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Principles of exercise prescription for patients with chronic heart failure

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Abstract Chronic heart failure (CHF) is a common and debilitating condition characterized by reduced exercise tolerance. While exercise training was once thought to be contraindicated for patients with CHF, a substantial body of data has been published over the last two decades to support the use of exercise programs for these patients. Improvements in exercise capacity, quality of life, and mortality have been demonstrated among patients with CHF who have participated in formal exercise programs. *Exercise prescription* is a means of assessing and interpreting clinical information and applying the principles of training to develop an appropriate regimen so that these benefits are achieved. The major principles of the exercise prescription are the *mode, frequency, duration, and intensity*. Importantly, safe and effective exercise prescription for patients with CHF requires more than the application of these principles; it also requires careful consideration of the individual patients' functional status, comorbid conditions, medications, contraindications, and personal goals and preferences. Recent studies have demonstrated that a wide spectrum of patients with CHF benefit from appropriately applied exercise training, including those with both systolic and diastolic dysfunction, atrial fibrillation, pacemakers, implantable cardioversion devices, and post-cardiac transplantation. Increasingly, the principles of exercise prescription are included as a component of comprehensive CHF management programs. Evidence has accumulated that CHF patients who participate in rehabilitation programs have better health outcomes in terms of reduced morbidity and mortality, as well as lower hospitalization rates and lower overall health care costs.

Keywords Heart failure · Rehabilitation · Exercise testing · Heart disease

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The hallmark symptom of chronic heart failure (CHF) is exercise intolerance, often exhibited by early fatigue or shortness of breath with a minimal degree of exertion. The pathophysiologic features of CHF that underlie reduced exercise tolerance have been the focus of numerous investigations the last two decades [1, 2]. These involve both central (cardiac) and peripheral (skeletal muscle and vascular) abnormalities, including impaired cardiac output responses to exercise, abnormal redistribution of blood flow, reduced mitochondrial volume and density, impaired vasodilatory capacity, and heightened systemic vascular resistance [1–4]. The reduced exercise tolerance that characterizes CHF has profound implications for the capacity to perform daily activities, disability, quality of life, and prognosis. Thus, one of the principal goals of treatment in CHF is to improve exercise capacity.

Until the late 1980s, patients with CHF were commonly excluded from rehabilitation programs due to concerns over safety, whether training caused further harm to an already damaged myocardium, and questions as to whether these patients could benefit from rehabilitation. These concerns have been allayed by numerous studies performed over the last two decades documenting that exercise training in patients with CHF is safe, that training causes no further damage to the myocardium, and that rehabilitation programs have been associated with numerous physiological, musculoskeletal, and psychosocial benefits

[1, 5]. However, this population presents some unique challenges for exercise programming. In this article, the underlying principles of aerobic exercise prescription for patients with CHF are discussed.

Approach to the patient with CHF

Prior to beginning an exercise program, all patients with a confirmed CHF diagnosis require a comprehensive clinical evaluation, including treatment of underlying causes of CHF, optimal pharmacologic therapy, and risk stratification (Table 1). The clinical approach to the patient with CHF who is considered for an exercise program is similar to that of the post-myocardial infarction patient with normal ventricular function, although several important differences are worth noting. While serious events during exercise are extremely low in all patients [6], the risk for sudden, arrhythmic events is a greater concern in patients with CHF. There are often more medications that can influence exercise responses, including vasoactive, antiarrhythmic, inotropic, and beta-blocking agents. There are more comorbidities to consider, and an increasing proportion of these patients have bi-ventricular pacemakers or implantable cardioversion devices (ICDs). Importantly, exercise capacity tends to be significantly lower than that in the typical patient with coronary artery disease.

The extent to which exercise capacity is impaired in CHF is typically 30–50% relative to age-matched normal subjects and is 20–30% lower than that among typical patients with coronary disease [1, 7, 8]. These impairments may be even more pronounced in women with CHF [9]. Numerous hemodynamic abnormalities underlie the reduced exercise capacity commonly observed in CHF, including impaired heart rate responses to exercise, an inability to distribute cardiac output normally, abnormal arterial vasodilatory capacity, abnormal cellular metabolism in the skeletal muscle, higher than normal systemic vascular resistance, higher than normal pulmonary artery pressures, and ventilatory abnormalities that increase the work of breathing and cause exertional dyspnea [1–4, 8, 10]. While studies performed over the last two decades have demonstrated that many of these abnormalities can be improved by exercise training [1, 5, 8, 9, 11, 12], they are important considerations prior to beginning an exercise program for the patient with CHF.

Most patients with reduced left ventricular function who are clinically stable and have reduced exercise tolerance are candidates for exercise programs. Stability can be assured by the absence of recent changes in body weight, the absence of recent changes in symptoms, and control of comorbid conditions. The benefits of training do not appear to be dependent on the etiology of CHF, or standard clinical measures such as baseline peak VO_2 or ejection fraction [11, 13]. Consideration of absolute and relative contraindications to exercise specific to CHF (Table 2) should be considered [11]. An exercise test is particularly important before initiating the program to ensure safety of participation. Expired gas exchange measurements are particularly informative in this group because they permit an assessment of ventilatory abnormalities that are common in this condition [1, 2, 10, 12, 14–16], and are important for risk stratification [15, 17]. Rhythm abnormalities, exertional hypotension, or other signs of instability should be ruled out. ECG monitoring during exercise is more often indicated in this group. Attention should be paid to daily changes in body weight, rhythm status, and congestive symptoms as they may alert the clinician to decompensated heart failure.

Exercise programming in CHF

The caveats described above notwithstanding, exercise programming in patients with CHF does not fundamentally differ from that in patients with normal ventricular

Table 1 Core components of cardiac rehabilitation in chronic heart failure

Baseline clinical assessment and risk stratification
Treatment of causative factors of heart failure (hypertension, coronary artery disease, atrial fibrillation, and valvular heart disease) and correction of precipitating causes (non-compliance with drugs, use of non-steroidal anti-inflammatory drugs and cyclooxygenases-2 inhibitors, nasal decongestants, infections, pulmonary emboli, dietary indiscretion, inactivity, hyperthyroidism)
Optimal pharmacological therapy directed by national and international guidelines
Management of HF-related diseases and competing comorbidities
Implementation of a continuing program on physical activity and exercise training
Counseling and education: lifestyle, dietary recommendations, coping strategies, medications, self-monitoring, prognosis
Psychological support
Planning of continuum of care thorough an efficient, organized linkage between hospital and community

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Table 2 Relative and absolute contraindications to exercise training among patients with stable chronic heart failure

Relative contraindications
1. ≥1.8 kg increase in body mass over previous 1–3 days
2. Concurrent continuous or intermittent dobutamine therapy
3. Decrease in systolic blood pressure with exercise
4. New York Heart Association Functional Class IV
5. Complex ventricular arrhythmias at rest or appearing with exertion
6. Supine resting heart rate ≥100 beats·min^{-1}
7. Preexisting comorbidities
Absolute contraindications
1. Progressive worsening of exercise tolerance or dyspnea at rest or on exertion over previous 3–5 days
2. Significant ischemia at low work rates (<2 METS, or ≈50 W)
3. Uncontrolled diabetes
4. Acute systemic illness or fever
5. Recent embolism
6. Thrombophlebitis
7. Active pericarditis or myocarditis
8. Moderate to severe aortic stenosis
9. Regurgitant valvular heart disease requiring surgery
10. Myocardial infarction within previous 3 weeks
11. New onset atrial fibrillation

From Recommendations for exercise training in chronic heart failure patients

Working Group on Cardiac Rehabilitation & Exercise Physiology and Working Group on Heart Failure of the European Society of Cardiology. Eur Heart J 2001;22:125–135

function. *Exercise prescription* essentially describes the process whereby a person's recommended regimen of physical activity is designed in a systematic and individualized manner. An "individualized manner" implies specific strategies to optimize return to work or activities of daily living, reduction of risk factors for future cardiac events, and maximization of the patient's capacity to maintain an active lifestyle. The development of an appropriate exercise prescription to meet the individual patient's needs has a sound scientific foundation, but there is also an art to effective exercise programming.

The art of exercise prescription for patients with CHF has become increasingly important in the current era of cost containment, in which rehabilitation periods tend to be shorter than in the past. Surgical and technologic advances have also changed rehabilitation (e.g., there are larger numbers of post-transplant patients, those with ICDs, those with pacemakers or post-cardiac resynchronization therapy (CRT) and left ventricular assist devices (LVAD) than in previous years). In addition, there is a multitude of new medicines available, which have improved outcomes for patients with CHF, while altering hemodynamic responses to exercise. There is no single program that is best for all patients or even one patient over time. Capabilities, vocational needs, and expectations differ among patients and can change with the passing of time. Thus, the art of exercise prescription relies on the practitioner's abilities to synthesize the patient's pathophysiologic, psychosocial, and vocational factors and tailor them to the patient's needs and realistic goals. A final but important consideration is the selection of activities that the patient enjoys, which will provide the best chance that he or she will continue to perform safely after the formal rehabilitation program ends.

Contraindications to exercise in heart failure

The absolute and relative contraindications to exercise listed in Table 2 should be carefully considered before beginning an exercise program in the CHF patient. In particular, signs of instability or decompensation such as recent changes in weight (≥4 lbs over 1–3 days), uncontrolled resting heart rate (e.g., >100 beats·min^{-1}), or a sudden change in symptoms or exercise tolerance, require immediate referral to the patient's primary physician. Notable absolute contraindications include valvular disease, particularly aortic stenosis, and active myocarditis. The exercise program can usually be continued once stability is assured. Benefits of training are not specific to the etiology of heart failure [11, 13]; although patients with very low ejection fractions (e.g., <20%) were thought to be poor candidates for exercise programs in the past, numerous studies have demonstrated that these patients can exercise safely and benefit to a degree that is similar to other patients [11, 13, 18, 19]. Recent evidence has also shown that patients with LVADs and ICDs are also good candidates for rehabilitation [20–23]. Optimizing the pacemaker programming, including the upper rate limit and rate responsiveness, will maximize the patient's capabilities to perform activities. In patients with ICDs, it is necessary to be particularly judicious about keeping the heart rate below the threshold of activating the pacemaker, and such patients are appropriate for continuous telemetry monitoring. The exercise specialist working with patients who have had CRT or those with ICDs must work closely with the patient's personal physician to ensure that the exercise program is conducted appropriately.

Cardiovascular signs and symptoms below which an upper limit for exercise intensity should be set are presented in Table 3. Comorbidities, including diabetes, obesity, pulmonary disease, and musculoskeletal disorders are common in patients with CHF, and these should also be carefully considered when developing an exercise program. These conditions can significantly limit a patient's exercise capabilities independent of their cardiovascular disease. In addition, many patients with CHF have little or no recent history of exercise participation, and are therefore severely deconditioned. Thus, the initial exercise intensity should remain in the lower range for the initial sessions. This lower intensity can be offset by increases in duration or frequency of exercise if tolerated.

ECG monitoring during exercise

It is currently appreciated that only a small percentage of patients require continuous ECG monitoring during exercise. Efforts to reduce the cost of rehabilitation in addition to the recognition that most patients can exercise quite safely without continuous telemetry have brought about this change. While earlier American College of Cardiology and other guidelines suggested ECG monitoring for the first 6–12 sessions [24], recommendations on this issue have varied widely. CHF patients who should be considered for longer ECG monitoring include survivors of sudden cardiac death as well as those patients with a history of serious rhythm disorders, severely depressed left ventricular function (ejection fraction under 25%), abnormal hemodynamic responses to exercise testing e.g., exercise-induced hypotension), severe coronary artery disease and marked exercise-induced ischemia, patients with ICDs, or those unable to self-monitor intensity due to physical or intellectual impairment.

Principles of exercise prescription

Training implies adaptations of the body to the demands placed on it. A *training* effect is best measured as an increase in maximal ventilatory oxygen uptake. However, not all institutions have gas exchange equipment, and there are many ways to quantify functional outcomes of rehabilitation. For example, some patients after rehabilitation may be better suited to carry out submaximal levels of activity for longer periods, remain independent, continue working, or rejoin their friends on the golf course. All of these can be important goals for a given patient and may occur even with a minimal change in maximal oxygen uptake.

The major ingredients of the exercise prescription are frequency, intensity, duration, mode, and rate of progression. In general, these principles apply for both the patient with coronary artery disease, CHF, and the healthy adult; however, the ways in which they are applied differ, and appropriate adjustments in each of these principles are necessary for patients with CHF (Table 4). On the basis of numerous studies performed since the 1950s, it is generally accepted that increases in maximal oxygen uptake are

Table 3 Signs and symptoms below which an upper limit for exercise intensity should be set[a]

Onset of angina or other symptoms of cardiovascular insufficiency
Plateau or decrease in systolic blood pressure, systolic blood pressure of >250 mmHg or diastolic blood pressure of >115 mmHg
≥1.0 mm ST-segment depression, horizontal or downsloping
Radionuclide evidence of left ventricular dysfunction or onset of moderate to severe wall motion abnormalities during exertion
Increased frequency of ventricular dysrhythmias
Other significant ECG disturbances (e.g., 2 or 3 degree atrioventricular block, atrial fibrillation, supraventricular tachycardia, complex ventricular ectopy, etc.)
Other signs/symptoms of intolerance to exercise

[a] The exercise heart rate generally should be at least 10 beats·min^{-1} below the heart rate associated with any of the referenced criteria. Other variables (e.g., the corresponding systolic blood pressure response and perceived exertion), however, also should be considered when establishing exercise intensity

From American College of Sports Medicine (2006) Guidelines for Exercise Testing and Exercise Prescription, 7th edn. Lippincott, Williams & Wilkins, Baltimore

Table 4 Components of the exercise prescription for patients with heart failure

Type
Aerobic, dynamic exercise
Light resistance training (high repetition, low resistance)
Avoid isometric, body-building type activities
Intensity
Below ventilatory threshold
Target work rate corresponding to 50–70% of peak VO_2
Rating of perceived exertion (Borg 6–20 scale) approximately 12–14
Heart rate reserve 60–80% of maximum
Duration
May need to start at only 10–20 min/sessions
Work up to 30–40 min/sessions
Frequency
3–5 times/week

achieved if a person exercises dynamically for a period ranging from 15 to 60 min, three to five times per week, at an intensity equivalent to 50–80% of their maximum capacity. It is appropriate to start an exercise program for a typical patient with new-onset CHF at the lower end of these ranges (e.g., ≈20 min at 50% capacity), and progress the duration and intensity as the patient's condition improves. Dynamic exercises are those that employ large muscle groups in a rhythmic manner, such as treadmill walking, cycle ergometry, rowing, stepping, and arm ergometry. Short warm-up and cool-down periods may be particularly important for the CHF patient because there tends to be a slower cardiovascular adaptation to and recovery from a given work rate. Again however, an effective exercise prescription must consider the patient's goals, health status, and availability of time in addition to practical considerations such as cost, availability of equipment, and facilities.

Much of the art of exercise prescription involves individualizing the exercise intensity. Typically, exercise intensity is expressed as a percentage of maximal capacity, either in absolute terms (i.e., workload or watts) or in relation to the maximal heart rate, maximal oxygen uptake, or perceived effort. Training benefits have been shown to occur with exercise intensities ranging from 40 to 85% of maximal oxygen uptake, which are generally equivalent to 50–90% of the maximal heart rate [25]. However, the intensity that a given individual can maintain for a specified period of time varies widely. In general, the most appropriate intensity for most patients in rehabilitation programs is 50–70% of maximal capacity. As mentioned above, it is usually most appropriate for patients with CHF to begin an exercise program at the lower end of this range, and gradually increase the intensity over several weeks. For patients who have undergone cardiopulmonary exercise testing, the ventilatory threshold is also a useful upper limit for the exercise intensity [26, 27]. Interval sessions, which involve intermittent periods of exercise (1–2 min) followed by low-intensity recovery periods, are suitable for patients early in their program who have difficulty maintaining exercise continuously [11, 28]. The actual prescribed exercise intensity for the patient should naturally depend on health status, length of time since infarction or surgery, symptoms, and initial state of fitness.

Training is a general phenomenon; there is no true threshold beyond which patients achieve benefits. Thus, as long as patients exercise safely, setting the exercise intensity is a less rigid practice than it was years ago. In addition, the CHF patient's ability to tolerate activities can change daily. Other factors, such as time of day, environment, and time since medications were taken, can influence the patient's response to exercise, and the exercise prescription must be adjusted accordingly. It is also useful to employ a window of intensity that ranges approximately 5% below and 5% above the desired level.

The graded exercise test is the foundation on which a safe and effective exercise prescription is based. To achieve a desired training intensity, oxygen uptake or some estimate of it must be quantified during a maximal or symptom-limited exercise test. As heart rate is easily measured and is linearly related to oxygen uptake, it has been a standard by which training intensity is estimated during exercise sessions. A useful and very common method is known as the heart rate reserve. This method uses a percentage of the difference between maximum heart rate and resting heart rate, and adds this value to the resting heart rate. For example, for a patient who achieves a maximum heart rate of 150 beats·min^{-1}, has a resting heart rate of 70 beats·min^{-1}, and wishes to exercise at intensity equivalent to 60% of maximum:

Maximum heart rate = 150 beats per minute
– Resting heart rate = 70
Heart rate reserve = 80
× Desired intensity (60%)
= 48
+ Resting heart rate = 70
= Training heart rate 118

A reasonable training heart rate range for this individual would be 115–125 beats·min^{-1}. This is also referred to as the Karvonen formula and is reliable for patients in normal sinus rhythm whose measurements of resting and maximum heart rates are accurate. An estimated target heart rate for exercise should be supplemented by considering the patient's MET level relative to his or her maximum, the perceived exertion, and symptoms. Exercise intensities corresponding to a perceived exertion level between 12 and 14 (Borg 6–20 scale) have been shown to be well-tolerated and associated with favorable training responses in patients with CHF [29]. Between 10 and 30% of patients with CHF have atrial fibrillation [30]; because heart rate is irregular in these patients, perceived exertion is particularly useful to guide training intensity.

Resistance exercise in heart failure

The use of resistance exercise as a component of the overall exercise prescription in patients with CHF represents a change from the past. Once thought to be strictly contraindicated, resistance training is currently widely recommended to assist the patient in restoring muscular strength. As a complement to aerobic conditioning, resistance training has been demonstrated to have favorable effects on cardiovascular endurance, hypertension, hyperlipidemia, and the capacity to perform activities of daily living [31]. Detailed overviews of the benefits of resistance training in CHF, its indications, contraindications, and appropriate methods are available [31–33].

Exercise training after cardiac transplantation

Increasing numbers of patients have undergone cardiac transplantation for end-stage heart failure, and approximately three-quarters of these patients remain alive after 5 years. A key objective after surgery for these patients is to return them to a functional lifestyle and optimize their quality of life. Therefore, post-transplant patients are presently considered excellent candidates for rehabilitation programs [34, 35]. As the transplant patient's heart is denervated, some unique hemodynamic responses to exercise are observed, and these are important considerations for prescribing exercise. The heart is not responsive to the normal actions of the parasympathetic and sympathetic nervous systems. The absence of vagal tone explains the high resting heart rates in these patients (100–110 beats·min^{-1}) and the relatively slow adaptation of the heart to a given amount of submaximal work. As a result, the delivery of oxygen to the working tissue is slower, contributing to earlier than normal metabolic acidosis and hyperventilation during exercise. Maximal heart rate is lower in transplant patients than in normal subjects, which contributes to a reduction in cardiac output and exercise capacity. The atypical response of the denervated heart to exercise requires that training intensity be guided by metabolic measurements and/or perceived exertion rather than by heart rate [34–36].

A growing number of reports have addressed the physiological effects of training after cardiac transplantation. These studies have demonstrated increases in peak oxygen uptake, reductions in resting and submaximal heart rates, and improved ventilatory responses to exercise after periods of training [34–37]. The major physiologic adaptations to exercise in these patients appear to be a combination of peripheral changes (skeletal muscle and vascular alterations leading to better oxygen extraction) and improved central hemodynamics, including an increase in maximal heart rate and maximal cardiac output. In addition, recent studies have demonstrated that resistance training is effective in improving muscular strength and offsetting corticosteroid-induced osteoporosis and skeletal muscle myopathy in transplant recipients [38, 39]. Psychosocial studies of rehabilitation in transplantation patients are lacking, as are studies of the effects of regular exercise on survival.

Exercise prescription as part of integrated disease management

Although exercise training remains the hallmark of rehabilitation, programs have evolved in recent years that incorporate rehabilitation as part of the spectrum of CHF disease management. These programs have evolved for several reasons: (1) a recognition of the deficiencies of "usual care"; (2) the incorporation of non-physician allied health professionals (such as nurse case managers or clinical exercise physiologists) has been shown to increase adherence to exercise and the ability of patients to achieve treatment goals; and (3) comprehensive, integrated disease management programs have been demonstrated to improve outcomes and reduce health care costs [40–43]. Time constraints placed on physicians by current medical practice have contributed to a treatment gap between proven therapies and clinical practice; in the current medical climate, clinicians often do not have the time to follow patient's clinical needs closely or frequently enough, nor to educate them about dietary changes, make recommendations about physical activity, or explain the importance of compliance with medications. Comprehensive case management lends itself well to the purview of cardiac rehabilitation, in which non-physician allied health professionals are able to interact more frequently with patients than are physicians. This approach has been applied using a variety of methods over the last decade, including specialized clinics, telemedicine (including frequent phone contact and internet-based monitoring of heart rate, physical activity, and changes in body weight), home visits, and intensive education and intervention. The application of these methods has been persuasive in demonstrating improvements in functional capabilities, reductions in hospital readmissions, and reductions in mortality in patients with CHF [40–44].

Summary

A wealth of data published over the last two decades has documented the physiological, psychosocial, and outcome benefits of exercise training programs in patients with CHF. Studies have shown that these patients benefit from training in a fashion that is similar to post-MI patients with normal ventricular function. While some of the specifics differ and there are more caveats to consider, the overall approach to prescribing exercise is similar between patients with CHF and those with normal left ventricular function. Appropriate consideration of exercise duration, frequency, intensity, and progression will contribute to an optimal physiologic response to training in CHF. A paramount consideration is the fact that each patient with CHF may differ in terms of their ability to tolerate the same relative training stimulus, requiring particular attention to individualizing the exercise program. Ideally, exercise should be an integral part of a comprehensive heart failure management program, as these approaches have been shown to optimize adherence to exercise and other lifestyle changes, and have led to improved outcomes and cost savings.

The recent public health message emphasizing physical activity as inherently beneficial independent of objective measures physiological fitness [45, 46] is also germane to cardiac rehabilitation in CHF in that it underscores the importance of making physical activity an integral part a patient's lifestyle in the long term. This emphasis has also led to a shift in focus from objective measurements of short-term fitness to issues related to maintaining an active lifestyle, optimizing a patient's capacity to perform the physical challenges offered by occupational or recreational activities, improving quality of life, and reducing mortality. Exercise prescription, either as part of a formal training program or as a means to promote daily activity, remains the cornerstone of rehabilitation and secondary prevention. Appropriately designed and individualized exercise programs favorably affect the underlying pathophysiology of CHF and thus the extent of disability, and the available evidence from combined trials suggests that exercise training reduces morbidity and mortality.

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