

JOURNAL-BASED CME ARTICLE

Combined Aerobic and Resistance Exercise Program Improves Task Performance in Patients With Heart Failure

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Program Overview

Heart failure (HF) is a leading cause of cardiac disability that is anticipated to dramatically increase over the next several decades largely due to an aging population, earlier identification, and advances in the treatment of coronary artery disease (CAD). Aerobic exercise has gained increasing support over the past two decades as an adjunct nonpharmacological therapy to partially reverse the underlying peripheral and musculoskeletal alterations that accompany heart failure (HF), without inducing greater cardiovascular stress. Heart failure management has traditionally focused on curtailing disease progression but fewer trials have reported strategies to attenuate cardiac related disability. This journal-based activity describes the results of a randomized controlled study that investigated whether a combined aerobic and resistance training program improves performance of physical activities of daily living (PADLs) routinely performed by most New York Heart Association (NYHA) class II and III HF patients.

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1. Describe an exercise program that combines aerobic and resistance activities for patients with New York Heart Association (NYHA) Class II or III heart failure (HF)
2. Describe the benefits and limitations of combined aerobic and resistance exercise on daily physical living activities for patients with NYHA Class II or III HF
3. Recognize that combined aerobic and resistance exercise improves health-related quality of life in patients with NYHA Class II or III HF
4. Recognize that combined aerobic and resistance exercise may reduce the risk of losing independence in patients with NYHA Class II or III HF

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Objectives: To assess the effects of a home-based aerobic and resistance training program on the physical function of adults with New York Heart Association (NYHA) class II and III patients and systolic heart failure (HF).

Design: Randomized controlled trial.

Setting: Home based.

Participants: Stable patients (N=24; mean age, 60±10y; left ventricular ejection fraction, 25%±9%; 50% white; 50% women) with New York Heart Association (NYHA) classes II and III (NYHA class III, 58%) systolic heart failure (HF).

Intervention: A 12-week progressive home-based program of moderate-intensity aerobic and resistance exercise. Attention control wait list participants performed light stretching and flexibility exercises.

Main Outcome Measures: A 10-item performance-based physical function measure, the Continuous Scale Physical Functional Performance test (CS-PFP10), was the major outcome variable and included specific physical activities measured in time to complete a task, weight carried during a task, and distance walked. Other measures included muscle strength, HRQOL (Minnesota Living With Heart Failure Questionnaire, Epworth Sleepiness Scale), functional capacity (Duke Activity Status Index), and disease severity (brain natriuretic peptide) levels.

Results: After the exercise intervention, 9 of 10 specific task activities were performed more rapidly, with increased weight carried by exercise participants compared with the attention control wait list group. Exercise participants also showed significant improvements in CS-PFP10 total score ($P<.025$), upper and lower muscle strength, and HRQOL ($P<.001$) compared with the attention control wait list group. Adherence rates were 83% and 99% for the aerobic and resistance training, respectively.

Conclusions: Patients with stable HF who participate in a moderate-intensity combined aerobic and resistance exercise program may improve performance of routine physical activities of daily living by using a home-based exercise approach. Performance-based measures such as the CS-PFP10 may provide additional insights into physical function in patients with HF that more commonly used exercise tests may not identify. Early detection of subtle changes that may signal declining physical function that are amenable to intervention potentially may slow further loss of function in this patient population.

Key Words: Exercise; Functional performance measures; Health-related quality of life; Heart failure; Rehabilitation.

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HEART FAILURE (HF) is a leading cause of cardiac disability that is anticipated to dramatically increase during the next several decades, largely because of an aging population, earlier identification, and advances in the treatment of coronary artery disease (CAD).¹ Aerobic exercise has gained increasing support during the past 2 decades as an adjunct nonpharmacological therapy to partially reverse the underlying peripheral and musculoskeletal alterations that accompany HF without inducing greater cardiovascular stress.²⁻⁵ Numerous studies, including the Randomized Controlled Trial Investigating Outcomes of Exercise Training in Heart Failure,⁶ supported the safety, efficacy, and improved cardiovascular outcomes associated with aerobic exercise in stable patients with systolic HF. However, some studies suggested that aerobic training alone may not optimally address the loss of muscle strength, functional decline, and progressive disability that occur.⁷⁻⁹ Concerns that resistance exercise may increase left ventricular remodeling and worsen hemodynamic status have dampened its wider acceptance and use among clinicians as a mode of exercise for patients with HF. The most recent guidelines for exercise in patients with HF advocate moderate-intensity dynamic resistance exercise as a safe and effective training mode, and that in conjunction with aerobic exercise, it may be most effective for maximizing physical function in this patient population.¹⁰

HF management traditionally focused on curtailing disease progression, but fewer trials reported strategies to attenuate cardiac-related disability.^{11,12} Performance-based measures that directly assess objective ability to perform physical activities of daily living (PADLs) are not used routinely in patients with HF or cardiovascular diseases in general. Performance measures represent aspects of physical function associated with routine daily activities that are important for maintaining independence in older adults. These measures integrate multiple dimensions of health and aging, such as disease processes, nutritional status, cardiorespiratory fitness, and psychological state, and provide a global assessment of physical function.¹³⁻¹⁶ Although performance measures are used widely in comprehensive geriatric assessment, their use has been very limited in patients with cardiac disease. However, recent studies indicated that they are practical and safe to administer and provide valuable insight regarding patients with HF and other cardio-

List of Abbreviations

6MWT	Six-Minute Walk Test
BNP	brain natriuretic peptide
CAD	coronary artery disease
CS-PFP10	10-Item Continuous Scale Physical Functional Performance
DASI	Duke Activity Status Index
ESS	Epworth Sleepiness Scale
HF	heart failure
HR	heart rate
HRQOL	health-related quality of life
ICD	implanted cardiac defibrillator
LVEF	left ventricular ejection fraction
MLHFQ	Minnesota Living With Heart Failure Questionnaire
NYHA	New York Heart Association
PADL	physical activity of daily living
RPE	rate of perceived exertion
t ₂	after 12 weeks
Vo ₂ peak	peak oxygen consumption

vascular diseases, who are most vulnerable for adverse events and outcomes.^{11,12,17-20}

Previous research in patients with HF primarily used self-report questionnaires or such single-task performance measures as the 6-Minute Walk Test (6MWT) for cardiorespiratory fitness that indirectly assess PADLs from only 1 perspective, endurance. For example, peak oxygen consumption (VO_2peak), the criterion standard for determining cardiorespiratory fitness, consistently has had low to moderate correlation with the ability to perform routine PADLs; very few patients perform these activities at maximum-intensity level, except those with advanced HF.^{21,22} In addition, because many household chores more often rely as heavily on strength as endurance, an instrument that incorporates measures of muscle strength may more accurately reflect the ability to perform these routine tasks.^{23,24} The ability to detect subtle changes in physical function may provide valuable insight into strategies that may be implemented to slow or partially reverse the disability associated with HF.²³

This study examined whether a combined aerobic and resistance training program improved performance of PADLs routinely performed by most patients with New York Heart Association (NYHA) classes II and III HF. The functional performance measure, the 10-item Continuous Scale Physical Functional Performance test (CS-PFP10), which has been validated against standard exercise tests (eg, VO_2peak , muscle torque, reaction time), was used to quantify physical function.^{25,26} The CS-PFP10²⁵ provides a total score and physical domain scores (Upper- [10-Item Continuous Scale Physical Functional Performance Upper-Body Strength domain] and Lower-Body Strength [10-Item Continuous Scale Physical Functional Performance Lower-Body Strength domain], flexibility, Balance and Coordination [10-Item Continuous Scale Physical Functional Performance Balance and Coordination domain], Endurance [10-Item Continuous Scale Physical Functional Performance Endurance domain]) for serially performed tasks that closely simulates PADLs, with higher scores reflecting better physical functioning. In the present study, we analyzed the time required for dressing, kitchen and household activities, and endurance walking. Additionally, we evaluated the ability to lift weighted items designed to simulate cooking and carrying groceries. We hypothesized that participants who underwent a combined aerobic and resistance exercise program would have significant improvement in speed, weight, or both for the 10 specific tasks included in the CS-PFP10²⁶ compared with an attention control wait list group. In addition, we evaluated changes and correlations between physical function, disease severity, health-related quality of life (HRQOL), and functional capacity in both groups from baseline to 12 weeks as secondary outcomes.

METHODS

Study Design

A randomized repeated-measures design was used to enroll and follow up subjects from baseline to 12 weeks (time 2 [t2]). After 12 weeks, t2 measurements were obtained.

Participants

The study sample included 24 men and women between the ages of 40 and 75 years (mean \pm SD age, 60 ± 10 y) with a diagnosis of stable NYHA class II or III systolic HF. Eligibility criteria included living within a 100-mile radius of the institution, left ventricular ejection fraction (LVEF) of 15% to 40%, diagnosis of systolic HF for a minimum of 6 months, using

Table 1: CS-P FP10 Items

Low difficulty	
Pot carry test:	Participant will place up to 30kg of sandbags in cooking pot and transfer ~1.80m from 1 counter to another.
Jacket test:	Participant will put on a light jacket, pull the front of the jacket together, and then remove it.
Reach test:	Participant will reach as high as possible and place a sponge on an adjustable wall-mounted shelf that has a maximum height of ~2.5m.
Moderate difficulty	
Floor sweep test:	Participant will sweep up a 118mL (½cup) of kitty litter in a .91×1.22m block.
Scarves test:	Participant will pick up 4 scarves, 1 at a time, from the floor.
Laundry test 1:	Participant will transfer clothes and sandbags weighing 4.5kg from a top-loading washer into a front-loading dryer.
Laundry test 2:	Participant will unload only the clothes from the dryer into a laundry basket, which is then placed on a cabinet .90m high adjacent to the dryer.
High difficulty	
Floor down/up test:	Participants will start in the standing position, sit down on the padded floor, and then immediately return to standing, finishing with arms at their side.
Stair climb test:	Participants will climb 1 flight of stairs, 9–11 steps 12 inches in depth and 6.5 inches high.
Grocery test:	Participant will carry a comfortable amount of groceries a total of 52.3m, including a set of bus steps and opening door. Maximum weight allowed is 30kg.
6MWT:	Allowing rest breaks, the participant will walk at a pace to cover the greatest distance in 6 minutes. Lap length is 35m, and the participant is not verbally encouraged during the task.

current cardiac medications for a minimum of 3 months, and permission to enroll in the study by an attending cardiologist in 1 of the 2 university-affiliated HF outpatient clinics. Exclusion criteria were (1) hospitalization for an acute HF exacerbation within the prior 2 months, (2) uncontrolled angina, (3) uncontrolled hypertension (blood pressure at rest ≥ 160 mmHg systolic or ≥ 90 mmHg diastolic), (4) dementia or a psychological disorder that would interfere with participation in exercise, and (5) contraindications to resistance exercise (ie, aneurysm, valvular disease). After receiving university-affiliated human subjects approval, potential patients were screened in 1 of the HF clinics. If eligibility criteria were met, a letter was sent to the potential candidate, and if interested, he/she was contacted by telephone to have the study explained. If participants agreed to participate in the study, they were required to provide written informed consent before initial baseline measurements were obtained. After baseline measurements were obtained, patients were randomly assigned by using a 1:1 allocation ratio to either the exercise or attention control wait list group.

Instruments

10-Item Continuous Scale Physical Functional Performance test. The CS-PFP10²⁰ was used to evaluate physical function (table 1). The CS-PFP10 consists of 10 tasks that are performed serially in a manner of usual function (a person's preferred manner vs a demonstrated manner). The tasks are quantified by weight, time, distance, or a combination of these and include a battery of items ranging from easy to difficult. The 10-item battery includes (1) pot carry, (2) jacket don/doff,

(3) scarf pick up, (4) reach, (5) sweep, (6) transfer laundry from washer and dryer, (7) floor sit down and return to stand, (8) grocery carry over 53m including 4 steps, (9) climb a flight of stairs, and (10) 6-minute walk (see table 1). Five domain scores (10-Item Continuous Scale Physical Functional Performance Upper-Body Strength domain, 10-Item Continuous Scale Physical Functional Performance Lower-Body Strength domain, Upper-Body Flexibility [10-Item Continuous Scale Physical Functional Performance Upper-Body Flexibility domain], 10-Item Continuous Scale Physical Functional Performance Balance and Coordination domain, 10-Item Continuous Scale Physical Functional Performance Endurance domain) and a total summary score are generated, with higher scores reflecting better physical function. Scores of 48 to 59 are associated with having an increased probability of losing independence.²⁷ The CS-PFP10 has been validated against standard exercise capacity measures (VO_2peak , peak torque, reaction time), which may be used to gain further insight into underlying physical impairments contributing to functional limitations.²⁵ At the conclusion of the CS-PFP10, participants were instructed to assess their rate of perceived exertion (RPE) using the 6- to 20-RPE Borg Scale.²⁸ In addition, participants wore a heart rate monitor (Polar)^a to evaluate any heart rate (HR) change occurring with each task. For additional information about the CS-PFP10, refer to the following website: www.coe.uga.edu/cs-pfp.

Six-Minute Walk Test. The 6MWT, a frequently used, reliable, and well-validated measure in patients with HF, was used to measure functional capacity. Participants walked for 6 minutes on a level hallway 50m long at baseline and again at t2. In our experience with the 6MWT, there was no significant difference in distance when 2 consecutive walks were performed on the same day or the participant had completed the CS-PFP10 before the 6MWT.²⁹⁻³¹

Handgrip. Handgrip strength was measured with a handgrip dynamometer (Jamar)^b by using a standardized protocol in both sides (dominant and nondominant) with a precision of 0.1kg. Participants were asked to self-adjust the dynamometer to fit comfortably with their hand size to achieve optimal performance. For the 3 serial measurements, subjects were seated with both arms resting on a table at a comfortable level with elbows flexed at a 90° angle with support, with the dynamometer facing outward from the body. A warm-up session to familiarize participants with the dynamometer was conducted to choose the best adjustment. Participants were instructed by voice command to grip the dynamometer with maximum strength. During the grip strength measurements, HR was monitored using the HR monitor and blood pressure was measured immediately before and after for safety reasons. Three trials were performed alternately on each side, with a rest period of at least 1 to 2 minutes between trials. The mean value for each hand was used for handgrip strength.³²

Upper- (forearm flexion) and lower-body muscle strength (knee extension). These were measured by using the hand-held dynamometer. For forearm flexion, the person sat at a table with the elbow at a 90° angle, palm up, with the dynamometer placed 2 inches above the wrist. Participants were instructed by voice command to pull upward with maximum strength against the dynamometer. For knee extension, participants were instructed to sit on a bed with knees at a 90° angle to the floor. The bed was raised so that feet were 10 to 12 inches off the floor. The dynamometer was placed 2 inches above the ankle, and when prompted, participants were instructed to kick the foot outward at a 90° angle. The mean force (kilograms) of 3 trials was calculated, with rest between each of the 3 contractions. Muscle strength testing was conducted by

2 data collectors for each test to ensure reliability. If a difference of 0.1kg was documented for a strength measure, another reading was obtained and mean force in kilograms was calculated as the strength for that testing procedure.^{33,34}

Health-related quality of life. HRQOL is defined as a multidimensional concept that reflects the influence of an individual's health on the ability to function in daily life, performance of social roles, and emotional status. HRQOL was measured by using a disease-specific measure,³⁵ the Minnesota Living With Heart Failure Questionnaire (MLHFQ).³⁶ The MLHFQ is a well-established 21-item disease-specific questionnaire designed to measure perceived physical, socioeconomic, and psychological impairment in persons with HF. Scores range from 0 to 105, with higher scores indicative of poorer HRQOL. A change in score of 5 points or more is considered clinically significant for improvement in symptom severity and HRQOL. Middel et al³⁷ found the MLHFQ to be more sensitive to change over time than other global measures of HRQOL. Cronbach α reliabilities of the total MLHFQ instrument, the physical subscale, and the emotional subscale are reported at .87, .81, and 0.84 and consistently are greater than .70 in published reports, respectively.³⁶

Duke Activity Status Index. The Duke Activity Status Index (DASI) is a 12-item questionnaire that measures perceived functional capacity with a score of 0 (worst) to 58.2 (best). A difference of 2 or more units on DASI score is considered clinically meaningful.³⁸ The DASI has been validated against VO_2peak ($r=.80$; $P<.001$) and has been used to successfully measure functional status in patients with HF.³⁹

Epworth Sleepiness Scale. The Epworth Sleepiness Scale (ESS)⁴⁰ is a well-established 8-item self-administered questionnaire that rates, on a 4-point scale (0–3), the chances of dozing off in different situations. Total ESS score ranges from 0 to 24, with higher scores reflecting more daytime sleepiness.

Brain natriuretic peptide. Brain natriuretic peptide (BNP) was measured by using a BNP test (Triage)^c to measure cardiovascular stress and ventricular load. BNP level increases in response to ventricular wall stress and volume overload from HF. BNP levels correlate well with left ventricular end-diastolic pressure, pulmonary artery wedge pressure, left ventricular hypertrophy, and systolic/diastolic dysfunction.⁴¹ As BNP level increases, the ability to perform PADLs may decrease as a consequence of worsening symptom severity.⁴²

Charlson Comorbidity Index. The Charlson Comorbidity Index⁴³ is well established as a measure of risk for 1-year mortality attributable to comorbid conditions and was used to assess the number and severity of comorbid diseases, using the original scoring version. Participants' medical records also were reviewed to ensure the accuracy of self-reported information concerning comorbid conditions.

Procedures

Overview of intervention: exercise program. Participants performed the combined aerobic and resistance exercise program for 12 weeks. They also received individualized instruction and a demonstration of how to monitor and record HR using the HR monitor, use of the 6- to 20-point Borg RPE Scale,²⁸ and any symptoms experienced during the walking or strength training sessions. Supervised weekly home-based sessions for 8 consecutive weeks and then every other week were conducted by a member of the research team (nurse or exercise specialist). At each home visit, the exercise prescription was adjusted, which progressively increased both walking and resistance exercise. Participants in the exercise group also received a DVD and exercise booklet as a reference to use during the unsupervised sessions.

Overview of intervention: aerobic exercise. Progressive low- to moderate-intensity walking was used for the aerobic exercise component. Based on the 6MWT, we estimated intensity level by using the HR reserve method,⁴⁴ with participants beginning at 50% intensity and progressing to 70% intensity for a minimum of 30 minutes and a maximum of 1 hour 3 times per week. Both at rest and exercise HRs are influenced by β -blockers, which are considered optimal therapy for patients with HF.⁴⁵ The HR reserve method⁴⁴ takes into account the patient's HR at rest, thereby decreasing the effect of β -blockade for the exercise prescription. Participants were instructed to maintain the RPE at 12 to 15.²⁸ Participants were supervised during only the first week of walking to better ensure safety and that self-monitoring techniques (HR, blood pressure, RPE, symptom severity) were understood. If there were no safety issues after the first session, participants walked unsupervised and performed self-monitoring independently for the rest of the intervention period. The weekly supervised sessions were used to monitor response to the resistance training protocol. However, during the weekly home visits, activity logs (step/cord calendars) were reviewed and both the walking and resistance prescriptions were adjusted accordingly.

Overview of intervention: resistance exercise. Color coded Thera-cords^d were used for the resistance exercise component. The color of the cord represents different levels of resistance. All participants began with a yellow or red cord, which reflects the lowest resistance level, to familiarize them with the exercise regimen and for safety reasons. The duration of the resistance exercise sessions was approximately 1 to 1.5 hours, depending on patient tolerance, and included a 5-minute warm up (low-intensity stretching/flexibility) and a 45- to 60-minute lower- and upper-body resistance training session. Lower-body resistance training included ankle plantar flexion and dorsiflexion; knee extension and flexion; hip extension, abduction, and adduction; and leg extension. Upper-body resistance training included exercises for shoulder abduction, flexion, and rotation; elbow extension and flexion; and wrist extension and flexion. Individual progression of resistance training was monitored and adjusted when the participant was able to perform 2 sets of 12 to 15 repetitions or less than 15 on the RPE scale. Participants were asked to perform the resistance exercises 2 or 3 times per week, but not on 2 consecutive days to avoid muscle fatigue and soreness. Several patients who were unable to perform standing exercises used a sitting protocol with the same exercise routines developed by the investigators. Most participants progressed during the 12-week study period to 3 sets of 15 repetitions 2 to 3 times weekly. Theraballs^d were used to improve handgrip strength and also were progressed as strength increased. Participants were asked to perform hand exercises a minimum of 5 minutes per day in each hand and not to squeeze the ball continuously to avoid potential adverse hemodynamic responses.

Overview of intervention: exercise adherence. Exercise adherence was assessed by using step/cord calendars and pedometers. The number of daily steps walked was assessed indirectly by using the Omron HJ 112.^e The device resets at midnight automatically; therefore, we were able to compare steps recorded by patients on the step/cord calendar with actual pedometer data to validate patient documentation. A number of studies have shown Omron pedometers to be accurate and reliable in adults and patients with HF⁴⁵⁻⁴⁸ and a more valid measurement than self-report questionnaires.⁴⁵ For adherence to the resistance exercise component, patients recorded Thera-cord color, exercises completed, and number of repetitions performed on the step/cord calendar. Each week, the nurse/exercise specialist recorded adherence from the previous week

on the intervention log sheet for each participant by using the step/cord calendar. To be considered 100% adherent to the protocol, 3 documented walking sessions and 2 strength training sessions weekly were required.

Overview of intervention: exercise progression. The primary method of progressing exercise was based on RPEs for both aerobic and resistance exercise because most participants was prescribed β -blockers. For the walking sessions, participants were asked to write the following values on a step/cord calendar: maximum HR, RPE during walk, number of steps walked, or symptoms during the aerobic session. For resistance exercise, the participant also was asked to record Thera-cord color and number of repetitions after each session, maximum HR, RPE, and any symptoms experienced. Patients were instructed to keep the target HR within a prescribed range and RPE at less than 15 for both modes of exercise.

Overview of intervention: attention control wait list group. Control participants were provided with instruction for stretching and flexibility movements, and no additional written materials were provided. After measurements were obtained at t2, control participants received the same instruction and equipment and 2 supervised home visits for resistance exercises, but received no additional outcome testing. Participants in the attention control wait list group received a total of 5 to 6 home visits during the 12-week period to control for attention received by the researchers in the intervention group.

Statistical Analysis

Values in tables are presented as mean \pm SD. Baseline differences for sociodemographic and outcome measures were tested by using independent-samples *t* tests. Paired *t* tests were used to determine within-group changes. Analysis of covariance was used to determine group differences at t2 on study outcomes, adjusting for baseline scores. Cohen *d* statistic was used to calculate effect size for the intervention.⁴⁹ Pearson *r* correlation coefficients were used to determine relationships among the key variables (not included in tables). Statistical analyses were carried out using SPSS software (Version 16.0).^f Significance level of $P < .05$ was used for hypotheses testing.

RESULTS

Study recruitment occurred during a 6-month period, and 615 patients were screened for study eligibility at 1 of the 2 university-affiliated HF outpatient clinics. Of this number, 463 (75%) were screen failures. Common reasons for screen failure included distance from the hospital, renal failure, NYHA class I or IV, documented nonadherence to medication regimen, or psychosocial issues that would affect compliance ability. The 152 (25%) eligible participants were sent a maximum of 2 letters during a 6-month period explaining the study details. Of this number, 21 participants were recruited by letter; 6, by flyers posted in HF clinics; and 1, by word of mouth. Because of time commitments, 3 participants dropped out before baseline measurements were obtained, and 1 participant was excluded during baseline measurements (not included in the analysis) because of uncontrolled hypertension. Twenty-four patients were randomly assigned in a 1:1 allocation sequence to either the exercise or attention control wait list group after baseline measurements. No participant dropped out of the study after baseline measurements were obtained.

At baseline, there were no group differences in sociodemographic characteristics (table 2), total and domain scores for the CS-PFP10, muscle strength, or HRQOL (table 3). However, there were a significantly greater number of insulin-dependent

Table 2: Baseline Sociodemographic and Clinical Characteristics for Total Group, Intervention and Control Participants

	Total (N=24)	Intervention (n=12)	Control (n=12)	P
Age (y)	60±10	59±11	61±10	0.56
Sex				0.41
Men	12 (50)	7 (58)	5 (42)	
Women	12 (50)	5 (42)	7 (58)	
Ethnicity				0.10
Black	11 (46)	3 (25)	8 (67)	
White	12 (50)	8 (67)	4 (33)	
Other	1 (4)	1 (8)		
NYHA class				0.41
II	10 (42)	4 (33)	6 (50)	
III	14 (58)	8 (67)	6 (50)	
LVEF (%)	25±9 (n=22)	23±8 (n=12)	27±9 (n=10)	0.24
Weight (kg)	99±18	95±19	102±18	0.34
Height (cm)	171±14	171±16	171±12	0.96
BMI (kg/m ²)	34±7	32±7	36±8	0.20
HR (beats/min)	72±9	72±9	73±9	0.31
Systolic BP (mm Hg)	114±17	109±19	116±12	0.18
Diastolic BP (mm Hg)	72±10	70±11	74±12	0.67
ICD	19 (79)	11 (92)	8 (67)	0.13
Comorbidity score	2.5±1 (1-5)*	2±1	3±1	0.46
Hypertension	12 (50)	4 (33)	8 (67)	0.10
Myocardial infarction	11 (46)	5 (42)	6 (50)	0.68
Diabetes	12 (50)	4 (33)	8 (67)	0.10
Depression history	13 (54)	7 (58)	6 (50)	0.68
Dyslipidemia	22 (92)	11 (92)	11 (92)	1.00
No. of medications	11±3 (3-16)*	11±3	11±4	0.86
ACEI	13 (54)	4 (33)	9 (75)	0.04
ARB	16 (67)	10 (83)	6 (50)	0.08
β-Blocker	19 (79)	9 (75)	10 (83)	0.62
Diuretic	21 (87)	11 (92)	10 (83)	0.54
Insulin	8 (33)	1 (8)	7 (58)	0.01 [†]
Oral hypoglycemic (n=22)	7 (32)	3 (25)	4 (40)	0.45
6MWT (m)	335±105	364±80	307±121	0.18

NOTE. Values expressed as mean ± SD or n (%) unless noted otherwise.

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index; BP, blood pressure.

*Range.

[†]*P*<.01.

patients with diabetes in the attention control wait list group, as listed in table 2. In addition, although all patients were receiving what is considered optimal medication therapy for HF according to guidelines,⁴⁵ there was a significantly greater number of attention control wait list patients receiving angiotensin-converting enzyme inhibitors and a higher proportion with angiotensin receptor blockers prescribed in the intervention group. All patients were receiving 1 or the other and outcomes therefore were unlikely to be influenced by these medication differences. Most had NYHA class III (58%; n=14), mean LVEF was 25%±9%, most (79%; n=19) had an implanted cardiac defibrillator (ICD), and most were obese (mean body mass index, 34±7kg/m²). Mean comorbidity score was 2.5±1, with diabetes the most common medical noncardiovascular disorder. Most (75%; n=18,) had a diagnosis of HF for more than 2 years. Only 2 participants (1 in exercise group, 1 in control group) had scores higher than the CS-PFP10 cutoff range (48–59) of having a higher probability of losing independence. At baseline, mean CS-PFP10 score was 42±16 (range, 8–76); at t2, mean score was 47±17 (range, 15–78). There were no serious adverse events in any study participant, and baseline medication changes were stable throughout the study period.

Exercise Intervention Group

Participants in the exercise group improved their time in seconds compared with baseline for completing most tasks (table 4). For tasks that involved weight and time, weight and time for the grocery carry significantly increased at t2, which likely brought about positive clinical and lifestyle changes. For the 6MWT, distance increased from 364±80 to 411±110m (*P*<.006). Overall CS-PFP10 score increased from 46±15 to 56±16 (*P*<.003). Domain scores for 10-Item Continuous Scale Physical Functional Performance Upper-Body Strength domain, 10-Item Continuous Scale Physical Functional Performance Upper-Body Flexibility domain, 10-Item Continuous Scale Physical Functional Performance Lower-Body Strength domain, 10-Item Continuous Scale Physical Functional Performance Balance and Coordination domain, and 10-Item Continuous Scale Physical Functional Performance Endurance domain increased significantly. Muscle strength also improved after the 12-week exercise intervention in most areas (see table 3). There was greater improvement in patients with NYHA class III from baseline to t2 for CS-PFP10 total scores, increasing from 37±13 to 49±15 compared with 62±16 to 68±10 in patients with NYHA class II (not shown).

Table 3: Muscle Strength, CS-PFP10 Score, and Health Status Changes From Baseline to t2 in Intervention and Control Participants

Variable	Control (n=12)				Exercise Intervention (n=12)				Between Groups			Post-Cohen d
	Pre	Post	Change: Post-Pre	Paired t Test (P)	Pre	Post	Change: Post-Pre	Paired t Test (P)	Pre t Test (P)	Post t Test (P)	Post ANCOVA (P)	Effect Size
Muscle strength												
R handgrip	28.4±10.7	28.1±9.8 (n=11)	-0.7±5.7 (n=11)	.702	28.0±9.2	35.1±8.8	7.1±8.9	.019	.936	.084	.016	0.76
L handgrip	24.8±10.4	25.4±10.4	0.6±4.7	.685	26.6±10.5	32.0±9.0	5.4±9.2	.069	.675	.109	.063	0.68
R FA flex	24.9±8.9	21.6±8.3 (n=11)	-2.0±4.8 (n=11)	.189	23.2±7.5	27.5±4.4	4.3±5.0	.012	.626	.042	.002	0.90
L FA flex	22.3±9.3	21.8±7.6	-0.4±4.5	.755	23.2±6.4	27.1±4.1	4.0±5.0	.018	.781	.045	.005	0.87
R knee ext	31.5±10.4	31.0±9.3	-0.5±7.4	.825	31.3±9.5	37.8±10.4	6.5±8.7	.025	.952	.110	.036	0.68
L knee ext	31.1±12.5	30.6±10.1	-0.4±76.3	.837	30.8±8.7	35.7±9.5	4.9±8.6	.072	.943	.222	.086	0.51
6MWT	306.6±121.3	309.7±135.4	3.1±58.1	.855	364.3±79.7	410.7±91.5	46.4±46.9	.006	.182	.045*	.074	0.87
BNP	105.8±159.1	108.4±158.9	2.6±104.3	.934	184.4±151.6	308.0±266.9	123.6±159.6	.021	.229	.037	.067	0.91
CS-PFP10												
Total	37.8±13.1	39.2±15.4	1.4±12.7	.707	45.4±18.1	55.7±16.0	10.3±9.3	.003	.252	.017	.025	1.05
UBS	37.1±16.1	39.2±17.0	2.1±13.8	.610	46.9±15.6	58.5±16.8	11.6±10.2	.002	.146	.011	.032	1.14
LBS	33.9±10.1 (n=11)	33.5±16.1	1.1±12.1 (n=11)	.763	39.4±17.8	50.7±17.3	11.3±10.2	.003	.383	.019	.032	1.03
UBS Flex	61.0±14.1	61.5±14.8	0.5±17.6	.925	59.8±20.3	69.4±18.5	9.6±8.4	.002	.868	.261	.107	0.47
BALC	38.8±13.4	39.8±17.2	1.1±14.7	.804	46.2±20.8	55.8±17.5	9.7±10.1	.007	.310	.034	.047	0.92
END	37.2±13.4	38.1±16.6	0.9±13.2	.808	45.4±19.6	55.2±16.7	9.8±9.3	.004	.244	.020	.029	1.02
HRQOL												
DASI	45.8±11.1	41.9±10.1	-3.9±8.7	.146	49.2±9.0	49.2±6.9	-0.1±8.7	.981	.410	.051	.076	0.84
MLHFQ	49.8±26.0	46.5±19.7	-3.3±18.6	.547	56.1±24.4	33.5±22.9	-22.6±18.4	.001	.551	.151	.017	0.61
ESS	8.5±3.5	10.0±5.4	1.5±4.5	.277	7.2±3.2	6.2±3.5	-1.0±3.4	.324	.340	.051	.096	0.84
BDI	17.4±9.1 (n=11)	12.9±9.0	-3.5±12.0 (n=11)	.350	11.5±6.8 (n=11)	8.9±6.2	-2.1±8.7 (n=11)	.442	.099	.218	.299	0.52

NOTE. Values expressed as mean ± SD unless noted otherwise. Cohen $d = t \sqrt{\frac{n1+n2}{n1*n2}}$, where t is test statistic for the 2-group t test at post, $n1$ is sample size for control, and $n2$ is sample size for exercise groups.⁴⁹

Abbreviations: ANCOVA, analysis of covariance; BALC, 10-Item Continuous Scale Physical Functional Performance Balance and Coordination domain; BDI, Beck Depression Inventory; END, 10-Item Continuous Scale Physical Functional Performance Endurance domain; ext, extension; FA, forearm; flex, flexion; L, left; LBS, 10-Item Continuous Scale Physical Functional Performance Lower-Body Strength domain; R, right; UBS, 10-Item Continuous Scale Physical Functional Performance Upper-Body Strength domain.

*Nonpooled t test performed.

Table 4: Specific Task Changes From Baseline to t2 in Intervention and Control Participants

Variable	Control (n=12)				Exercise Intervention (n=12)				Between Groups			
	Pre	Post	Change	Paired t Test (P)	Pre	Post	Change	Paired t Test (P)	Pre t Test (P)	Post t Test (P)	ANCOVA (P)	Post-Cohen d (P)
Weight carry time (s)	4.11±1.1	4.3±1.2	0.1±1.4	.728	3.8±0.9	3.0±0.8	-0.8±0.6	.001	.456	.006	.009	1.23
Weight carry weight (kg)	13.1±5.6	14.3±4.9	1.2±4.1	.333	16.6±6.8	19.1±6.6	2.5±4.7	.093	.188	.058	.181	0.82
Jacket (s)	16.2±3.5	15.7±4.9	-0.5±5.4	.752	17.5±7.6	13.4±5.0	-4.1±4.5	.009	.625*	.252	.089	0.48
Scarves (s)	8.7±3.2 (n=11)	9.5±4.6	0.2±3.5 (n=11)	.850	8.5±4.7	6.3±4.1	-2.2±2.3	.007	.917	.088	.055	0.73
Reach (cm)	224.4±12.4	223.9±14.7	-0.5±5.0	.727	229.6±23.4	230.9±23.8	1.3±4.5	.344	.508	.399	.412	0.35
Floor sweep (s)	23.5±9.3 (n=11)	22.9±8.5	-0.8±6.2 (n=11)	.671	26.0±11.5	21.0±7.4	-5.0±5.9	.014	.567	.567	.124	0.24
Laundry 1 (s)	29.1±10.4 (n=11)	35.5±19.4	5.6±12.6 (n=11)	.169	30.3±8.1	28.2±6.2	-2.1±5.3	.195	.768	.228	.058	0.51
Laundry 2 (s)	23.2±7.4 (n=11)	23.6±9.7	0.7±9.1 (n=11)	.810	20.7±6.8	17.3±4.9	-3.4±5.3	.050	.393	.061*	.093	0.82
Floor sit (s)	12.9±6.2 (n=10)	19.1±10.9 (n=11)	4.2±5.0 (n=10)	.026	21.1±27.7	13.0±10.1	-8.2±19.8	.181	.371	.177	.023	0.58
Grocery carry (s)	94.6±37.7 (n=11)	97.9±37.9	2.8±10.7 (n=11)	.407	87.5±47.9	73.7±28.4	-13.8±38.8	.243	.696	.090	.061	0.72
Grocery carry (kg)	9.3±4.1 (n=11)	9.8±5.1 (n=11)	1.9±3.2 (n=10)	.099	12.3±3.0	16.1±8.2	3.8±7.9	.123	.069	.039	.444	0.92
Stair climb (s)	9.8±4.8 (n=11)	11.5±6.6 (n=11)	0.6±2.1 (n=10)	.412	8.8±5.4	7.3±3.6	-1.5±2.2	.031	.635	.079*	.026	0.81

NOTE. Values expressed as mean ± SD unless noted otherwise. Cohen d = $t \sqrt{\frac{n1+n2}{n1*n2}}$, where t is test statistic for the 2-group t test at post, n1 is sample size for control, and n2 is sample size for exercise groups.

Data from Cohen.⁴⁹

*Nonpooled t test performed.

Subjective responses associated with quality of life (MLHFQ) were significantly better at t2 ($P<.001$). Responses on functional capacity (DASI) improved after 12 weeks of exercise (see table 3), but were not significant. Scores on the ESS decreased, but not significantly, suggesting that participants perceived less daytime sleepiness compared with baseline. At baseline, there also was moderate correlation between the physical subscale of the MLHFQ and CS-PFP10 total score ($r=.48$; $P<.018$). At t2, changes in total CS-PFP10 scores correlated with changes in handgrip ($r=.51$; $p<.01$) and knee extension ($r=.42$; $P<.04$), but did not correlate significantly with subjective responses associated with the MLHFQ or DASI (not shown). Adherence was 83% and 99% for the walking sessions and resistance exercises, respectively. Mean number of steps increased by 1500 per session ($P<.001$) during the first consecutive 8 weeks of the intervention.

Attention Control Wait List Group

In the control group, there were no significant changes for any of the outcome variables. Overall CS-PFP10 score essentially was unchanged at t2 (38 ± 13 vs 39 ± 15 ; $P<.70$), and none of the 5 domain scores increased from baseline. Notably, it took significantly longer for attention control wait list group participants to perform the grocery carry, 1 of the difficult tasks, at t2 (see table 4).

There were clinically meaningful improvements in HRQOL, evidenced by a score change of 5 points on the MLHFQ. However, perceptions of functional capacity were lower and daytime sleepiness and depressive symptoms were higher compared with baseline (see table 3).

Between Groups

Between-group analysis showed that a decrease in time to complete most tasks was greater in exercise participants compared with the attention control wait list group (see table 3). Specifically, exercise participants performed the pot carry and laundry test 1, as well as got up from the floor significantly more quickly, than the attention control wait list group, adjusting for covariates. Weight during the pot carry tended to be higher in the exercise group and was significantly higher for the grocery carry, but was not significant after covariate adjustments were made. There also were significant increases in total CS-PFP10 score and most domain scores compared with the attention control wait list group (see table 3). Exercise participants had significant improvements in physical function, HRQOL, and daytime sleepiness compared with the attention control wait list group (see table 3). The effect was moderate for most intervention variables, including the CS-PFP10, muscle strength, and HRQOL measures. Most specific tasks also had moderate effect sizes, with the exception of the floor sweep and reach test (see table 4).

DISCUSSION

Physical Function

Physical function, or the capacity to perform PADLs such as walking and performing household chores,⁵⁰ substantially decreases in patients with HF as a consequence of decreased aerobic capacity and skeletal muscle myopathy.¹⁻⁵ Supporting our hypothesis, the major finding from this study was that a program of combined aerobic and resistance exercise was able to significantly improve speed and ability to carry heavier amounts of weighted items that simulate physical tasks that are routinely performed by most patients with NYHA classes II and III. This study clearly showed the poor physical function experienced by most patients

with HF and was lower in patients with NYHA class III, as anticipated. Most (92%) participants had poor physical function at baseline, evidenced by total CS-PFP10 scores less than 48, which indicated a higher probability of experiencing loss of independence and disability. However, participants in the exercise group had significant improvements in physical function that increased from 45 (less than threshold levels) to 56 (near threshold levels), associated with independent living during a 12-week period. We also found that even complex patients with HF with a poorly functioning left ventricle and an ICD can safely derive benefit from a home-based exercise program if close monitoring and careful progression are used. The finding that muscle strength improved after a combined aerobic and resistance exercise was similar to that in previous studies.⁵¹⁻⁵⁴ However, to our knowledge, this is the first study to document objective improvement in ability to perform PADLs after exercise in patients with HF.

Only 1 other study evaluated specific tasks included in the CS-PFP10 as an outcome measure after an exercise intervention in patients with cardiovascular disease.^{55,56} In that study, there were similar improvements in specific tasks, as well as CS-PFP10 total and domain scores, in older women (mean age, 72y) with CAD after a 6-month resistance training program. The increase in weighted task items in older women with CAD and endurance-related tasks were similar to our findings. For example, the mean increase in distance walked on the 6MWT was approximately 49m in women with CAD compared with 55m in our sample. In a previous study, we observed that aerobic exercise alone did not improve performance for the weighted items.⁵⁷ These findings suggest that a combined aerobic and resistance program may have an advantage over either exercise mode alone for improving functional performance in patients with advanced cardiovascular disease, but needs further study.

Findings from this study suggest that patients with NYHA class III who had lower physical function and greater disease severity may derive benefit from exercise, although results from this small sample size should be interpreted with caution. CS-PFP10 scores also indicate that patients with NYHA class III were more vulnerable to losing independence; however, after exercise, they had significant gains in physical function that may potentially translate to decreased risk for losing independence.²⁷ Routine evaluation that uses objective multidomain performance-based measures such as the CS-PFP10 may detect subtle clinical changes and provide time to intervene in patients with HF before functional abilities become even more compromised.

The CS-PFP10 provides information that may be used to supplement traditional exercise tests for a more comprehensive evaluation of physical function. Domain scores may help clarify the nature of self-reported functional limitations. For example, in 2 patients with similar CS-PFP10 total scores, the domain subscales might show that 1 adult has problems with the 10-Item Continuous Scale Physical Functional Performance Upper-Body Strength domain and balance, whereas the other has problems with 10-Item Continuous Scale Physical Functional Performance Lower-Body Strength domain and 10-Item Continuous Scale Physical Functional Performance Endurance domain.²⁵⁻²⁷ With this information, clinicians would be able to more closely prescribe tailored exercise, more appropriately targeting exercises to improve physical function for domain-specific areas.²³⁻²⁷ In a larger more diverse sample, there is potential to develop normative data by which individual CS-PFP10 and domain scores may be used as benchmarks against such established values as NYHA class, VO_2 peak, or other reference points.

Brain Natriuretic Peptide

The finding of increased BNP levels in some participants after exercise was documented in some, but not all, studies.^{58,59} The increase in BNP levels from 184 ± 153 (range, 11–428pg/mL) to 306 ± 269 pg/mL (range, 5–929pg/mL) occurred in 54% ($n=13$) of participants. In the 5 participants (2 exercise, 3 control) with BNP levels greater than 400pg/mL at baseline, 3 increased (1 exercise, 2 control) and 2 decreased (1 control, 1 exercise), indicating that factors other than exercise contributed to the higher BNP levels.⁵⁹ Previous studies showed that BNP level greater than 324pg/mL was associated with a risk ratio of 8.8 for adverse cardiac events.⁶⁰ However, variability in BNP level is well documented, and these results must be interpreted with caution.⁶¹

Health-Related Quality of Life

The few exercise studies that included HRQOL as an outcome measure had limited and inconsistent findings. For example, Be-lardinelli et al⁶² found that changes in HRQOL paralleled changes in VO_2 peak, whereas other studies found no association between HRQOL and aerobic capacity.^{63,64} A recent meta-analysis examining the effects of exercise training on HRQOL in patients with HF found only 1 study that included a significant positive correlation between change in aerobic capacity and change in HRQOL.⁶⁵ In the present study, we found that despite significant improvement in HRQOL in exercise participants, there was no relationship to subjective or objective measures of physical function at t2. Participants in the attention control wait list group experienced clinically meaningful improvement in HRQOL. Reasons may have included the attention from the research team during the placebo exercise sessions. In addition, attention control wait list participants may have perceived improvement in physical function from involvement in the placebo exercise, which in turn may have positively influenced HRQOL. The knowledge that they would receive the same exercise equipment and instruction at the end of the study also may have improved HRQOL in the attention control wait list group. Finally, our findings also suggest that exercise may provide an inexpensive and readily available treatment option that may improve daytime sleepiness and depressive symptoms in patients with HF, a major contributing factor for poor HRQOL in this patient population.^{66,67}

Study Limitations

This study had several limitations that may influence generalization of results. First, sample size was small and prevented the use of tests to evaluate change across time between groups in a comprehensive procedure. In addition, data were collected primarily from 1 academic center and may have lacked general representation of patients with HF. Data collectors were not blinded to group allocation, which introduces the possibility of bias. A standard protocol was adhered to during administration of the CS-PFP10, and enough time had passed that familiarity was not a significant factor concerning study outcomes. Despite randomization, there was a greater number of patients with diabetes in the attention control wait list group, which may have influenced physical function outcomes. Therefore, results should be interpreted with caution. Enrolling patients with HF is difficult, shown by only 21 of the eligible 152 responding to recruitment despite intensive recruitment efforts on the part of the investigators. The ability and practicality of providing this type of exercise intervention remains uncertain in a larger more diverse group of patients with HF.

CONCLUSIONS

Findings from this study suggest that complex patients with HF are able and willing to perform exercise safely and at a level that

improves the ability to perform measured tasks. The study also showed the feasibility and acceptability by patients of a home-based aerobic and resistance exercise program that may be used to design future interventions. A combined regimen of aerobic and resistance exercise may be the most advantageous for patients with HF in terms of optimizing physical function, maximizing independence, and enhancing HRQOL, but needs further study in a larger more diverse HF population.

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