al. [46] demonstrated substantial improvements in VO_2peak and endothelial function with HIIT compared with moderate-intensity continuous training (MICT) and no-exercise control. Furthermore, only HIIT reversed left ventricular remodeling [46]. Subsequent meta-analyses have confirmed a superior effect of HIIT for improving VO_2peak compared with MICT in patients with HFrEF [45, 47, 48]. However, the large multicenter SMARTEX HF study [49] failed to replicate findings that HIIT provides superior improvements in VO_2peak than MICT in HFrEF. In the SMARTEX HF study, poor adherence to the prescribed intensity was a major limitation with 51% of HIIT patients exercising below prescribed targets and 80% of MICT patients exercising above the prescribed target [49]. Furthermore, workload progression per training session was substantially less than smaller studies in HFrEF that showed superiority of HIIT compared with MICT for improving VO_2peak (~ 0.5 Watts per session vs 2 Watts per session) [50]. In patients with HFpEF, Donelli da Silveira et al. [51] demonstrated a superior effect of HIIT for improving VO2peak compared with MICT; however, these findings were not replicated in the large multi-center OptimEX-Clin study [52]. While Donelli da Silveira et al. [51] demonstrated excellent adherence to exercise intensity in their HIIT and MICT groups, the OptimEX-Clin study [52] did not report any results pertaining to the fidelity of training intensity [52]. To date, there are no studies comparing HIIT protocols in patients with HF, and therefore, the optimal HIIT protocol for HFrEF and HFpEF is unknown. In the meta-analysis by Pattyn et al. [45], sub-group analyses indicated that total energy expenditure and the extent of exercise intensity during the HIIT protocol appear to have a greater influence on changes in VO_2peak than interval duration alone.

Principles of exercise prescription

There are several therapeutic goals of exercise training in patients with HF: To reduce the symptoms of HF (e.g., fatigue, dyspnea, exercise intolerance); increase exercise capacity to improve autonomy with daily living activities and quality of life; reduce the risk of future clinical events and mortality; and improving pathophysiology (e.g., cardiac remodeling, skeletal muscle capacity, autonomic function) [22, 53]. It is also important to consider specific goals of the patient (e.g., returning to work, carrying out independent activities, rejoining friends on the golf course) as these can provide functional outcomes of exercise training and can be valuable motivators for the patient to maintain regular exercise and physical activity [7].

The fundamental components of exercise prescription involve frequency, intensity, time (duration), type (mode), volume, and progression, commonly known as the FITT-VP principles [21]. When these principles are applied effectively, exercise training provides a sufficient stimulus to promote beneficial physiological adaptations. There is no "one size fits all" approach to exercise training in patients with HF, and instead, an individualized approach is recommended [20]. Due to differences in pathophysiology, comorbidities, medications, and prior exercise experience, patients may differ in their ability to tolerate the same relative intensity [7]. Furthermore, patient preferences, availability of equipment/facilities, and behavioral characteristics of the patient should be considered to facilitate long-term adherence to exercise training [20, 53]. Table 3 outlines recommended ranges for frequency, intensity, time (duration), type, and progression, for aerobic training, resistance training, and inspiratory muscle training in patients with HF. The total volume of exercise (aerobic and resistance training combined) should be progressed to 3–7 MET-h (or 180–420 MET-min) per week and exceeded if tolerated [54]. In clinical practice, metabolic equivalents (METs) can be estimated from a Compendium of Physical Activities [55] or treadmill and cycle workload equations [56, 57]. The MET value of the activity is then multiplied by the time spent in the activity (hours or minutes) to calculate the MET-hours or MET-minutes accumulated.

Early mobilization

Early mobilization and gentle calisthenic exercises should begin as soon as possible once patients are hemodynamically stable, to prevent muscle wasting, improve movement coordination, and enhance respiratory capacity [20]. To commence inpatient rehabilitation, patients should not have any contraindications to exercise (Table 1) and should meet the additional following criteria: (1) no new or recurrent chest pain (within 8 h), (2) stable or falling creatinine kinase and troponin values, (3) no decompensated HF (e.g., resting dyspnea or bibasilar rates), and (4) normal cardiac rhythm and stable electrocardiogram (within 8 h) [21]. The optimal dose of exercise for inpatient rehabilitation is unknown. Current guidelines by the American College of Sports Medicine recommend a progression from self-care activities (sitting, standing, toileting) to range of motion upper body exercises performed without weight and short to moderate distance walking (minimal to no assistance) performed under supervision up to four times per day [21]. Patients should be monitored for new cardiovascular signs or symptoms (e.g.,

Table 3 Recommendations for prescribing aerobic and resistance training in patients with heart failure

Training parameter	Initial prescription***	Optimal progression
Aerobic training		
Frequency	2–3 days/week	Moderate intensity: 3–7 days/week High intensity: 1–3 days/week
Intensity	40–50% VO_2R or HRR; 45–55% VO_2peak; RPE 11–12 Until 20 min duration is achieved May use short intervals if unable to maintain continuous exercise	Continuous: 70–80% VO_2R, or HRR; 75–85% VO_2peak; RPE 11–14 High-intensity intervals: 80–90% VO_2R, or HRR; 85–95% VO_2peak; RPE 15–17
Time (duration)	Session total: 15–30 min Work intervals: 20–30 s or longer (1–2 min) as tolerated	Session total: 45–60 min High-intensity intervals: 1–4 min interval duration (3–6 repeated bouts)
Type (mode)	Dynamic, rhythmic activities involving lower or upper body such as treadmill walking, cycling, and arm ergometer	Dynamic, rhythmic activities involving lower and/or upper body such as treadmill walking/jogging, cycling, rowing, stepper, elliptical, and arm ergometer
Resistance training		
Frequency	2–3 non-consecutive days/week	
Intensity	< 30% 1-RM; RPE 11–12	40–70% 1-RM; RPE 12–15
Time (duration)	1–2 sets/day for each muscle group, 5–10 repetitions, 4–6 exercises	2–3 sets/day for each muscle group, 8–15 repetitions, 8–10 exercises
Type (mode)	Fixed weight machines, resistance bands, handheld weights, or bodyweight exercise. Commence with isolated muscles	Fixed weight machines, resistance bands, handheld weights, or bodyweight exercise
Inspiratory muscle training		
Frequency	Standard protocol: 6–7 days/week (twice daily) High-intensity protocol: 3–5 days/week	
Intensity	Standard protocol: 50% of PI_{max} High-intensity protocol: 20–30% PI_{max}	Standard protocol: 50% of PI_{max} High-intensity protocol: 40–70% PI_{max}
Time (duration)	Session total: 20–30 min Standard protocol: 30 breaths (twice daily) High-intensity protocol: 2 min of work, 1-min recovery, repeated 7 times	
Type (mode)	Pressure threshold device	

Adapted from Keteyian et al. [22], Piepoli et al. [53], Meyer [58], and the American College of Sports Medicine [21]

HRpeak, peak heart rate, *HRR* heart rate reserve, *MET* metabolic equivalent, *VO_2peak* peak oxygen uptake, *PI_{max}* maximal inspiratory mouth pressure, *RM* repetition maximum, *RPE* rating of perceived exertion 6–20 Borg scale

***Start at lower end of intensity ranges for deconditioned or high-risk patients

chest pain, shortness of breath, palpitations, fatigue) along with electrocardiogram (rhythm disturbances, ST segment changes) and appropriate hemodynamic responses (e.g., heart rate, systolic blood pressure) [21]. Table 2 outlines the signs or symptoms for terminating exercise during inpatient rehabilitation.

For patients with moderate to severe HF and/or who are unable to actively exercise, functional electrical stimulation (FES) has been shown to elicit superior improvements in peak oxygen uptake (VO_2peak), 6-min walk test distance, and quality of life compared with control or sham FES [59]. A passive form of muscle contraction, FES involves electrically stimulating muscles to produce muscle contraction (generally of the lower extremities) [60]. While inferior to conventional exercise training, FES may be used to accelerate early mobilization and prevent muscle wasting in the acute stages of HF before exercise training can be commenced or in patients who cannot perform active exercise (e.g., non-ambulatory, NYHA class lV) [59].

Aerobic training

All exercise sessions should include 5–10 min of warm-up and cool-down activities including dynamic and static stretching and aerobic activities of a very light or light intensity [21]. Exercise prescription recommendations for aerobic training are outlined in Table 3. Aerobic training should involve activities that employ large muscle groups in a rhythmic manner such as walking, cycling, rowing, stepping, swimming, or arm ergometry. A pragmatic approach is to begin with lower or upper body exercises that are easily learned (treadmill, cycling, arm ergometry), particularly for deconditioned patients [20], and then progress to more challenging exercises that involve lower and upper body exercise (rowing, elliptical machines). Most patients can commence their training with several 5–15-min periods at a lower intensity either on the same piece of equipment or divided into 2 to 3 modalities [22]. For patients who are unable to maintain exercise continuously early on in their program, moderate-intensity intervals (or intermittent exercise) can be employed with low-intensity recovery periods (passive if required), gradually increasing the exercise period and reducing the recovery period over time [7, 61].

Continuous training of moderate-vigorous intensities (at steady state energy metabolism) can typically be performed for prolonged periods (45–60 min). This type of training is the most established form of exercise prescription for patients with HF, with demonstrated efficacy and safety [18, 20, 62]. A graded maximal exercise test provides the best foundation for safe and effective exercise, allowing for the determination of exercise intensity as percentage of maximal oxygen uptake reserve (%VO_2R), percentage of peak oxygen uptake (%VO_2peak), or percentage of maximal heart rate reserve (%HRR) where gas exchange data are unavailable. The use of %HRR (Karvonen formula) is preferred to %HRpeak since %HRR accounts for the dynamic change between resting and peak values, rather than a static peak HR, reflecting the relative intensity more accurately [21, 28, 63]. Current guidelines recommend an optimal exercise intensity for continuous aerobic exercise to be at a moderate-vigorous level in the range of 70–80% VO_2R or HRR or a rating of perceived exertion (RPE) of 12–14 on the Borg 6–20 scale [21, 22, 53]. Intensity can be gradually increased from a low intensity (40–50% VO_2R or HRR) to a moderate intensity (60% VO_2R or HRR; ~ first ventilatory threshold) and then progressed as tolerated to a moderate-vigorous intensity (70–80% VO_2R or HRR; ~ second ventilatory threshold) [21, 53]. Exercise intensity can be the most challenging component of exercise prescription as the same relative intensity can have a varied tolerance between different patients, as well as by the same patient based on factors such as time of day, environment (temperature, humidity, air quality), and time since medications were taken [7]. Therefore, it is often practical to prescribe an intensity range approximately 5% below or above the desired intensity [7]. In the absence of a graded exercise test or maximal heart rate data, or for patients with atrial fibrillation, frequent ectopy, or marked chronotropic intolerance (< 85% of predicted HRpeak), exercise intensity may be guided by an RPE of 11–14 (6–20 Borg scale) and a target heart rate of 20–30 beats.min^{-1} above rest [21, 22]. There are no data to support the use of estimated maximal heart rate equations in patients with HF [21]. Frequency of exercise training can commence at 2–3 days/week (rest days in between as needed), with the goal to increase frequency to 3–5 days/week or preferably all days of the week [53].

Progression of exercise programming is vital for ensuring beneficial adaptations with exercise training and improvements in exercise capacity [64, 65]. At the same time, progression that is too rapid may result in adverse effects such as cardiovascular symptoms, orthopedic injury, delayed muscle soreness, or failure to recover from an exercise session [64]. In general, it is recommended to only change one FITT component at a time, and exercise duration should be progressed to a desired level (by 1–5 min per session) before increasing exercise intensity and frequency [22, 32, 64]. Increases in duration and intensity of 5–10% per session are typically well tolerated [64].

Guidelines suggest HIIT can be included 1–3 days/week in patients with HF, typically using MICT and HIIT during alternate exercise sessions [22, 53, 64]. Studies involving patients with HF have prescribed high-intensity intervals within the range of 70–90% VO_2peak, 75–90% HRR, or 80–95% HRpeak [31, 45]. During the initial weeks of exercise training, sustaining high-intensity exercise for longer than 1–2 min may be challenging for HF patients, particularly those who are exercise naïve, have comorbidities, or a higher degree of exercise intolerance [66]. To gradually introduce HIIT, prescription can commence with shorter interval durations (1–2 min) and progress to longer interval durations (3–4 min) as exercise intolerance and fitness level improve [31]. While vigorous activities can acutely increase the risk of sudden cardiac death and myocardial infarction in susceptible persons, this risk is typically greater in adults who are less physically fit and active [67]. Moreover, it is important to highlight that for patients with HF, many activities of daily living can require efforts equivalent to a vigorous intensity [44]. HIIT has shown a low rate of major adverse events in patients with HF and CAD when applied in cardiac rehabilitation settings with baseline exercise testing [68]. Recent ESC guidelines [69] outline that high-intensity exercise is appropriate for HF patients who are stable, without high-risk atherosclerotic lesions or exercise-induced dysrhythmias. Appropriate progression of exercise from low-moderate intensity to moderate-vigorous intensity before commencing HIIT (as outlined in Table 3) is a sensible approach to assess the exercise response, improve exercise tolerance and physical fitness, and minimize musculoskeletal injuries [31].

Resistance training

Resistance training is a key component of the exercise program for HF patients to counteract skeletal muscle myopathy and increase muscular strength and endurance [70–72]. The resistance training prescription should be individualized and tailored to the findings of the baseline assessments and the presence of frailty. Resistance training exercises can generally be added within 2–4 weeks of starting the aerobic exercise program or sooner according to clinical judgment [73]. Patients should be instructed to avoid the Valsalva maneuver (holding their breath during exhale) during resistance training exercises. Proper lifting technique and training should be provided including the instruction to exhale during the concentric phase and inhale in the eccentric phase of the lift [72]. Table 3 provides recommendations for initial prescription aimed at improving muscular endurance starting with low weights and high repetitions with a preference for dynamic exercises (e.g., chair sit-to-stand, leg press, chest press, bicep curl, tricep extension, knee flexion/extension, latissimus pulldown). In those that are severely deconditioned, the initial exercises can be prescribed unilaterally or as segmental training working the limbs individually to allow for peripheral adaptations without inhibition from the impaired cardiac output [72]. Mode of exercise can begin with handheld weights or resistance bands and progress from unilateral to bilateral exercises (in severely deconditioned) and eventually to weight machines. Weight machines are safe and aid in proper lifting form and technique. In those that are more conditioned, progression of the resistance training program can transition from the initial low workload phase to an endurance phase (30–40% 1-RM, 12–25 reps, RPE 12–15) followed by the strength phase at higher intensity (40–60% 1-RM; 8–15 repetitions; RPE > 15) [20, 53]. Circuit weight training is a viable option and has been associated with a 13% improvement in VO_2peak [74]. The exercises should be progressed gradually and include functional movements that will aid in completing activities of daily living [75].

Inspiratory muscle training

Inspiratory muscle weakness is prevalent in patients with HFrEF and HFpEF [76, 77]. Those with inspiratory muscle weakness are more likely to have impaired mobility and greater risk of myocardial infarction, and increased rates of all-cause and cardiovascular mortality and stroke [78–81]. Therefore, inspiratory muscle training (IMT) is an additional element to consider in the exercise prescription. In the absence of a standardized IMT prescription, the current evidence includes recommendations for both a "standard" prescription and a "high intensity" prescription. The "standard" prescription recommends 30 dynamic efforts twice daily, 6–7 days per week for 4–10 or more weeks using a pressure threshold device at a load equivalent to 50% of maximal inspiratory pressure (MIP or PI_{max}) [82–84]. The IMT prescription is progressed by instructing the individual to increase the load so that completion of the 30 breaths is at the limit of their tolerance [84]. This prescription was associated with improvements in MIP, reductions in sense of dyspnea, and exercise capacity as measured by VO_2peak and 6-min walk test [85–89]. The "high intensity" prescription recommends 2 min of loaded inspirations with 1 min of recovery, repeated seven times, performed 3–5 days per week for at least 8 weeks at a threshold load starting at 20–30% PI_{max} and progressing to 70% of baseline PI_{max} by the third or fourth session [90]. Further progression is achieved by increasing the load such that they are only able to complete the final 2-min interval [90]. Improvements in MIP, dyspnea, fatigue, and 6-min walk distance were achieved with this protocol [91]. The European Secondary Prevention Guidelines recommend a more gradual approach to load progression, starting with a gradual increase in load every 7–10 days from 30% PI_{max} to 60% PI_{max} [53].

Clinical considerations

Medications

For patients with HFrEF, guideline-directed medical therapy currently includes four major classes of medications: (1) β-adrenergic receptor blockers (β-blocker); (2) sodium-glucose cotransporter 2 inhibitor; (3) mineralocorticoid receptor antagonist; and (4) either angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, or angiotensin receptor-neprilysin inhibitor, depending on New York Heart Association Stage [15]. In addition to reducing mortality, hospitalizations, and disease progression, these medications help to reduce myocardial load and improve exercise tolerance [15, 21]. For exercise testing and training, patients should be instructed to take their medications as prescribed. Patients on β-blockers can have an attenuated heart rate response to exercise, with the extent depending on the dose and timing in relation to exercise [21]. If the β-blocker dose changes during an exercise program, a new graded exercise test is recommended to establish the new maximal heart rate; however, if this is not feasible, noting the heart rate response at the workload most recently used to determine the new heart rate target [21]. Mineralocorticoid receptor antagonists are a type of diuretic, which are used to lower blood pressure and prevent fluid overload. Diuretics can increase the risk of volume depletion, orthostatic hypotension, and dehydration [21]. Blood pressure response with exercise and in recovery should be monitored along with symptoms of dizziness or light-headedness, and an extended cool-down period can be helpful to prevent post-exercise hypotension [21].

Implantable devices

Exercise training can be performed safely in patients with a pacemaker or an ICD [92]; however, certain considerations should be taken into account. Rigorous upper extremity exercises should be avoided for at least 3–4 weeks following implantation (e.g., swimming, bowling, elliptical machines, rowing, lifting weights, golf) [21, 22]. Exercise testing is strongly recommended to assess rate responsiveness and optimize the heart rate response [21]. It is important that the pacemaker or ICD programming settings are optimized (upper rate limit and rate responsiveness) to maximize a patient's ability to perform activities and exercise effectively [7]. If a patient's heart rate does not increase with exercise testing, then exercise training should be postponed until the exercise sensing mechanism (to movement or respiration) has been adjusted by the device specialist [21]. Exercise specialists should be familiar with the reason for ICD implantation, the triggers for dysrhythmia (e.g., ischemia or specific heart rate), the individual intervention threshold, and the sequence of therapy (monitoring zone, anti-tachycardia pacing, shocks) [20, 22]. Heart rate monitoring is advisable when exercise is prescribed close to the device's programmed intervention zone. Exercise should be prescribed at an intensity where maximal training heart rate is 10–20 beats.min^{-1} below the programmed threshold for ICD intervention [20, 21]. For patients who have a history of symptomatic dysrhythmias or ICD discharges, exercise modalities should be chosen in which short loss of consciousness would be less harmful (e.g., cycling or arm ergometry), and water exercise should be avoided unless supervised [20].

Exercise-induced ischemia

For patients with exercise-induced ischemia or angina, exercise intensity should be set to elicit a heart rate of 10 beats.min^{-1} below the threshold of ischemia or angina symptoms [21]. A longer warm-up time can increase the time to ischemia and the ischemic threshold, which is thought to be due to a slower rise in cardiac workload from improved myocardial perfusion and preconditioning [93]. As exercise duration increases (particularly in warmer environments), the same workload may cause a progressive increase in heart rate, and workload may need to be reduced to maintain the desired heart rate below the ischemic threshold. For patients who experience angina with exercise below the recommended intensity targets or routine daily activities, the use of prophylactic sublingual nitroglycerin (taken 10 min before the start of exercise) may be a strategy that exercise specialists or cardiac rehabilitation staff can discuss with the patient's physician, which can typically allow patients to exercise without symptoms and at slightly higher workloads [22, 94]. Since nitroglycerin has a vasodilatory effect which can cause patients to feel light-headed, patients should be seated when administered, and additional blood pressure monitoring may be needed before and after administration, and prior to commencing exercise.

Frailty/cachexia/sarcopenia

There is a bidirectional relationship between HF and frailty such that older individuals with HF are at risk of developing frailty, and frail older individuals are at risk of developing HF [95]. An estimated 45% of patients with HF have concurrent frailty identifying a significant area of focus for exercise prescription [96, 97]. Cardiac rehabilitation and exercise training programs are uniquely designed to counteract and address the components of frailty that have significant crossover with HF comorbidities (sarcopenia, limited mobility/sedentary lifestyle, fatigue, cognitive impairment, mood disorders and/or depression, self-efficacy, and quality of life) [98]. The exercise prescription should be tailored by shifting the time spent in aerobic, strength, and balance/flexibility components [99]. In those identified as pre-frail, the exercise prescription has a greater focus initially on resistance training (20 min; 80% 1-RM; 2–3 times per week), balance exercises (20 min; 2–3 times per week), and only 10 min of aerobic exercise [99]. For individuals with frailty, the overall exercise time decreases to 45 min with a shift in aerobic exercise duration back to 20 min, a reduction of resistance training to 10 min, and the remaining 15 min as balance/flexibility exercises [99].

Conclusion

Evidence-based guidelines for exercise training in patients with HF recommend a combination of aerobic, resistance, and inspiratory muscle training. Following the FITT-VP principles of exercise prescription, with a particular focus on progression to optimal intensity and volume, helps to produce a sufficient stimulus for promoting beneficial physiological adaptations that lead to improvements in exercise capacity, HF symptoms, and prognosis. There is no "one size fits all" approach to exercise training in patients with HF. This review has provided rationale and outlined exercise prescription recommendations and practical strategies to adapt exercise training prescription based on degree of exercise intolerance, medications, and other clinical considerations for HF patients.

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Declarations

Conflict of interest The authors declare no competing interests.

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