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Resistance training for chronic heart failure patients on beta blocker medications[☆]

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Abstract

Background: Resistance training increases the skeletal muscle strength and functional ability of chronic heart failure patients. However, there is limited data regarding the effect of resistance training on the hemodynamic responses and peak oxygen consumption (peak VO_2) of chronic heart failure patients treated with beta-blocker. This study examined the effect of resistance training on hemodynamics, peak aerobic capacity, muscle strength and quality of life of chronic heart failure patients on beta-blockers medication.
Methods: Fifteen men diagnosed with chronic heart failure were matched to either a resistance training program or non-training control group. At baseline and after 8 weeks of resistance training patients performed both Balke incremental and maximal strength tests and completed quality of life questionnaires.
Results: The resistance training group demonstrated a significant increase of walking time and peak VO_2 by 11.7% (p=0.002) and ~19% (p<0.05), respectively Peak VO_2 was significantly correlated with both walking time (r=0.54, p=0.038) and change in total weight lifted (r=0.55, p=0.034). Quality of life significantly increased by 87% (p=0.030). The improvement in quality of life was correlated with post training peak VO_2 (r=0.58, p=0.025) and total weight lifted during the post maximal strength test (r=−0.52, p=0.047).
Conclusions: The benefits from resistance training for chronic heart failure patients on beta-blocker medication included an increased aerobic and exercise capacity, skeletal muscle strength and most importantly, an improvement in the quality of life, which is the main goal of cardiac rehabilitation programs. Furthermore, with appropriate supervision, it is recommended that resistance exercise be added to the exercise rehabilitation program of these patients when possible.

Keywords: Resistance training; Chronic heart failure patient; Beta blocker medication

1. Introduction

A reduction of aerobic capacity and a decrease of skeletal muscle mass and strength are characteristics of chronic heart failure patients [1,2]. It is widely accepted that changes in skeletal muscle structure, such as muscle atrophy and muscle fiber alteration [1], and in metabolism, such as a reduction in oxidative enzymes activities and early anaerobic metabolism [3,4], are major contributors to these phenomena. The role of resistance training in heart disease patients is to promote dynamic skeletal muscle strength [5] with an associated decrease in the numbers of falls and injuries related to falls with an improved functional ability of elderly and chronic heart failure patients [6–8].

Beta-blocker therapy is considered a standard therapy for people with chronic heart failure [9]. It was shown that beta-blocker therapy reduces the clinical progress of the disease

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[10], decreases the heart rate and blood pressure and increases the ejection fraction and improves the quality of life [11,12]. However, despite these improvements peak oxygen consumption (peak VO_2) and exercise capacity has not consistently improved following beta-blocker therapy [13,14].

Previous studies demonstrated a correlation between peak VO_2 and muscle mass (r between 0.57 and 0.71) [15–17] which suggests that resistance training may improve the aerobic capacity of people with chronic heart failure [1]. However, studies that examined the effect of resistance training on peak VO_2 of chronic heart failure patients on beta-blocker medications are limited and the data available for other cardiac populations is inconclusive [18–21]. The inconsistencies between the studies regarding the effect of resistance training on peak VO_2 may be as a result of the different types of training protocols used (intensities, length and duration of the program) and the different types of cardiac patients. Hence, the purpose of this study was to examine the effect of resistance training on peak aerobic capacity, muscle strength and quality of life of chronic heart failure patients on beta-blocker medication.

2. Method

Fifteen men with mean (±SD) age 57.0±10.2 years diagnosed with chronic heart failure (ejection fraction= 34.7±7.2) and treated with beta-blockers for at least 3 months volunteered to participate in the study. Subjects were matched to either a resistance training program (n=8) or non-training control group (n=7) according to their age and ejection fraction. The study protocol was approved by the Human Research Ethics Committee, Southern Cross University (ECN-02-110) and John Flynn Private Hospital (02/08). Prior to participation, all subjects were informed about the nature of the study and signed an informed consent.

Patients who suffered from the following contraindications were excluded from the research: smokers, those with severe locomotive disability, ventricular arrhythmias, unstable angina or who had a resting diastolic pressure above 95 mm Hg, a resting systolic pressure above 160 mm Hg or uncontrolled congestive heart failure, acute myocarditis, severe valvular stenosis and persons who were unable to consent for themselves.

2.1. Study protocol

Prior to participation, patients resting ejection fraction was evaluated by 2D guide M-mode echocardiography (Cypress, Acuson, version 11) according to the recommendation of the American Society of Echocardiography [22]. At baseline and after 8 weeks of resistance training both groups performed a Balke incremental treadmill test [23] where walking speed remained constant (3 km/h) and the grade increased by 2.5% every 2 min (overall six stages) and a maximal strength test. Heart rate, systolic blood pressure, and diastolic blood pressure were measured prior to the incremental test after 4–5 min of resting in a sitting position. During rest and the incremental test, heart rate and 12 lead electrocardiograph (ECG) were monitored and brachial blood pressure was measured by auscultation. Peak VO_2 was determined by gas analysis (Medgraphics, Cardio2 and CPX/D System-Utilizing Breezeex Software, 142090-001, Revia, MN) providing data every 15 s. Calibration against three standard alpha gases was conducted prior to each test.

Maximal strength tests were performed after a familiarization session with the resistance equipment (Schwinn 780 SI Strength System) and training for correct lifting techniques. A correct breathing technique was explained and practiced in order to avoid a Valsava maneuver. Maximal strength was defined as the heaviest weight a patient could lift (between one and four repetitions) with a proper lifting technique and normal breathing pattern, without compensatory movements. Tests were performed for chest press, leg press, lateral pull-down, triceps extension, knee extension, upright row, sitting row and biceps curl. The test was performed after 5–10 min of warm-up on a treadmill and stretching regime. The maximal strength tests included one set of 10 repetitions followed by a gradual increase in weight until failure. Heart rate was monitored constantly during the test by Polar sport tester (Polar Electro Oy, Finland) while blood pressure was measured by auscultation immediately after each exercise. For both tests terminating criteria followed the recommendations of the American College of Sport Medicine [24].

Assessment of patients' quality of life was made by using "The Minnesota Living With Heart Failure Questionnaire". Each one of the 21 questions was scaled from 0 (not at all) to 5 (very much), a lower total score represented a better quality of life [25].

2.2. Training protocol

The resistance-training program was performed three times per week for 8 weeks. At least 48 h of recovery was allowed between sessions. Training consisted of 8 different exercises for the major muscle groups (same exercises as for the maximal strength test) and one abdominal exercise (abdominal curl). Each training session included 5 minutes warm-up and stretching regime, 50 min of resistance exercises and 5 minutes cool down activities. The training exercises followed the recommendations of the American College of Sport Medicine [24] and the American Heart Association [26] for training programs for cardiac patients. Initial intensity corresponded to 40–60% of maximal strength, one set between 15 and 20 repetitions, and then gradually increasing intensity up to 80–90% of maximal strength during weeks 7 and 8 and at the same time decreasing the number of repetitions to between 8 and 12 repetitions for three sets.

2.3. Data analysis

One-way ANOVA was used to examine the differences in the patients' characteristics between the groups at baseline. The effect of training data was analyzed by a repeated measured ANOVA model, which was constructed to analyze the effect of primary interest by time (pre and post) for each group (training or control). Repeated measure ANOVA also was used to examine the effect of treatment (training and control) over time (pre and post) between the two groups (referred as p value "Group×Time"). Due to small sample size, the model was used for each variable separately. Spearman row correlations were conducted to assess the relationship between walking time and quadriceps strength and walking time and peak VO_2. Also Spearman row was used to assess the correlation between quality of life and peak VO_2 and between quality of life and change in muscle strength. All data reported as mean±standard deviation and all statistical analysis was conducted at the 95% level of significance.

3. Results

3.1. Baseline comparison

No differences were found between the groups at baseline for age, weight, height, ejection fraction, peak VO_2 and total weight lifted in the maximal strength test (groups' clinical characteristics are shown in Table 1).

Table 1
Groups' Clinical characteristics

	Training (8)	Control (7)	p value
Age, years	57.3±11.1	56.7±10.0	0.924
Weight, kg	91.4±14.0	91.1±10.7	0.972
Height, cm	178.6±4.7	177.7±10.5	0.827
EF, %	35.4±6.3	34.0±8.8	0.750
Peak VO_2, ml/kg/min	14.4±2.8	14.9±1.0	0.712
Total weight lifted, kg	394.4±100.2	353.5±123.6	0.718
Beta-blocker			
Carvedilol	5	6	
Bicor	1	1	
Atenolol	1	–	
Inderal	1	–	
ACE inhibitors	6	6	
Diuretics	3	2	
Anti cholesterol	4	6	
Digoxin	2	1	
Anti arrhythmic	2	2	
Pain reliefs	3	3	
Diabetes medications	1	2	

Note: EF (ejection fraction), ACE (angiotensin-converting enzymes).

The beta-blocker doses were slightly changed in two subjects during the study. All subjects completed 8 weeks of training without injuries or muscle soreness. No adverse effects were recorded during and for 24 h after the tests or during the training. Four subjects did not perform the leg press exercise due to position discomfort (one from the training group and two from the control) or due to injury to the knee (one subject from the training group, not related to the study). This subject also did not perform the knee extension exercise. Two subjects (one from each group) did not perform the lateral pull-down exercise due to difficulty in raising the arms above shoulder level.

3.2. Resistance training effect on Balke walking test

Walking time increased significantly by 11.7% in the training group (p=0.002) while no significant change was observed in the control (p=0.68). However, the differences in the walking time between the groups did not reach statistical significance (p=0.058) (Table 2).

The resistance training group demonstrated an increase of ~19% in both absolute and relative peak VO_2 (1298±233 to 1614±242 ml/min and 14.4±2.8 to 17.7±1.3 ml/kg/min, respectively, p=0.001) compared to ~−2% in the control group (1347±134 to 1317±201 ml/min, p=0.724, and 14.9±1.8 to 14.7±23.2 ml/kg/min, p=0.818, respectively) (p<0.05 between groups for both measurements) (Table 2).

Walking time post training was significantly correlated with quadriceps strength (Knee extension) post treatment (r=0.63, p=0.02). Additionally, walking time and peak VO_2 ml/kg/min were correlated post treatment (r=0.54, p=0.038) and also the change in total weight lifted during maximal strength test (pre vs. post) was correlated with peak VO_2 ml/kg/min post treatment (r=0.55, p=0.034). No change for resting heart rate, systolic and diastolic blood pressure or peak heart rate was found within group or between groups (Table 2).

3.3. Resistance training effect on maximal strength

Due to equipment limitations, maximal strength measurement (1–4 repetitions) could not be assessed for the sitting row in some patients (limited weights on the machine). As a result, some patients lifted the maximal weight of the machine more than four times. Hence, it is likely that the actual strength as reflected by weight lifted is even greater than reported.

Table 3 shown the changes in maximal strength for each exercise. Total weight lifted (sum of all eight exercises) increased by 18% in the resistance training group (394± 100.6 to 478.4±98.2 kg) compared to −2% of the control (353.5±123.6 to 347.6±124.7 kg) (p=0.000). Maximal lower limb strength (leg press and knee extension) was increased by 22% and upper body strength increased by 15% in the resistance training group.

Table 2
Comparisons of resting hemodynamics, peak VO_2 and walking time before and after treatment

	Control (n=7)		Resistance training (n=8)		p value
	Pre	Post	Pre	Post	Group×Time
RHR, bpm	68.0±16.1	67.9±13.7	71.4±9.1	69.5±8.7	0.654
RSBP, mm Hg	109.7±22.1	106.9±13.5	111.3±18.9	111.3±17.3	0.672
RDBP, mm Hg	72.6±9.2	69.7±11.3	69.5±8.3	71.3±6.4	0.333
PHR, bpm	101.8±16.4	102.3±15.8	109.6±21	106.8±20.7	0.421
Peak VO_2, ml/kg/min	14.9±1.8	14.7±3.2	14.4±2.8	17.7±1.3†	0.011*
Peak VO_2, ml/min	1347±134	1317±201	1298±233	1614±242†	0.010*
Walking time, min	10.9±1.6	11.1±1.6	10.6±1.2	12.0±0*	0.058
LWHFQ score	34.7±17.3	36.0±18.9	23.9±25.2	12.9±17.4*	0.030*

RHR (resting heart rate), RSBP (resting systolic blood pressure), RDBP (resting diastolic blood pressure), PHR (peak heart rate), VO_2 (oxygen consumption), total weight (the sum of weight lifted during the maximal strength tests).
* Significant of p<0.05.
† Significant of p<0.001.

3.4. Resistance training effect on quality of life score

Patients in the training group reported an improvement in their quality of life score by 87% with no change (−4%) in the control (p=0.030) (Table 2).

Moderate but significant correlation was found between the changes in quality of life (pre-post intervention) and post training peak VO_2 (r=0.58, p=0.025) and between quality of life score and total weight lifted during the post maximal strength test (r=−0.52, p=0.047) (negative correlation since a lower score in the questionnaire represents better quality of life).

4. Discussion

There is limited data in the literature reporting the effect of progressive resistance training on chronic heart failure patients in general and for those on beta-blocker medication in particular. Studies that examined the effect of resistance training on cardiac and chronic heart failure patients also involved some degree of aerobic training (such as circuit weight training) [27,28]. Although these studies demonstrated significant improvement in the patient's strength and functional ability, due to the combination of training methods employed it is difficult to distinguish which one of the training methods contributed to the improvement.

To our knowledge, this study was the first to examine the effect of resistance training on peak VO_2, muscle strength and quality of life of chronic heart failure patients on beta-blocker medication. The major findings of the current study were (a) resistance training showed an effect of increasing both absolute and relative peak VO_2 of chronic heart failure patients on beta-blocker medication. (b) Beta-blocker therapy did not inhibit strength gains following a resistance training program and (c) 8 weeks of resistance training improved the quality of life in chronic heart failure patients.

Peak VO_2 may assist in prognostic assessment and is a major independent predictor of death in chronic heart failure patients [29,30] where patients with peak VO_2 less than 14 ml/kg/min have a poor prognosis [31]. A major finding of the current study was that 8 weeks of progressive resistance training increased both absolute and relative peak VO_2 by approximately 19%. This finding was in contrast to some studies that investigated the effect of resistance training on cardiac patients [7,19] however is similar to others [32,33]. It has been suggested that in some patients the limiting factor during exercise is weak leg

Table 3
Changes in maximal strength within and between groups after treatment

Schwinn exercise	Control		Resistance training		p value
	Pre	Post	Pre	Post	Group×Time
Chest press	37.0±13.5	37.6±13.6	40.3±11.2	51.1±12.3†	0.000†
Lateral pulldown	41.6±9.7	43.1±10.2	44.8±8.0	55.8±10.4†	0.002*
Tricep extension	20.1±5.8	20.1±5.8	21.0±6.8	25.5±7.6†	0.000†
Upright row	52.5±19.9	49.9±1.4	63.6±17.5	71.5±18.3†	0.003*
Bicep curl	38.9±11.7	36.3±12.6	39.2±13.1	46.5±13.0†	0.002*
Sitting row	81.0±20.4	78.5±20.4	82.9±16.1	94.2±3.2*	0.027*
Knee extension	56.0±17.6	56.0±16.2	64.9±16.7	86.3±7.4†	0.007*
Leg press	65.7±11.4	69.9±4.0	68.9±13.3	87.0±17.3†	0.031*
Total weight, kg	353.5±123.6	347.6±124.7	394.4±100.6	478.4±98.2†	0.000†

Weight in kg.
* Significant at p<0.05.
† Significant at p<0.001.

muscles rather than cardiovascular dysfunction [34,35]. Our finding supports that theory. The change in total weight lifted during maximal strength test was significantly correlated with peak VO_2 post training (r=0.55, p=0.034), which demonstrated that weak skeletal muscles were contributors to the reduction in aerobic capacity of chronic heart failure patients. An increase of lower limb strength is associated with an increased exercise (working) capacity [36,37], which consequently may lead to increase peak VO_2. Tyni-Lenne et al. [32] reported that 8 weeks of resistance training with rubber bands (two sets and 25 repetitions) increased walking distance (by 11%), which was accompanied by a significant increase in peak VO_2 (by 8%) of chronic heart failure patients (mean ejection fraction=30%). As shown in Table 3, the leg strength of the training group increased by 22%. That improvement was associated (r=0.63, p=0.02) with the significant increase in walking time (higher workloads) during the post-incremental test (by 12%) is evident by the significant positive correlation. As such, patients in the training group exhibited an increase in quadriceps muscle strength which was followed by an increase in walking time. Also, walking with a higher workload increases the demand for oxygen by the working muscle resulting in an increase in peak VO_2 [38]. Patients in the present study demonstrated a significant relationship between walking time and peak VO_2 (r=0.54, p=0.038), indicating that the increase in peak VO_2, to some extent, may be related to the increase in walking time. It may be concluded therefore that resistance training increases skeletal muscle strength which is accompanied by both an increase in walking time and an increase in aerobic capacity.

Resistance training has been shown to increase skeletal muscle mass (e.g. hypertrophy) in healthy elderly subjects [39,40]. The increase in muscle mass is associated with increased peak VO_2 [15–17]. Frontera et al. [41] examined the influence of 12-week resistance training (eight repetitions for three sets at 80% of one repetition maximum) on sedentary older men (age 60–72). Their patients demonstrated an increased mid-thigh muscle size and quadriceps area (11.9% and 9.3%, respectively). Hypertrophy has been shown to occur in all fibre types following resistance training in elderly subjects [39]. Fibre type I increases by 10–45% [40–43], fibres type IIa by 28–34% [40,43] and fibres type IIb by 27–52% [40,41]. Hepple et al. [44] reported an improvement of 8% in peak VO_2 of elderly men which was accompanied by an increase in the vastus lateralis cross sectional area (from 3874$\pm$314 to 4916$\pm$309 μm^2, p<0.05). According to these studies resistance training of 8–12 weeks at 60–80% of one repetition maximum may increase both muscle mass and shift muscle fibers towards the slow, oxidative type. It has been suggested that resistance training with a high number of repetitions may increase aerobic capacity [45]. In the present study the initial number of repetitions was 15–20 (40–60% maximal strength) and then gradually decreased to 8–12 (80–90% maximal strength, three sets). The relatively high number of repetitions and the gradual increase in intensity may suggest both muscle hypertrophy and shift of muscle fibers towards the oxidative fibres as previously reported. Consequently, the current resistance training may have altered muscle structure, resulting in increased peak VO_2. Further studies are needed to substantiate this speculation.

The increase of peak VO_2 in the present data may be attributed also to changes in the muscles metabolism following resistance training. Previous studies reported an increase in the capillary density, mitochondria content or oxidative enzymes activity as a result of resistance training [46–48]. These changes may lead to improve oxygen delivery and utilization in the skeletal muscle. It has been suggested that the increase in capillary content related to the improvement in peak VO_2 [49]. Additionally, investigators found high negative correlation between peak VO_2 and type IIB fibers (r=−0.728) [48] and high positive correlation between peak VO_2 and mitochondria volume density (r=0.89) [4].

It is most likely that the increase of aerobic capacity in the current study was due to changes in the periphery (e.g. increased muscle mass and improved oxidative metabolism). Periphery changes enable the muscle to uptake more oxygen from the blood contributing to an increased arterial-venous oxygen difference rather than increase in stroke volume and cardiac output [50]. It was demonstrated that stroke volume of severe chronic heart failure patients did not change or even decrease during exercise (both aerobic and resistance) [51]. Moreover, the maximal heart rate in the present chronic heart failure patients did not change after training. These findings support the concept that peak VO_2 in chronic heart failure patients increases due to peripheral changes (arterial-venous oxygen difference) [52]. Nevertheless, further study is required to address the change in peak VO_2, fiber muscle types, mitochondria content and muscle metabolism in patients with chronic heart failure after resistance training.

As shown in other cardiac patients, resistance training has no effect on resting heart rate, systolic blood pressure and diastolic blood presure in chronic heart failure patients on beta-blocker [27,32,37,50]. It is possible that resistance training on its own is not sufficient enough to reduce the resting heart rate and systolic and diastolic blood pressure since it is not a prolonged effort (such as in aerobic exercise) but a short burst exercise [50]. Moreover, in this study all patients were on beta-blockers which are designed to reduce resting hemodynamic parameters [11,12], therefore, further reduction in resting hemodynamics may be limited.

Eight weeks of resistance training increased significantly the self reported quality of life of the training group as measured by the Living With Heart Failure Questionnaire while no change was found in the control group (Table 2). There were two main contributors to the improvement in quality of life of the current patients. Firstly, the increase in peak VO_2 as evident by the significant correlation (p=0.58, p=0.025). It is similar to other studies that demonstrated moderate but significant correlation between peak VO_2 and quality of life as measured through difference parameters such as social competence and general health perception [53] and emotional function and self perceived control [54]. Secondly, the increase in skeletal muscle strength (r=−0.52, p=0.047). In previous studies patients who underwent resistance training improved their functional ability [7], self-efficacy [55], and as a result, their quality of life [54].

In view of the current results, there is one main limitation that should be acknowledged, due to ethical limitations, the incremental test was stopped after the sixth stage (speed 3.0 km/h and grade 12.5%) even if the subject did not exhibit clinical symptoms. Hence, some patients might have been able to tolerate greater workloads.

In summary, the current study demonstrated that chronic heart failure patients on beta-blocker therapy may benefit from resistance training in a similar manner to other cardiac patients. These benefits included an increased aerobic and exercise capacity, skeletal muscle strength and most importantly, an improvement in the quality of life, which is the main goal of cardiac rehabilitation programs. Furthermore, with appropriate supervision, it is recommended that resistance exercise be added to the exercise rehabilitation program of these patients when possible.

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