2014

Rehabilitation considerations for the older adult with heart failure: A review of the literature.

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Published online: 7 June 2014
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Abstract Affecting more than 5.1 million Americans in 2013, heart failure (HF) is a debilitating syndrome that causes dyspnea, reduced exercise tolerance, fatigue, and diminished quality of life. Most commonly diagnosed in individuals over 65 years of age, the prevalence of HF and its associated health care costs are expected to grow significantly. Aerobic exercise, resistance training, and inspiratory muscle training (IMT) are interventions that are currently used in the treatment of older adults with HF. A literature search was conducted for meta-analyses, systematic reviews, and large randomized control trials to evaluate the effect of aerobic exercise, resistance training, and IMT interventions on exercise tolerance and quality of life in individuals with HF. Overall, aerobic exercise, resistance training, and IMT appear to be safe and effective in appropriately selected individuals for improving exercise tolerance and quality of life in individuals with HF. The benefits of resistance training in isolation are not clear.

Keywords Heart failure · Resistance training · Aerobic training · Exercise training · Strength training · Inspiratory muscle training · Respiratory training

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Introduction

Heart failure (HF) is a debilitating clinical syndrome that affected 5.1 million Americans in 2013 [1•]. The ventricular dysfunction and impaired cardiac output that comprise HF manifest in the form of dyspnea, fatigue, exercise intolerance, and diminished quality of life (QOL) [2]. Cardiac impairments may also lead to pulmonary or peripheral edema resulting in further diminished tissue perfusion to vital organs [3•, 4•]. “Congestive heart failure” is a term reserved for these signs and/or symptoms in the presence of fluid overload. Various structural and metabolic disorders—myocardial injury, cardiac valve dysfunction, coronary vascular impairment, left ventricular abnormalities—are all possible contributors to the development of HF [3•].

Despite an already astonishing prevalence of HF in the United States with >650,000 new cases reported annually, the incidence of HF is anticipated to rise [3•]. Among older adults, 20 per 1,000 individuals aged 65–69 years have a diagnosis of HF compared to greater than 80 per 1,000 individuals for those 85 years and older [5]. An admitting diagnosis of HF was observed in more than one million hospitalizations in the United States in 2013 [1•]. Re-admissions within 1 month are noted to be as high as 25 %, accounting for more than 50 % of the \$32 billion spent annually on HF and significantly contributing to the exceptional cost of HF [6, 7•].

The morbidity and mortality associated with HF is considerable. Research has shown that approximately 50 % of individuals with a mean age of 74.5 years will die within 5 years of receiving an HF diagnosis [8]. Heart failure was also listed as a contributing diagnosis on one out of nine death certificates for Americans in 2009 [1•]. Symptoms and limitations experienced by individuals with HF include fatigue, dyspnea on exertion, muscle atrophy, weakness, reduced QOL, and poor exercise

tolerance [9–11], with exercise intolerance reported as the most frequent and debilitating symptom [12].

With the projected increase in the number and proportion of older adults (up to one in five persons will be >65 years in the United States by 2050) [13], the care needs and financial burden imposed by HF will require that rehabilitation clinicians utilize evidence-based intervention strategies for individuals with HF. The purpose of the review is to present current evidence and recommendations for rehabilitation interventions in older adults with HF including aerobic training, resistance training, and inspiratory muscle training (IMT). Therefore, a search for systematic reviews and large randomized control trials was conducted in PubMed, CINAHL, and the Cochrane Database of Systematic Reviews using various combinations of the following terms: Heart failure; Chronic heart failure; Congestive heart failure; CHF; Resistance training; Aerobic training; Exercise training; Strength training; High intensity interval training; Inspiratory muscle training; IMT; Respiratory training.

Aerobic Exercise Training

The primary physiologic mechanisms causing exercise intolerance, dyspnea on exertion, and fatigue that are targeted by aerobic exercise training interventions include reduced peak oxygen uptake associated with reduced cardiac output and metabolic skeletal muscle changes [12, 14•, 15, 16•, 17, 18].

Four meta-analyses [19•, 20, 21, 22•], two systematic reviews [16•, 23], two non-systematic reviews [14•, 24•], and one randomized control trial (RCT) [17, 18], summarize the best available evidence using the previously described search methodology. Table 1 provides a summary of each. Together, these papers account for over 60 controlled trials and over 5,000 total patients ranging from New York Heart Association (NYHA) Class I to IV, with the majority being Class I to III.

Effects of Aerobic Exercise Training on Exercise Tolerance

Of the aforementioned papers that evaluated peak oxygen consumption, two of two meta-analyses [19•, 22•], three of three systematic reviews [4•, 16•, 23], two of two non-systematic reviews [14•, 24•], and the HF-ACTION RCT [18] demonstrate that aerobic exercise training results in improved peak oxygen consumption in individuals with HF. Improvements in peak oxygen consumption ranged from 4 % to 46 %. Differences in supervised vs. unsupervised exercise protocols may have contributed to the large range of improvement. Evidence suggests that supervised sessions are correlated with improved adherence and, therefore, greater improvements in peak oxygen consumption.

Of the included randomized control trials, systematic reviews, meta-analyses, and review papers evaluating the effect of aerobic exercise training on exercise tolerance using the 6-min walk test (6MWT), all three reported significant improvements [14•, 17, 22•]. Van der Meer et al. [22•] and Keteyian et al. [14•] reported an average improvement of nearly 50 m among aerobic exercise training groups, and the HF-ACTION trial [17] demonstrated an improvement of 20 m compared to 5 m in the usual care group.

Haykowsky et al. [20] suggested that the possible underlying mechanism for the improvements observed in aerobic capacity was positive remodeling of the left ventricle as evidenced by the increase in left ventricular ejection fraction (LVEF) observed in exercising subjects compared to non-exercising controls. The review by Keteyian et al. [14•] reported that exercise training increases cardiac output by increasing local blood flow in individuals with HF.

Effects of Aerobic Exercise Training on Quality of Life

Although aerobic exercise training clearly results in improved exercise tolerance in individuals with HF, it is important to understand the way in which these improvements translate into improved QOL. All three systematic reviews [16•, 21, 22•], one of one non-systematic reviews [14•], and the HF-ACTION RCT [18] concluded that aerobic exercise training results in improved quality of life as measured by either the Kansas City Cardiomyopathy Questionnaire or the Minnesota Living with Heart Failure Questionnaire. In the review by Keteyian et al. [14•], the authors noted that improvements in QOL were consistent despite differences in age, gender, and race.

Effects of Aerobic Exercise Training on Mortality and Hospitalization

Only one meta-analysis [21], two systematic reviews [16•, 23], one non-systematic review [14•], and the HF-ACTION RCT [17] evaluated the effect of aerobic exercise training on mortality and hospitalization. The meta-analysis by Davies et al. [21] did not find a significant reduction in all-cause mortality in individuals with HF. However, Davies et al. [21] did find a significant reduction in HF-related hospital admissions in the exercise group. In contrast, the systematic review by Smart et al. [23] revealed an overall reduction in mortality and adverse events following exercise training, in addition to a possible survival benefit with an odds of death being 0.71 in exercise training groups compared to controls during the study and follow-up periods. Similarly, after a median follow-up of 30 months, the HF-ACTION RCT [17, 18] demonstrated a modest reduction in all-cause hospitalizations and mortality, but only when adjusting for cardiopulmonary exercise test duration, left ventricular ejection fraction, Beck Depression

Table 1 Summary of Evidence

Study	Design/Sample Size	Intervention Investigated	Effects on Exercise Tolerance	Effects on QOL/Symptoms	Effects on Mortality/Hospitalization	Safety	Effects on Cardiac Remodeling/Other
Aerobic Exercise Training							
Keteyian 2011 [14•]	LR: NR	AT and RT	VO _{2peak} : + 6MWT: +	QOL: +	+	No adverse events	LV remodeling: + cardiac output: +
Arena et al. 2012 [16•]	SR: 3 studies 96 subjects	HI-AIT and AT HI-AIT vs. AT	VO _{2peak} : modest +	QOL: +	NR	No adverse events	LV EF: +, LV remodeling: +, Systolic/diastolic function: + (HI-AIT)
Flynn et al. 2009 [17] O'Connor et al. 2009 [18]	RCT: 2,331 subjects	AT and usual care vs. usual care	VO _{2peak} : + 6MWT: +	QOL: + (AT and usual care > usual care alone)	After adjusting for key clinical end points: +	Hospitalization after exercise: AT- 37/ 1,159 Usual care- 22/1,172	NR
Haykowsky et al. 2013 [19••]	MA: 7 studies 168 subjects	HI-AIT vs. AT	VO _{2peak} : + (HI-AIT > AT)	NR	NR	No adverse events	LV EF: + (HI-AIT and AT)
Haykowsky et al. 2007 [20]	MA: 14 RCTs 812 subjects	9 studies AT; 1 study RT; 4 studies AT and RT	NR	NR	NR	NR	LV remodeling: + AT but no greater benefit with AT and RT
Davies et al. 2010 [21]	SR+MA: 19 studies 3,647 subjects	AT	NR	QOL: +	Mortality: No Δ Hospitalization: +	No adverse events	NR
Guiraud et al. 2012 [24•]	LR: NR	HI-AIT vs. AT	VO _{2peak} : + (HI-AIT > AT)	NR	NR	No adverse events	Endothelial function: + Glucose metabolism: +
Van der Meer et al. 2011 [22••]	MA: 22 studies 3,826 subjects	9 studies AT and RT 13 studies AT	VO _{2max} : + 6MWT: +	QOL: +	NR	No adverse events	NR
Smart et al. 2004 [23]	SR: 81 studies 2,387 subjects	40 studies AT; 3 studies RT; 13 studies RT and AT	VO _{2peak} : +	NR	+	No adverse events directly related to exercise	NR
Resistance Training							
Hwang et al. 2010 [25]	SR: 8 studies 241 subjects	4 studies RT; 4 studies RT and AT	VO _{2peak} : no Δ RT Alone 6MWT: + RT Alone resting SBP and max HR for older subjects > 65: +	QOL: no Δ RT alone	NR	2 adverse events – 1 A-fib, 1 sudden death No adverse events	LV EF: No Δ
Swank et al. 2010 [26]	Cohort: 42 subjects	AT and RT	VO _{2peak} : + (both AT and AT+RT) VO _{2AT} : + (both AT and AT+RT)	NR	NR	No adverse events	Strength: +
Bouchla et al. 2011 [29•]	RCT: 20 subjects	10 subjects AT; 10 subjects AT and RT	No Δ	No Δ	NR	No adverse events	Strength: + (AT and RT > AT alone)
Spruit et al. 2009 [30]	SR: 10 studies 194 Subjects	5 studies RT; 5 study RT and AT	VO _{2peak} : no Δ	NR	5 dropouts reported	No adverse events	No Δ
Anagnostakou et al. 2011 [32•]	RCT: 28 subjects	14 subjects AT; 14 subjects AT and RT	VO _{2peak} : no Δ	NR	NR	No adverse events	Vascular reactivity: + (AT > RT)
Inspiratory Muscle Training							
Plentz et al. 2012 [37•]	MA: 6 studies 150 subjects	IMT	VO _{2peak} : + 6MWT: +	NR	NR	NR	Plmax: +

Table 1 (continued)

Study	Design/Sample Size	Intervention Investigated	Effects on Exercise Tolerance	Effects on QOL/Symptoms	Effects on Mortality/Hospitalization	Safety	Effects on Cardiac Remodeling/Other
Smart et al. 2012 [38•]	MA: 11 studies 287 subjects	IMT: 1/11 not IMT alone	VO _{2peak} : + 6MWT: +	QOL: +	NR	NR	P _{max} : + VE/VCO ₂ slope: +
Cahalin et al. 2013 [39••]	LR: 19 studies 693 subjects	IMT: 4/19 not IMT alone	VO _{2peak} : + 6MWT: +	QOL: + Dyspnea: +	NR	NR	P _{max} : +, VE/VCO ₂ slope: + LVEF: +, Quadriceps strength: +
Lin et al. 2012 [4••]	SR: 12 studies 265 subjects	IMT	VO _{2peak} : + 6MWT: +	QOL: + Dyspnea: +	NR	NR	P _{max} : +

Abbreviations: LR- Literature Review; SR- Systematic Review; MA- Meta-analysis; RCT- Randomized Controlled Trial; AT- Aerobic Exercise Training; RT- Resistance Training; IMT, Inspiratory Muscle Training; 6MWT- 6 Minute Walk Test; VO_{2peak}, peak oxygen consumption; + positive effect; no Δ no effect; NR, Not Reported; P_{max}- Maximal Inspiratory Pressure; QOL- Quality of Life; LV- Left Ventricle; HI-AIT- High-Intensity –Aerobic Interval Training; LVEF- Left Ventricular Ejection Fraction; A-Fib- Atrial Fibrillation; SBP- Systolic Blood Pressure; HR- Heart Rate; VE/VCO₂, Ventilatory Equivalent Slope for Carbon Dioxide

Inventory II score, and history of atrial fibrillation/flutter. Davies et al. [21] and O'Connor et al. [18] note that many, if not all, of the individuals with HF included in RCTs are treated with beta-blockers and angiotensin-converting enzyme inhibitors. Many also have implantable cardioverter-defibrillator or biventricular pacemakers which have also resulted in greater survival. Therefore, the ability to demonstrate additional benefits of aerobic exercise training on mortality and hospitalization may be attenuated.

Safety of Aerobic Exercise Training

All but one of the papers considered by the present review evaluated the safety of aerobic exercise training for individuals with HF. All three meta-analyses [19••, 21, 22••], both systematic reviews [16•, 23], both non-systematic reviews [14••, 24•], and the HF-ACTION RCT [18] all concluded that aerobic exercise training was safe and that there was not an increase in adverse events in the exercise training groups. Of note, Smart et al. [23] reported no exercise-related deaths in more than 60,000 patient-hours of exercise training. Of the 1,159 patients in the exercise group in the HF-ACTION trial [18], only 37 (3 %) had a hospitalization during or within 3 h of exercising. These results were similar to the usual care group, with 22 (2 %) patients out of 1,172 hospitalized.

It should be noted that the majority of aerobic exercise training clinical trials have utilized programs that include continuous aerobic exercise at a moderate intensity. However, new evidence is emerging in support of high-intensity aerobic interval training (HI-AIT), which is defined as periods of relatively shorter, high-intensity intervals interspersed with longer, lower-intensity intervals that result in an overall higher metabolic demand than that achieved with continuous exercise [16•]. Preliminary studies indicate that HI-AIT leads to greater improvements in ventilatory efficiency and peak oxygen consumption compared to continuous aerobic exercise [16•, 19••, 23]. A limitation of the research surrounding HI-AIT is that only small sample sizes have been studied, and these samples have not been sufficiently heterogeneous to provide assurance of safety across a relatively wider variety of individuals with HF similar to those studied using moderate intensity, continuous aerobic exercise training [19••, 24•].

It is important to note that all studies evaluating the effects of aerobic exercise training have utilized stringent inclusion and exclusion criteria that ensured the clinical stability of participants and relative absence of significant comorbidities. Stability of participants was ensured by only including patients receiving stable doses of optimal pharmacologic therapies and by excluding any participants with recent cardiovascular events or procedures (<6 weeks) or co-morbidities that did not allow them to participate in exercise. Table 2 highlights the exclusion criteria from some of the larger published clinical trials. Therefore, cautious and somewhat limited

Table 2 Common Exclusion Criteria

Study	Exclusion Criteria
AEROBIC EXERCISE TRAINING	
Belardinelli et al. 2012 [40]	Hemodynamically significant valvular heart disease, uncontrolled diabetes and hypertension, orthopedic or neurological problems, renal insufficiency (creatinine: >2.5 mg/dl).
Nilsson et al. 2008 [41]	Acute myocardial infarction (within 4 weeks), unstable angina pectoris, uncontrolled atrial fibrillation, symptomatic peripheral vascular disease, obstructive pulmonary disease with forced expiratory vital capacity <50 % or predicted, 6-min walk test distance >550 m, and workload of the ergometer cycle test >110 W.
Whellan DJ et al. 2007 (HF-ACTION) [42]	<18 years, inability to perform exercise training, major cardiovascular event or procedure (included ICD) within the previous 6 weeks, cardiovascular procedure or hospitalization planned within 6 months, pregnancy or plan to become pregnant in the next year, expectation of receiving a cardiac transplant within the next 6 months, HF secondary to congenital heart disease or obstructive cardiomyopathy, already exercising more than once per week at a moderate- to vigorous-intensity any time in the previous 6 weeks, fix-rate pacemakers, pacemakers without the ability to attain a target HR, ICDs with HR limits set lower than the target HR, participation in a clinical trial not approved for co-enrollment
Passino et al. 2006 [43]	NYHA Class IV, myocardial infarction or unstable angina within 6 months before the examination, exercise-limiting diseases and severe pulmonary or renal disease.
Austin et al. 2005 [44]	Significant comorbidity that would prevent entry into the study because of terminal disease or inability to participate, resident outside of the catchment area, refusal to participate.
Wielenga et al. 1999 [45]	Corticosteroid-dependent chronic obstructive pulmonary disease (COPD), documented exercise-induced ischemia or exercise-induced ventricular tachycardia, NYHA Class IV symptoms, uncontrolled hypertension or orthopedic pathologies, peripheral vascular or neurological disease limiting ability to exercise.
RESISTIVE EXERCISE TRAINING	
Dracup et al. 2007 [46]	Myocardial infarction or recurrent angina within the previous 3 months, orthopedic impediments to exercise, severe obstructive pulmonary disease with a forced expiratory volume <1 L in 1 s as measured by spirometry, stenotic valvular disease as measured by echocardiogram, history of uncontrolled ventricular tachyarrhythmias (documented by electrophysiology study or 24-h Holter monitor), or absence of an implantable cardioverter-defibrillator despite a history of sudden cardiac death.
Feiereisen et al. 2007 [47]	NYHA Class IV, malignant ventricular arrhythmias, renal dysfunction, stroke, COPD, and orthopedic limitations.
Senden et al. 2005 [48]	Interfering diseases such as COPD, fasting glucose level of more than 7.0 mmol/L (i.e. diabetes mellitus), neuromuscular disorders and hypertension (systolic blood pressure higher than 170 mmHg and/or diastolic pressure higher than 110 mmHg).
Giannuzzi et al. 2003 [49]	Any systemic disease limiting exercise, hypertrophic cardiomyopathy, valvular disease requiring surgery, angina pectoris, sustained ventricular arrhythmias, severe hypertension, excess variability (>10 %) at baseline cardiopulmonary exercise test, and inability to participate in prospective study for any logistic reason.
McKelvie et al. 2002 [50]	Inability to attend regular exercise training sessions, exercise testing limited by angina or leg claudication, abnormal blood pressure response to exercise testing (systolic blood pressure during exercise >250 mmHg or diastolic blood pressure response >15 mmHg, systolic blood pressure response decrease of >20 mmHg after a normal increase of decrease below the resting level), cerebrovascular or musculoskeletal disease preventing exercise testing or training, respiratory limitation (forced expired volume in 1 s and/or vital capacity <60 % of predicted), poorly controlled cardiac arrhythmias, and any noncardiac condition affecting regular exercise training or decreasing survival.
Radzewitz et al. 2002 [51]	Severe pulmonary diseases, cognitive disorders, and patients with physical limitations which would have prevented them from taking part in our training program. Patients who were unable to answer questions about health-related quality of life and psychological well-being adequately were also excluded.
INSPIRATORY MUSCLE TRAINING	
Bosnak-Guclu et al. 2011 [52]	Acute myocardial infarction, cognitive disorders, complex arrhythmias, uncontrolled hypertension, angina pectoris, recent viral infections (6 months prior to study), orthopedic problems, rheumatologic diseases.
Stein et al. 2009 [53]	Unstable angina, myocardial infarction, cardiac surgery within 3 months of study, chronic metabolic, orthopedic or infectious disease, prior pulmonary disease with forced vital capacity < 80 % of predicted value or forced expiratory volume over 1 s <70 % of predicted value, treatments of steroids, hormones of cancer chemotherapy, exercise induced asthma, smokers.
Padula et al. 2009 [54]	Not formally listed; Inclusion criteria: adult, community dwelling, stable NYHA Class II or II heart failure with ejection fraction of less than 45 %, without co-existing pulmonary disease, no significant cognitive impairment as evidenced by Mini Mental Examination.

Table 2 (continued)

Study	Exclusion Criteria
Winkelmann et al. 2009 [55]	Pulmonary disease, current smoking, angina, recent myocardial infarction or cardiac surgery of > 6 months prior to study, orthopedic or neurologic disease, treatment with steroids, or cancer chemotherapy.
Dall'Ago et al. 2006 [56]	Unstable angina; myocardial infarction; cardiac surgery within 3 months of study; chronic metabolic, orthopedic, or infectious disease; prior pulmonary disease with forced vital capacity < 80 % of predicted value or forced expiratory volume over 1 s < 70 % of predicted value; treatments of steroids, hormones, or cancer chemotherapy; exercise-induced asthma; smokers.
Weiner et al., 1999 [57]	Not formally listed; Inclusion criteria: NYHA Class II-III, left ventricular ejection fraction of < 30 %, no evidence of lung disease, clinical stability, maximal inspiratory pressure < 70 % of predicted normal values.

generalization of the current best evidence to all individuals with HF is warranted, especially those who are medically complex with multiple comorbidities and/or tenuous clinical stability.

Summary - Aerobic Exercise Training

For individuals with HF, the safety and efficacy of continuous aerobic exercise training at a moderate intensity is well established for improving exercise tolerance and QOL. The effect of aerobic exercise training for reducing mortality and HF-related hospitalizations is less clear. Higher-intensity training paradigms such as HI-AIT are not well studied when compared to moderate intensity training. Although the evidence in support of HI-AIT is promising, controlled trials have been limited by small sample sizes and homogenous sample characteristics. Therefore, further research is needed to ultimately determine the safety of HI-AIT, especially with regard to its effects on QOL, mortality, and HF-related hospitalization.

Resistance Training

It is well established that HF-associated fatigue and exercise intolerance lead to muscle weakness and atrophy [2, 25–27]. Furthermore, individuals with HF have difficulty ambulating and completing simple activities of daily living due to this loss of strength resulting in decreased QOL [2, 26, 28•]. This inability to participate in routine daily activity creates a perpetual cycle of inactivity, deconditioning, and muscle disuse atrophy [28•].

Skeletal muscle mass and strength are not only predictors of exercise capacity and functional limitation, they are also independent prognostic indicators of survival [28•, 29•].

Relatively few studies have examined the effect of an isolated resistance training intervention in individuals with

HF; resistance training has been studied mostly as an adjunct to aerobic exercise training. In considering the available literature, there are two meta-analyses [20, 22•] and three systematic reviews [23, 25, 30]. Additionally, there are three individual studies that have been published since the most recent systematic review [26, 29•, 32•]. This body of evidence represents 45 individual studies involving 1,604 participants. Unfortunately, the aforementioned review papers provide minimal insight to the two most relevant questions: 1) Is there benefit to adding a resistance training program to an aerobic exercise training program, and 2) what are the isolated effects of resistance training, and how do these effects compare to those of an aerobic exercise training program?

Effect of Resistance Training on Exercise Tolerance

A systematic review by Hwang et al. [25] concluded that although resistance training alone did not result in improvements in peak oxygen consumption, there were improvements in 6MWT distance in those groups that received only resistance training. However, the addition of resistance training to an aerobic exercise training program did not provide any additional benefit. Because of the limited number of studies, they were not able to make definitive comparisons between isolated aerobic and resistance training programs. A systematic review seeking to compare resistance training alone to combined aerobic and resistance training was unable to provide any definitive conclusions about the potential benefits of resistance training on exercise tolerance due to significant threats to internal validity in the included studies, including ineffective randomization and combination of interventions [30]. Another systematic review with meta-analysis included 22 RCTs of either aerobic training or combined aerobic and resistance training, and observed improvements in 6MWT distance in studies utilizing the combined intervention [22•]. The authors made no conclusions regarding whether or to what degree these improvements were directly attributable to the resistance training component.

Effects of Resistance Training on Muscle Strength

One systematic review concluded that there was a greater improvement in peripheral muscle strength for combined aerobic and resistance training, compared to aerobic exercise training alone [30]. Although peripheral muscle strength was examined as a study endpoint in numerous RCTs (by means of various methods, including 1-repetition maximum (1RM), 2-repetition maximum (2RM), hand-held dynamometry, and isokinetic dynamometry), no systematic review or meta-analysis has evaluated this effect, and it is beyond the scope of the present review paper to systematically review available individual trials. However, a recent RCT [29•] concluded combined aerobic and resistance training resulted in greater improvements in peripheral muscle strength (41 %, $p < 0.05$) than aerobic training alone (10 %, $p < 0.05$) when using the 2RM measurement [29•].

Effect of Resistance Training on Quality of Life

The use of resistance training to improve QOL in individuals with HF is based on the premise that, as exercise tolerance and strength improve, so does the ability to complete ADLs, in turn improving independence and a general sense of well-being [31]. One systematic review [25] concluded that there was greater improvement in QOL when adding resistance training to an aerobic exercise training program, while another systematic review [30] provided no definitive conclusions due to the aforementioned threats to internal validity of included studies.

Effects of Resistance Training on Ventricular Remodeling

A meta-analysis [20] and a systematic review [25] both concluded that there was no effect of resistance training on left ventricular function when compared to control groups or when used in combination with aerobic exercise training compared to exercise training alone.

Exercise Prescription Parameters for Resistance Training

Summaries of exercise prescription parameters for resistance training were provided by several of the studies included in the systematic reviews and meta-analyses, as well as in individual RCTs reviewed for the purposes of this paper [20, 25, 26, 29•, 30, 32•]. In general, most studies used either a 1RM or 2RM method to determine an individualized resistance training program for the subjects. Most studies used moderate intensity exercise training (40 % to 70 % of 1RM or 2RM), with only a few using high-intensity training (70 % to 80 % of 1RM or 2RM) or low-intensity training (20 % to 40 % of 1RM or 2RM). All studies utilized a frequency of 1 to 3 days per week and a training duration of

8 to 12 weeks. Repetitions and sets of training varied widely between studies examined.

Safety of Resistance Training

One meta-analysis, two systematic reviews, and two recent RCTs investigating resistance training in individuals with HF evaluated safety and concluded that resistance training alone, or in addition to an aerobic exercise program, is safe for individuals with stable mild to moderate HF (NYHA Class I-III) [22•, 25, 29•, 30, 32•]. Among this body of evidence, mild- to moderate-intensity resistance training programs were either established and/or supervised by physicians, physical therapists, and/or exercise physiologists, and some included additional independent, home-based exercise components. It is important to note that further research is needed to investigate the safety of moderate- to high-intensity resistance training. Because of the extensive exclusion criteria listed in Table 2 and similar to the issues related to safety of aerobic exercise training, it is difficult to generalize the safety of resistance training to all individuals with HF, especially those with significant comorbid disease and/or tenuous clinical stability.

The Working Group Report [31] reported that the amount of cardiovascular stress expected during resistance exercise depends on the muscle group and muscle mass involved. For example, double arm exercise with a given load resulted in greater cardiovascular stress than single arm exercise. Therefore, it may be beneficial to prescribe resistance training using contractions of small muscle groups using a segmental approach for individuals with low exercise tolerance or individuals who are in advanced stages of HF (NYHA class III-IV) [31].

Summary - Resistance Training

Moderate-intensity resistance training is likely to be a safe treatment modality for individuals with HF who are clinically stable and free of significant comorbidity. However, the isolated benefits of resistance training on a variety of clinical outcomes, especially on QOL, are not clear. In theory, progressive resistance training may be more important than aerobic conditioning given that activities of daily living are performed at submaximal levels [26], and given that impaired peripheral muscle strength is associated with difficulty ambulating, completing simple activities of daily living, and decreased QOL [2, 26, 28•]. It is, therefore, not clear as to why the body of evidence regarding the benefits of resistance training in individuals with HF is largely inconclusive. It is likely that the methodological flaws noted by Spruit et al. [30] are primarily responsible, especially with regard to ineffective randomization and combination of interventions. However, it is also possible that minimal-to-no effect has been

demonstrated due to the non-selective application of resistance training. That is, resistance exercise training may be most beneficial for those individuals who demonstrate considerable strength deficits, determined through clinical assessment, to be the primary cause of the individual's functional deficits, QOL, and exercise intolerance. To our knowledge, no study has selectively recruited and studied such individuals.

Inspiratory Muscle Training

Individuals with HF not only exhibit deficiencies in cardiovascular function and peripheral muscle function of the extremities, but often present with accompanying reductions in strength and endurance of the inspiratory musculature. Dyspnea, limited exercise tolerance, diminished QOL, and poor prognosis are all associated with impairments in inspiratory muscle function [33, 34]. In addition to the role of elevated pulmonary pressures resulting from cardiac muscle failure, ventilatory muscle weakness and deconditioning may further increase respiratory effort during activity in those with HF [35, 36]. Inspiratory muscle training has been utilized in an attempt to improve ventilatory deficits and the aforementioned sequelae. Inspiratory muscle training also has the potential to allow even the most severely debilitated individuals with CHF—NYHA Classes III and IV—to participate in some form of rehabilitation when aerobic and/or resistive exercise training cannot be tolerated or are contraindicated.

Four recently published reviews examined the effects of IMT on individuals with HF including two meta-analyses [37, 38], a systematic review [4], and a literature review [39]. In total, the three systematic reviews/meta-analyses examined 11 studies, with six additional studies considered by the literature review [39]. A total of 708 participants across the 17 total studies ranged from NYHA Class I to IV, with most studies focusing on Classes II–III.

Effects of Inspiratory Muscle Training on Exercise Tolerance

Three of the four review papers concluded that IMT results in significant improvements in peak oxygen consumption [4, 38, 39], with changes in peak oxygen consumption comparable to that which occurs with aerobic exercise training [38]. However, a meta-analysis reported a non-significant improvement when compared with control groups [37].

An increase in 6MWT distance post-IMT training was reported in all reviews. Improvements in 6MWT distance ranged from 34.5 m to 69 m, most of which exceed the changes resulting from aerobic exercising training in the HF-ACTION RCT [18]. Again, Smart et al. [38] noted a similar magnitude of improvement in 6MWT distance compared to that found with aerobic or resistance training. These significant

improvements in 6MWT performance suggest that IMT has the potential to significantly improve functional ambulatory capacity in individuals with HF. However, further study is needed to directly compare IMT to aerobic exercise training.

Effects of Inspiratory Muscle Training on Dyspnea

Neither meta-analysis explored the effect of IMT on dyspnea in those with HF, but the systematic review [4] and literature review [39] concluded that IMT results in reduced dyspnea [4, 39].

Effects of Inspiratory Muscle Training on Quality of Life

The effects of IMT on QOL are supported by a limited number of studies. In the systematic review by Lin et al. [4] and the literature review by Cahalin et al. [39], two of three studies and five of seven studies, respectively, that measured QOL revealed significant improvements in QOL. Additionally, the most notable improvement was revealed in the meta-analysis by Smart et al. [38] with a mean weighted improvement in Minnesota Living with Heart Failure Questionnaire scores of 12.25 points.

Effect of Inspiratory Muscle Training on Pulmonary Function

Of 17 studies considered by the four reviews, 16 measured maximal inspiratory pressure (PI_{max}) with all 16 demonstrating a significant improvement despite variations in protocols [4, 37, 38, 39]. Improvements in sustained PI_{max} , oxygen consumption, and ventilatory threshold were also noted but not as widely investigated.

Inspiratory Muscle Training Parameters and Safety

A focus of the literature review by Cahalin et al. [39] was to investigate and compare training protocols for IMT treatment. The most frequently utilized training loads for all investigations were reported between 30 – 60 % of PI_{max} —the most common being 30 % PI_{max} —for a duration of 6–12 weeks. Inspiratory loads were most often adjusted weekly according to patient's evolving PI_{max} . On average, individuals were instructed to perform 30 min of training 7 days/week. Variability was noted between studies with regard to the amount of supervised sessions provided, as well as how IMT was combined with education or traditional exercise training. Although not specifically addressed by any of the reviews, no adverse events were reported in any individual studies.

Summary - Inspiratory Muscle Training

Overall, the available evidence demonstrates multiple benefits of IMT for individuals with HF. Inspiratory muscle training

has the potential to improve cardio-respiratory fitness and, therefore, positively impact functional capacity and QOL in this population. Given the similar magnitude of improvements when compared to aerobic exercise training, IMT could be considered a clinically effective alternative for those who cannot engage in aerobic or resistance exercise training.

Conclusions

The present literature review considered meta-analyses, systematic reviews, and large RCTs to summarize the current evidence regarding rehabilitation interventions for older adults with HF. The safety of aerobic exercise training, resistance training, and IMT is well established is appropriately selected individuals. Available research evidence supports the use of aerobic exercise training as a primary intervention that should be considered for improving exercise tolerance and QOL in individuals with HF. Additional interventions that may be considered as an adjunct to an aerobic exercise training program include resistance training and IMT. Given that the available research evidence has not clearly defined the benefits of resistance training when broadly applied across the HF population, resistance training should be considered for those individuals who, based on clinical assessment, demonstrate exercise intolerance, functional limitations, and decreased quality of life due to impaired strength. In contrast, IMT may be used as both an effective adjunct or in isolation to improve exercise tolerance and quality of life in individuals with HF.

Compliance with Ethics Guidelines

Conflict of Interest Jessica L. McLeod, Ashley A. Van Dam, Ashley K. Heiss, and Michael J. Shoemaker declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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