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The effect of physical training in chronic heart failure

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Abstract

Background: Supervised cardiac rehabilitation programs have been offered to patients following myocardial infarct (MI), coronary artery bypass graft surgery (CABG) and percutaneous coronary intervention (PCI) for many years. However, limited information is available on the usefulness of rehabilitation programs in chronic heart failure (CHF). The aim of our study was to evaluate the outcome of supervised physical training on CHF patients by measuring both central and peripheral factors.
Methods: This was a prospective randomized study, including 43 patients with CHF, New York Heart Association (NYHA) class II or III, mean age 68 years. After initial measurements of VO_2peak, 6 min walk distance, muscle strength, plasma levels of atrial natriuretic peptide (ANP) and brain natriuretic peptide (BNP), echocardiogram, measurements of pulmonary function and quality of life questionnaire, patients were randomized to either a training group ($n=21$) or a control group ($n=22$). The training group had supervised aerobic and resistance training program twice a week for five months. After the training program was completed, all measurements were repeated in both groups.
Results: No training related adverse events were reported. Significant improvement was found between groups in the six minute walk test (+37.1 m vs. +5.3 m, $p=0.01$), work load on the bicycle exercise test (+6.1 W vs. +2.1 W, $p=0.03$), time on the bicycle exercise test (+41 s vs. +0 s, $p=0.02$) and quadriceps muscle strength test (+2.8 kg. vs. +0.2 kg., $p=0.003$). Quality of life factors that reflect exercise tolerance and general health, improved significantly in the training group compared to the control group. No other significant changes were found between the two groups.
Conclusion: Supervised physical training as used in this study appears safe for CHF patients in NYHA class II or III. The improvement in functional capacity observed in the training group seems to be related to peripheral factors rather than in central cardiovascular performance.

Keywords: CHF; Physical training; Vo2max; Exercise tolerance; 6 min walk test; Quality of life

1. Introduction

The syndrome of chronic heart failure has become one of the most common cardiovascular disorders in western societies [1,2]. Due to more effective treatment of cardiovascular diseases, the number of patients living with heart failure is increasing [3]. In spite of advances in pharmacological treatment, prognosis in heart failure remains poor, and morbidity and mortality rates among patients with severe heart failure remain relatively high [4–6].

Patients with heart failure generally have reduced exercise capacity, and two of the main symptoms in heart failure are exercise intolerance and fatigue [7–11]. Recently more emphasis has been placed on the role of peripheral factors as the cause of exercise intolerance in CHF. This is in part due to the fact that, exercise capacity and left ventricular systolic function are poorly correlated [12,13]. While pharmacological therapy can improve central hemodynamics in CHF patients, corresponding improvements in exercise capacity are often delayed for weeks or even months [12,14].

The aim of our study was to evaluate the effect of physical training in chronic heart failure patients by measuring both central and peripheral factors. The results

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will be of value in deciding whether chronic heart failure patients should attend cardiac rehabilitation programs.

2. Methods

This was a prospective randomized study. The study was approved by the Icelandic National Bioethic Committee. All participants signed a written informed consent prior to inclusion in the study. The inclusion and exclusion criteria are listed in Table 1.

The study population was identified by screening approximately 500 patients who were hospitalized due to heart failure in the Reykjavik area during a three year period. Fifty-one patients were identified, but after the randomization process, eight patients withdrew consent for various reasons, so the study started with 43 patients.

After initial measurements, patients were randomized to either a *control group* or a *training group*. Initial measurements consisted of *cardiopulmonary exercise test on ergometer bicycle, 6 min walk test, muscle strength test, measurements of ANP and BNP levels in plasma, dynamic spirometry, 2-D echocardiography and quality of life questionnaire.* The training group entered a supervised exercise program twice a week for five months. The control group continued their previous level of physical activity, which varied from performing little physical activity up to taking a daily walk outdoors. All participants in the control group were contacted via telephone once during the study period. After five months all measurements were repeated in both groups.

2.1. Measurements

Cardiopulmonary exercise test. The patients performed a symptom limited cardiopulmonary exercise test on an electronically braked upright bicycle ergometer (Sensor Medics/Ergometrics 900). After a period of resting and unloaded pedaling, work load was increased progressively by either 5, 10 or 15 W/min until exhaustion was reached, or other symptoms that caused the patient to stop the test. Heart rate and rhythm were recorded continuously by 12-lead EKG, and blood pressure was assessed manually every minute. The respiratory gas exchange was measured and recorded continuously by the *breath by breath* manouvre using mass flow ventilometry (Vmax Sensormedics, Yorba Linda). Peak VO_2 was determined as the VO_2 value relative to body weight in ml/min/kg., achieved at the patients peak work load on the bicycle. Gas analyzers and flow probes were calibrated before each test.

Minimum time for the test to be considered valid was 4 min cycling on the work load.

6 min walk test. This was a standardized indoor 6 min walk test. Patients were instructed to walk as far as possible in 6 min. Four tests were performed each time, the first two for the patient to get familiarized with the procedure of the test and surroundings, and the second two were the actual tests, where the better (farther distance) was chosen. Blood pressure, heart rate, and respiratory rate was measured and reported before and after each test.

Muscle strength test. Muscle strength was measured in skeletal muscle groups in upper and lower extremities using the Evient sequence equipment *leg-press*, *arm-pull* and *arm-press*, and a *quadriceps-bench* for knee extension. The heaviest weight lifted once through a full range of motion was the patient's 1-repetition maximum (1RM). Statistical analyses were performed on the muscle strength data obtained from knee extension, *musculus quadriceps*.

Plasma ANP and BNP levels. Blood samples were obtained to determine the plasma levels of atrial- and brain natriuretic peptides. The samples were stored at −70 °C prior to analysis with a 19-IRMA ANP and BNP commercial analysis kit.

Spirometry. Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and flow volume loop were measured.

Echocardiogram. Left ventricular ejection fraction (LVEF) was assessed with 2-D echocardiography (Acuson 128XP/10c) using the biplane Simpsons method [15].

Quality of life. Quality of life was measured with a valid Icelandic quality of life questionnaire *Heilsutengd lífsgæði* [16]. It consists of 32 questions, sorted in 12 different categories. Each question gives scores from 1 to 10, the scores within each category are added together and a specific *T*-score is found. The higher the *T*-score, the better the self reported quality of life.

Rehospitalization. A retrospective assessment was made 12 and 28 months after study closure to record rehospitalizations among the patients in our study.

Table 1
Inclusion and exclusion criteria for participation in the study

Inclusion criteria:
CHF-diagnosis
On CHF medication
Clinical symptoms of CHF
Clinically stable >3 months before study entrance
Fullfill one of the following criteria:
- previous MI
- hospitalized because of CHF
- lung oedema and cardiac enlargement on X-ray
Exclusion criteria:
COPD
Orthopedic disabilities
Psychiatric disabilities
Cancer
Senility
>80 years

CHF=Chronic heart failure; MI=Myocardial infarction; COPD=Chronic obstructive lung disease.

2.2. Training protocol

Patients in the training group attended outpatient supervised physical training twice a week for five months. Each session started with a 10 min warm-up period, either sitting or standing. It consisted of breathing exercises and free non-resistance arm and leg movements. This was followed by 15 min of pedaling on a bicycle and 20 min of circuit resistance training using Evient sequence equipment, with free weights and elastic rubber-bands (Thera-bands). Each session ended with a cool down for 5 min with stretching of the engaged muscle groups. The work load on the bicycle started with 50% of the peak work load from the cardiopulmonary exercise test, and then gradually increased for each individual as their endurance improved during the five months. The resistance in the circuit training started with 20–25% of 1RM in the muscle groups involved, and most of the patients continued to be on the same resistance throughout the study, but a few were on 35–40% of 1RM at the end of the study. The training was supervised by physical therapists. Blood pressure, pulse, oxygen saturation, dyspnea, exertion and body weight were measured and reported in each session.

In addition to the exercise program, the training group had three educational lectures, about *nutrition*, *physical activity* and *relaxation*.

Table 2
Baseline characteristics

	Control group (n = 22)	Training group (n = 21)
Age/year(±SD)	69(±5.3)	68(±6.6)
Male; Female	18; 4	16; 5
EF % (±SD)	40.6(±13.7)	41.5(±13.6)
6 min walk distance/meters(±SD)	482(±70)	482(±75)
Etiology		
IHD	16 (73%)	18 (85%)
AF	4 (18%)	1 (5%)
Valvular	2 (9%)	1 (5%)
Hypertension	0 (0%)	1 (5%)
Drugs:		
ACE-I	5 (23%)	8 (38%)
Beta-blockers	14 (64%)	11 (52%)
Diuretics	19 (86%)	17 (81%)
Statins	4 (18%)	8 (38%)
Antiarrythmics	14 (64%)	10 (48%)
A-II blockers and ARB	10 (45%)	13 (62%)
Aspirin	18 (82%)	20 (95%)
Nitrates	8 (36%)	7 (33%)

Data presented as mean values(±SD), number of patients and/or percentage. EF = Ejection fraction; IHD = Ischemic heart disease; AF = Atrial fibrillation; ACE-I = Angiotensin Converting Enzyme Inhibitors; A-II /ARB = Angiotensin II Receptor Blocker.

2.3. Statistical analysis

If not otherwise stated, the data is presented as mean ± SD. Student's t-test and Mann Whitney U-test were used to compare values within groups and between groups. Statistical significance was defined as $p < 0.05$.

3. Results

Demographic data are shown in Table 2. The two groups were comparable at baseline for age, sex, EF, and distance walked on the 6 min walk test. Two patients were excluded from the end of study assessment, one because of a car accident and the other withdrew consent. Both of these patients were in the control group.

Cardiopulmonary test. Cardiopulmonary test data from three patients was excluded from the analysis as follows. Two patients in the control group because they didn't complete the minimum four minutes of work load on the bicycle, and one patient in the training group because the patient stopped the test early due to ventricular tachycardia.

Exercise time, and work load on the bicycle improved significantly in the training group compared to the control group (Table 3). Seventeen out of twenty patients in the training group (85%) that completed the bicycle test increased their time and work load, compared to five out of twenty one patients in the control group (24%). No significant difference was found between groups in VO_2peak.

6 min walk test and muscle strength test. There was highly significant improvement in the training group compared to the control group in the distance walked on the 6 min walk test ($p = 0.01$) and quadriceps muscle strength ($p = 0.003$) (Table 3).

ANP,BNP, LVEF and respiratory function. No significant difference was found between groups in the ANP or BNP concentration in plasma, left ventricular ejection fraction (LVEF) (Table 3), FVC or FEV_1. The mean FVC in the control group at baseline was 3.69 L, and 3.62 L at study closure and in the training group 3.52 L vs. 3.48 L *(p = NS)*. The mean FEV1 in the control group was 2.6 L both at study entrance and study closure, and in the training group 2.5 L both at study entrance and study closure *(p = NS)*.

Quality of life. There was no significant difference between groups in the total score of the quality of life questionnaire (Table 3). In the category of exercise capacity, there was significant change in the training group between measurements, the mean values were 44.0 T-scores at study entrance vs. 50.2 T-scores at study closure *(p = 0.001)*, compared to the control group where the mean values at study entrance were 45.7 T-scores vs. 46.7 T-scores at study closure *(p = NS)*. This difference was also significant between groups ($p = 0.01$).

Rehospitalization. Twelve months after study closure, five patients from the control group and two from the training group had been rehospitalized, this increased after

Table 3
Exercise capacity

	Control group		Training group		Between groups
	before–after	p	*before–after*	p	p
VO_2(L/min)	1.45 (0.36)–1.52 (0.39)	ns	1.28 (0.40)–1.27 (0.35)	ns	NS
VO_2peak(ml/kg/min)	16.32 (3.10)–16.87 (4.05)	ns	14.92 (3.44)–14.76 (3.02)	ns	NS
Exercise time(min)	8.9 (2.15)–8.9 (2.18)	ns	8.2 (2.60)–9.1 (3.11)	0.01	0.02
Max.HR(beats/min)	122.8 (24.71)–123.9 (25.59)	ns	117.0 (26.33)–121.1 (24.29)	ns	NS
Work load(W)	103.8 (25.97)–104.1 (27.68)	ns	88.3 (26.79)–95.9 (30.36)	0.007	0.03
Work load/k.(W/kg)	1.2 (0.31)–1.2 (0.38)	ns	1.0 (0.31)–1.1 (0.30)	ns	0.04
LVEF(%)	41.5 (13.6)–43.5 (11.1)	ns	41.5 (13.5)–45.6 (10.3)	ns	NS
ANP(ngr/L)	53.8 (36.33)–54.8 (53.92)	ns	58.1 (61.31)–60.9 (40.90)	ns	NS
BNP(ngr/L)	122.2 (121.8)–124.5 (154.7)	ns	173.2 (180.4)–171.7 (155.1)	ns	NS
6 min walk test(meters)	489.2 (66.33)–494.60 (66.40)	ns	489.3 (75.00)–526.4 (71.90)	0.001	0.01
Muscle strength (kg)	12.8 (2.99)–13.0 (2.99)	ns	11.3 (3.8)–14.1 (3.2)	<0.0001	0.003
QoL (*T*-score)	42.50 (13.7)–44.10 (14.04)	ns	44.50 (10.4)–47.55 (8.7)	ns	NS

Data shown are mean values (±SD). Statistical significance: $p<0.05$.
Before are measures at the beginning of the study, and *after* at the study closure.
VO_2 = Oxygen consumption; HR = Heart rate; LVEF = Left ventricular ejection fraction; ANP = Atrial natriuretic peptide; BNP = Brain natriuretic peptide.

twenty eight months, to eleven patients in the control group and seven from the training group. None of the rehospitalizations in the training group was due to worsening of heart failure, three hospitalisations in the control group were due to worsening heart failure. Two patients in the training group and two patients in the control group had died 28 months after study closure.

4. Discussion

Some studies have shown improvement in VO_2peak after exercise training [17–19] but others have not [12,20–22]. In our study no significant improvement was found in VO_2peak, ejection fraction (EF) or ANP and BNP plasma levels. This may imply that the training did not affect left ventricular contractility or cardiac function in general, marked by the atrial- and brain natriuretic peptide plasma levels. We found significant improvement in the distance walked in the 6 min walk test, muscle strength, and time and work load on the bicycle ergometer test. The six minute walk test has been found to be of value in evaluating functional capacity in patients with chronic heart failure [23,24]. In some studies physical training has not been shown to improve the walk distance [25], but in others it has [26,27]. The significant improvement in the training group in exercise time, work load on the bicycle ergometer test and distance walked in the 6 min walk test in our study indicates an increase in functional capacity. The strength of the quadriceps muscle also increased significantly in the training group, compared to the control group. This occurred even though the weight/resistance which the patients worked against in the exercises, increased only slightly during the five months of the exercise program. We used isotonic-type resistance exercises, to avoid any training related increase in haemodynamic burden, which has been reported to be caused by isometric-type resistance exercises [28].

The lack of significant improvement in the quality of life measurements in the training group is a disappointment. On the other hand, significant improvement in the questionnaire's category of exercise capacity was found for the training group compared to the control group, which is congruent with other results of our study.

No adverse events occurred during the exercise training, and all patients in the training group completed the five month exercise program. Among the patients in the training group that were rehospitalized within 12 or 28 months after study closure, none was due to worsening of the heart failure. These facts can imply that supervised physical training is safe for CHF patients. Exercise tolerance and muscle strength improved significantly in the training group compared to the control group. This outcome is considered favorable for these patients.

The lack of improvement in ANP and BNP plasma levels in our study fits well with the lack of improvement in other indices of cardiopulmonary function.

5. Conclusion

In conclusion, the main effect of this training program for patients with CHF is on muscle strength and functional capacity. Supervised exercise training can therefore be of value for these patients. The intensity of the training must always be customized for each patient, and it must be born in mind that these patients have poor prognosis and should be treated with extra care. Further studies are necessary to evaluate how peripheral improvement is achieved, without significant central changes.

6. Study limitations

Our study has relatively small sample size and included only CHF patients in NYHA functional class II or III with stable heart failure, who were able to perform a symptom limited exercise test, and eventually take part in a physical training group. Therefore the results cannot be generalized to all CHF patients.

References

[1] Tyni-Lenné R, Dencker K, Gordon A, Jansson E, Sylvén C. Comprehensive local muscle training increases aerobic working capacity and quality of life and decreases neurohormonal activation in patients with chronic heart failure. European Journal of Heart Failure 2001;3:47–52.

[2] Mosterd A, Hoes AW, deBryune MC, et al. Prevalence of heart failure and left ventricular dysfunction in the general population. European Heart Journal 1999;20:447–55. s.

[3] Riedinger MS. Predictors of quality of life in women with heart failure. Journal of Heart and Lung Transplantation 2000;19:598–608.

[4] Gitt AK, Wasserman K, Kilkowski C. Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for high risk of early death. Circulation 2002;109:3079–84.

[5] Cohn JN, Fowler MB, Bristow MR, et al. Safety and efficacy of carvedilol in severe heart failure. Journal of Cardiac Failure 1997;3:173–9.

[6] Packer M, Bristow MR, Cohn JN, et al. The effect of Carvedilol on morbidity and mortality in patients with chronic heart failure. New England Journal of Medicine 1996;334:1349–55.

[7] McKelvie RS, Teo KK, Roberts R, et al. Effects of exercise training in patients with heart failure: the exercise rehabilitation trial (EXERT). The American Heart Journal 2002;144:23–30.

[8] Group EHFT. Experience from controlled trials of physical training in chronic heart failure. European Heart Journal 1998;19:466–75.

[9] McKelvie RS, Teo KK, McCartney N, Human D, Montague T, Yusuf S. Effects of exercise training in patients with congestive heart failure; a critical view. Journal of the American College of Cardiology 1995;25:789–96.

[10] Green DJ, Watts K, Maiorana AJ, O'Driscoll J, Gerry MB. A comparison of ambulatory oxygen consumption during circuit training and aerobic exercise in patients with chronic heart failure. Journal of Cardiopulmonary Rehabilitation 2001;21:164–74.

[11] Dubach P, Myers J, Dziekan G, et al. Effects of high intensity exercise training on central hemodynamic: responses to exercise in men with reduced left ventricular function. Journal of the American College of Cardiology 1997;29:1591–8.

[12] Pina IL, Apstein CS, Balady GJ, et al. Exercise and heart failure. Circulation 2003;107:1210–25.

[13] Myers J, Froelicher VF. Hemodynamic determinants of exercise capacity in chronic heart failure. American Internal Medicine 1991;115:377–86.

[14] Wilson JR, Martin JL, Ferrara N. Impaired skeletal muscle nutritive flow during exercise in patients with congestive heart failure; role of cardiac pump dysfunction as determined by effect of dobutamine. The American Journal of Cardiology 1984;53:1308–15.

[15] Feigenbaum H. Echocardiography. 4 ed. Philadelphia: Lea & Febiger; 1986.

[16] Björnsson JK, Tómasson K, Helgason T. The Icelandic Medical Journal.

[17] Coats AJS. Controlled trial of physical training in chronic heart failure: exercise performance, hemodynamics, ventilation, and autonomic function. Circulation 1992;85:2119–31.

[18] Barlow CW, Qayyum MS, Davey PP, Conway J, Patterson DJ, Robbins PA. Effects of physical training on exercise-induced hypercalcemia in chronic heart failure: relation with ventilation and catecholamines. Circulation 1994;89: 1144–52.

[19] Belardinelli R, Georgiou D, Cianci G, Berman N, Ginzton L, Purcaro A. Exercise training improves left ventricular diastolic filling in patients with dilated cardiomyopathy. Circulation 1995;91:2775–84.

[20] Belardinelli R, Georgiou D, Cianci G, Purcaro A. Randomized, controlled trial of long-term moderate exercise training in chronic heart failure. Circulation 1999;99:1173–82.

[21] Wilson JR, Groves JR, Rayos G. Circulatory status and response to cardiac rehabilitation in patients with heart failure. Circulation 1996;94:1567–72.

[22] Willenheimer R, Erhardt L, Cline C, Rydberg E, Israelsson B. Exercise training in heart failure improves quality of life and exercise capacity. European Heart Journal 1998;19:774–81.

[23] Guyatt GH, Thompson PJ, Berman LB, et al. How should we measure function in patients with chronic heart and lung disease? Journal of Chronic Diseases 1985;28:517–24.

[24] Cahalin LP, Mathier MA, Semigran MJ, Dec W, DiSalvo T. The six-minute walk test predicts peak oxygen uptake and survival in patients with advanced heart failure. Chest 1996;110:325–32.

[25] Kostis JB, Rosen RC, Cosgrove NM, Shindler DM, Wilson AC. Nonpharmacologic therapy improves functional and emotional status in congestive heart failure. Chest 1994;106:996–1001.

[26] Kavanagh T, Myers MG, Baigrie RS, Mertens DJ, Sawyer P, Shephard RJ. Quality of life and cardiorespiratory function in chronic heart failure: effects of 12 months' aerobic training. Heart 1996;76:42–9.

[27] Meyer K, Schwaibold M, Westbrook S, et al. Effects of exercise training and activity restriction on 6-min walking test performance in patients with chronic heart failure. The American Heart Journal 1997;133:447–53.

[28] Pollock M. Resistance training in individuals with and without cardiovascular disease: an advisory from the committee on exercise rehabilitation and prevention. Circulation 2000;101:828–33.