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PERIPHERAL MUSCLE TRAINING IN PATIENTS WITH CLINICAL SIGNS OF HEART FAILURE

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ABSTRACT. The aim of the study was to evaluate, in a controlled setting, the effects of a 5-month dynamic peripheral training programme in patients with clinical signs of congestive heart failure with special reference to their anaerobic threshold, muscle function, heart rate variability and quality of life. Twenty-four randomized patients with clinical signs of heart failure in NYHA II–III entered the study. Training resulted in a significant ($p = 0.01$) change in the anaerobic threshold, the patients' ability to lift weights ($p = 0.01$) and performance of heel-lift ($p = 0.01$). The heart rate recorded during the training exercises decreased significantly ($p = 0.04$). There were no significant differences in peak oxygen uptake, isokinetic and isometric strength, HRV and quality of life except for three items in the control group. The results of this study indicate that peripheral training is beneficial for patients with clinical signs of congestive heart failure.

Key words: congestive heart failure, exercise, circuit weight training, quality of life, heart rate variability, anaerobic threshold.

INTRODUCTION

Heart failure affects approximately 1% of the population in the Western world. The number of persons with significant heart failure has increased as the population has aged. Congestive heart failure (CHF) carries a poor prognosis, with a survival rate of 50% after 5 years (6, 17, 28).

The most common symptoms in CHF are fatigue and breathlessness, which influence exercise capacity and restrict the ability to perform physical activities. This in turn affects the patient's work, leisure time, social and sexual activities and mood (7, 19).

There is little correspondence between haemodynamic features (including ejection fraction) and physical performance in CHF or quality of life attributes (19, 28). Several authors debate whether a peripheral abnormality in the skeletal muscles, such as altered balance of skeletal fibre types, altered capillarization and altered metabolic function, are responsible for the deteriorated exercise capacity (5, 15, 24, 27).

It has long been recognized that CHF, either through reduced cardiac output, physical deconditioning, or for some other unknown reason, results in an impaired skeletal muscle vascular bed and an altered oxidative capacity. Several histological changes have been noted in the skeletal muscle of patients with heart failure (3, 4, 18, 19).

Formerly, it was believed that cardiac rehabilitation and any physical training by persons with chronic heart failure were harmful, causing worsening of symptoms and further compromising cardiac function (27). During the last decade, however, it has been suggested that physical training is beneficial in heart failure patients. Exercise capacity, measured as maximal oxygen consumption or exercise duration, may be increased, and this increase is associated with several beneficial peripheral and metabolic adaptations. Sullivan et al. (25) have focused on the importance of early skeletal muscle anaerobic metabolism in CHF patients and have shown that exercise training delays anaerobic threshold. This improves the patient's exercise capacity.

Most previous studies have assessed the effect of bicycle training, which mainly affects the central circulation system (4, 5, 7, 8, 16, 19, 22, 27).

A different way to exercise is to work with a high relative load on individual muscle groups while maintaining low central circulatory stress levels. This can be achieved by a dynamic peripheral training exercise programme based on circuit weight training, i.e. a program consisting of resistance training, with work sessions followed by recovery for 30–60 min duration (10). Gaffney et al. (9) suggested the use of this peripheral training for patients with impaired cardiac function.

Low heart rate variability (HRV) in patients with ischaemic heart disease carries an adverse prognosis. A previous exercise study, with training involving the central circulation in patients with CHF, has demonstrated a favourable increase in HRV, suggesting a shift in the sympatovagal balance towards parasympathetic predominance (5).

The aim of this study was to evaluate a 5-month dynamic peripheral training program with special reference to the anaerobic threshold, muscle function, HRV and quality of life. Our hypothesis was that training would result in a better aerobic capacity, increased muscle strength and improved quality of life.

MATERIALS AND METHODS

Study population

Inclusion criteria. Seventy-five years or younger, history of chronic CHF of at least 1 year, present evaluated functional capacity NYHA classes IIa–IIIb (20).

Exclusion criteria. Diabetes, claudicatio intermittence, status post-stroke or orthopaedic problems.

Twenty-four patients (8 women, 16 men) were recruited from the Department of Cardiology, Sahlgrenska Hospital in Gothenburg, The diagnosis of CHF was determined by their regular cardiologist, based on a history of dyspnea on exertion, fatigue or fluid retention, and/or radiographic examination or echocardiography. Medication had to be stable for 6 months prior entering the study. The aetiology of CHF was due to ischaemic heart disease in 21 patients, cardiomyopathy in 2 and valvular disease in 1. The patients were treated for CHF with the following medication: ACE inhibitors 46%, beta-blockers 50%, diuretics 79% and digitalis 38%. Echocardiography was not performed at the onset of the study to evaluate the ejection fraction. After the baseline testing the patients were randomized to an intervention or a control group.

One patient in the intervention group dropped out due to a severe asthma attack requiring hospitalization.

Methods

The study, which was approved by the Ethical Committee at the Medical Faculty, Gothenburg University, was a randomized comparison of 5 months' peripheral training. All patients gave their informed consent to this study. The sequence of testing was as follows.

Physical parameters

Peak oxygen uptake and anaerobic threshold. These were tested on a bicycle ergometer (Mijnhardt, Netherlands) with a 10 W stepless increase every minute in a climate-controlled room. Gas exchange was recorded during bicycle exercise by measuring the expired gas flow and expiratory oxygen consumption and carbon dioxide concentrations with gas meters, which were calibrated against gas mixtures of known concentrations before each test. Oxygen consumption and carbon dioxide production were measured continuously at a standard temperature and pressure.

Heart rate was recorded from the ECG tracings, and blood pressure was measured with a sphygmomanometer every minute during the test and at peak exercise.

Before each test, the patient was familiarized with the equipment and asked to breathe through the mouthpiece for 3 minutes with a noseclip on. After this, a 3-minute period of pedalling with friction resistance took place before the exercise test started. The test started at 0 W. The exercise test was supervised by a physiotherapist and a physician. The test could be discontinued by the physician if necessary. Each patient performed a maximum test, i.e. was encouraged verbally to continue as far as he/she could, which meant Borg scale 18–19 of 20 (2). The anaerobic threshold was defined as when the rise in CO_2 production was higher than the rise in oxygen consumption (1). This was determined by a computer programme (Medical Graphic Cooperation, St. Paul, MN, USA) and checked by two independent physicians, neither of whom were present at the exercise test.

Isokinetic and isometric peak torque and endurance. These were measured in the knee extensors on a KINetic COMmunicator^{TM} II (KIN-COM, Chattecx Corporation, Chattanooga, TN, USA), which is an isokinetic hydraulically-driven and microcomputer-controlled device.

The isokinetic strength in both legs was tested at 60 and 180 degrees per second with the patient in a sitting position. Endurance was tested as 50 repeated contractions at 180°/second, and the decline in torque was calculated as a percentage from baseline. Endurance was then recorded in the right leg as the time the patient could keep 40% of the maximum isometric strength at a 60° knee angle. The recovery was then followed for 5 minutes, with repeated maximum contractions once every minute (26).

Plantar flexion. This was tested with the patient lying in a supine position. The patient performed the maximum isometric plantar flexion.

All the tests were performed by the same experienced lab technician, and a physician was present the whole time. The patients were verbally encouraged to exert themselves as much as they could.

Heel-lift. This was performed on a 10° tilted wedge with the foot in a dorsiflexed position. The patient lifted his/her foot once every other second and was allowed to touch the wall to keep his/her balance. The contralateral foot was held slightly above the floor (9).

Heart rate variability. HRV was assessed by a 24-hour Holter recording: 19 patients with a stable sinus rhythm were accepted, and 5 recordings of less than 20 hours of analysable data were excluded. The 24-hour recordings were digitized on a Marquette Series 8000 Holter scanner submitted to standard Marquette algorithms for QRS labelling and editing. Then tapes were manually reviewed to make sure that classification of the QRS was correct. HRV was then analysed on a Marquette Heart Rate Variability Software Version 002A. The programme provides measurement within the time domain and for spectral components using the Fast Fourier Transformation algorithm.

HRV was analysed before and after the training period, and the difference was calculated (23).

Psychosocial parameters

The Nottingham Health Profile (NHP) and the Quality Of Life Questionnaire—Heart Failure (QLQ-HF) (14, 29), two self-administered questionnaires were given to the patient at the first visit to the clinic for completion at home and returned at the third visit.

The NHP was used to assess basal health-related quality of life. NHP measures the subjective emotional, functional and social impact of chronic disease. NHP was developed in Britain and has been extensively tested in that country for reliability and validity (12, 13). The rationale for using NHP in the present study was that it had been translated into Swedish, and its reliability and validity had been tested and found to be high (30).

The NHP consists of two parts. Part I reflects the patients degree of distress within the sections of mobility, energy, pain, sleep and emotional reaction and social isolation (altogether 38 yes/no questions). The total weight in each section is 100, indicating the presence of all possible problems within the section; 0 indicates that the patient has no problems at all. Part II of NHP contains seven yes/no statements referring to health-induced problems within the domains of work, home life, social life, family life, sex life, hobbies and holidays. In part II, the percentage of yes answers for each question is counted. The NHP had previously been used to evaluate life quality in cardiac patients (31).

QLQ-HF is specially aimed to assess quality of life in severe heart failure. Compared to other available instruments, QLQ-HF is simple and short, containing only 23 items. The questionnaire includes somatic and emotional aspects, life satisfaction and physical limitations. The reliability and validity of QLQ-HF have been tested and found to be high (29).

Intervention

A 60-minute training programme based on peripheral dynamic training principles was offered twice a week for 5 months.

Patients trained as a group twice a week for 60 minutes. The exercise regimen was designed to include muscles utilized in functional activities such as walking, dressing, getting up from a chair, etc.

The exercises were based on a circuit weight training regimen. The weights were individually chosen, 60% of one repetition maximum (RM) (9, 10). The heart rate did not exceed 30 beats above the resting value. Frequency of exercise was one activation every other second for 1 minute. The resting period was 15 seconds. Each set of exercises was performed twice. The exercises are described in Table I.

Once a month the weights were retested and individually corrected as described above. Heart rates recorded at the end of each exercise were also checked once a month by using telemetry (SIEMENS Sirecust 1481 T, Gothenburg, Sweden).

Statistics

Data analyses were performed on a Macintosh computer using the Statview SE+ program. Group data presented are expressed as means ± SEM. Wilcoxon's signed rank test was used to determine whether significant differences ($p < 0.05$) in the variables existed between the experimental and control subjects as a result of the training programme.

RESULTS

The baseline characteristics of the patients are given in Table II.

There were no significant differences in baseline variables between the intervention and control group.

Overall, the training programme was well tolerated. Eleven of the 12 subjects in the intervention group completed the trial. One subject had a serious asthma attack and was excluded from the study.

Compliance was expressed as the number of sessions the patient participated in during the 5-months intervention period. The mean compliance was 75%, range 65–100%.

Table I. *Peripheral training programme**

Heel lift Touching the wall for balance, a maximal heel-lift on a 10° tilted wedge, one lift every other second. The contralateral foot was held slightly above the floor.	*Pulley exercises* (Medema, Stockholm, Sweden) Pulley exercises using the muscles (muscle groups) mentioned below. —M. Latissimus dorsi —M. Triceps brachi (elbow extension) —M. Biceps brachi (elbow flexion) —Hip abductors —Hip adductor —Hip flexors —Hip extensor
Getting up from a chair Sitting on a stool 0.45 m from the floor. Raise to standing position and back to sitting again without touching the lap with the hands.	
Weights Standing on the floor in an erect position with one handle in each hand. The exercises are done bilaterally. —Shoulder flexion —Shoulder abduction —Elbow flexion	*Quadriceps table* (Medema, Stockholm, Sweden) The weight arm is placed 0.35 m from the joint axis, 60° angle in extension and 120° angle in flexion —Knee flexion —Knee extension
Hand strength (Gula Rehab, Kungälv, Sweden) Standing in an erect position using strengthen device in each hand. —Grip strength	*Stretching* Stretching of the used muscle groups.
	Relaxation therapy Deep breathing in combination with stretching.

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Table II. *Patient characteristics at baseline*

Variable	Training ($n = 12$)	Control ($n = 12$)
Age (years)	61.8 ± 9.8	64.7 ± 5.3
Sex (male/female)	9/3	7/5
Weight (kg)	76.1 ± 12.9	75.8 ± 12.2
Height (cm)	171.6 ± 9.5	172.2 ± 6.7
Heart rate (beats/min)	61.1 ± 12.3	68.1 ± 6.7
Blood pressure (mm Hg)		
Systolic	132.5 ± 13.8	131.8 ± 18.7
Diastolic	85.8 ± 7.6	81.8 ± 9.3
NYHA IIa/IIIa/IIIb	7/3/2/0	5/2/3/2
Peak oxygen uptake (ml/min/kg)	14.9 ± 8.5	13.7 ± 4.2
Diagnosed ICD/CMP/VD	10/1/1	11/0/1

Results are expressed as mean value ± SEM.
NYHA, New York Heart Association classification of heart failure.
ICD: Ischaemic cardiac disease, CMP: cardiomyopathy, VD: valvular disease.

Physical parameters

Training did not significantly increase the peak *oxygen uptake* compared with the baseline data. There was a significant difference ($p = 0.01$) in the *anaerobic threshold* after training in the intervention group compared to the control group after 5 months' peripheral training.

There was no significant alteration in *heart rate*, recorded during bicycle test, at rest, submaximal exercise and maximal exercise in the two groups.

Isokinetic strength, at either velocity, and *isokinetic endurance* did not improve significantly in the intervention group after training compared to the control group.

Isometric strength in knee-extensors at a 60° knee angle and *isometric endurance* were not significantly higher after training in the intervention group compared to the control group.

No significant difference was found in the measurements of *plantar flexion* between the intervention and control group before and after training.

There was a significant ($p = 0.01$) difference in the ability to perform *heel-lifts* in the intervention group, after training, compared to the control group.

There was no significant difference between the two groups when changes in *HRV parameters* were compared.

There was a significant reduction ($p = 0.04$) in heart rate only recorded in the intervention group during

Table III. *Results of physical parameters used in this study*

		Training Mean value, SEM	Control Mean value, SEM	p value
Anaerobic threshold (W)	before	48.9 ± 2.0	56.0 ± 21.0	
	after	54.8 ± 12.1	36.9 ± 38.9	0.01
Peak oxygen uptake (ml/min/kg)	before	14.9 ± 8.5	13.7 ± 4.2	
	after	15.1 ± 2.5	15.0 ± 6.5	ns
Submaximal heart rate (on bicycle/min)	before	99 ± 12	102 ± 10	
	after	98 ± 10	101 ± 11	ns
Isokinetic				
Peak torque (60°/sec Nm)	before	129.3 ± 39.9	117.9 ± 35.9	
	after	130.7 ± 41.3	112.6 ± 30.2	ns
Peak torque (180°/sec Nm)	before	96.1 ± 37.5	87.1 ± 24.6	
	after	98.8 ± 30.3	84.3 ± 26.3	ns
Endurance (Nm)	before	45.8 ± 14.1	49.1 ± 12.6	
	after	43.2 ± 10.2	49.4 ± 12.4	ns
Isometric				
Peak torque 60° knee angle (Nm)	before	154.4 ± 52.7	130.6 ± 39.0	
	after	161.8 ± 53.1	134.9 ± 37.2	ns
Endurance (Nm)	before	84.5 ± 32.6	92.2 ± 43.0	
	after	85.2 ± 33.4	95.1 ± 44.1	ns
Plantar flexion (Nm)	before	24.8 ± 9.1	25.7 ± 6.7	
	after	25.2 ± 13.6	24.8 ± 10.9	ns
Heel-lift (No.)	before	19.7 ± 6.0	26.0 ± 14.1	
	after	25.1 ± 6.4	22.3 ± 10.5	0.01
Heart rate at training exercises/min	before	96.1 ± 3.0		
Quadriceps table	after	89.7 ± 2.0		0.04
Weightlifting in the training group	before	3.75 ± 1.1		
Quadriceps table/kg	after	4.96 ± 0.9		0.01

the peripheral training period at the actual exercise sessions.

There was a significant improvement in ($p = 0.01$) the patients' ability to lift heavier weights in the intervention group after the 5 months period (Table III).

Psychosocial parameters (Table IV)

NHP Part I. There were no significant differences between the intervention group and the control group in the six sections: energy, pain, emotional reaction, sleep, social isolation and physical mobility.

NHP Part II. The results are expressed as the fraction of yes answers in each of the seven sections: work, home life, social life, family life, sex life, hobbies and holidays. There was a significant improvement in the control group in social life, hobbies and holidays.

QLQ-HF. There were no significant differences between the intervention group and the control group in physical activity, life satisfaction, emotions and somatic symptoms.

Results are given in Table IV.

DISCUSSION

The results of this study indicate that peripheral training results in a significant difference in the anaerobic thresh-

Table IV. *Results of psychosocial parameters used in this study*

		Training Mean value (SEM)	Control Mean value (SEM)	p Value
NHP Part I				
Energy	before	26.3 ± 22.5	17.3 ± 31.9	
	after	34.4 ± 45.7	20.4 ± 13.1	ns
Physical mobility	before	12.9 ± 11.8	16.1 ± 16.1	
	after	18.1 ± 28	20.4 ± 34.2	ns
Pain	before	13.4 ± 24.3	16.6 ± 19.7	
	after	13.4 ± 30.1	10.8 ± 14.2	ns
Sleep	before	29.2 ± 34.5	19.2 ± 22.6	
	after	27.2 ± 34.9	12.4 ± 16.1	ns
Emotion	before	20.4 ± 26.4	6.4 ± 8.7	
	after	19.5 ± 33.3	16.4 ± 24.4	ns
Social isolation	before	8.8 ± 17.2	2.1 ± 7.2	
	after	17.8 ± 31.3	6.1 ± 9.8	ns
		χ^2test df = 3.84, $p = 0.05$		
NHP Part II				
Work	before	33	9	
	after	18	8	ns
Home life	before	25	36	
	after	27	33	5.82
Social life	before	25	18	
	after	36	8	ns
Family life	before	17	18	
	after	18	17	ns
Sex life	before	42	36	
	after	36	50	ns
Hobbies	before	33	45	
	after	55	33	6.77
Holidays	before	33	45	
	after	45	17	12.83
QLQ-HF				
Life satisfaction	before	21.6 ± 5.2	22.4 ± 4.6	
	after	21.6 ± 4.4	23.8 ± 5.1	ns
Physical activity	before	26.2 ± 5.3	26.2 ± 6.7	
	after	28.8 ± 6.3	29.7 ± 8.1	ns
Somatic symptoms	before	25.8 ± 5.1	27.1 ± 4.5	
	after	26.8 ± 6.3	28.5 ± 5.7	ns
Emotions	before	24.1 ± 5.4	25.9 ± 4.6	
	after	24.8 ± 5.4	26.3 ± 4.3	ns

old compared to the control group. The patient is also able to lift heavier weights and is able to perform more heel-lifts. The heart rate during the training exercises decreased significantly. These results show that dynamic peripheral training with a low central circulatory stress can produce adaptive changes in skeletal muscles and thereby influence the central circulatory system. This has been suggested by Gaffney and coworkers in healthy subjects (9).

Some authors have assessed the effect of central exercise and have found that it influences both haemodynamic features and peripheral muscle function (4, 15, 16, 22). A problem with traditional exercise such as cycling is that it results in an increased heart rate, which some patients with severe CHF have difficulty in tolerating. For these patients, a peripheral training regimen, which aims to minimize heart rate increase during exercise, is the only possible way to exercise. The significant difference in the anaerobic threshold between the intervention and the control group is a positive indication of the effect of peripheral training on the CHF patients. The ability to supply oxygen to the working muscles in order to maintain aerobic metabolism is improved. The threshold appeared at a lower watt level after the intervention period in the control group, while there was a small rise in watt level in the intervention group. This means that their cardiorespiratory mechanism is able to provide an adequate oxygen supply to maintain aerobic metabolism in working muscles (15).

Training appears to counteract the deterioration the CHF patients face, as shown in the control setting.

The maximal exercise capacity was not improved in the training group. There is some disagreement in the literature whether weight training has any effect upon the cardiovascular system. The differences in the effects of circuit weight training on cardiovascular fitness could be attributed to the relative intensity of exercise in the used programmes used (10, 11, 31). Peripheral training does not affect heart rate more than 20–30 beats above the resting value, so the direct effect on the central circulatory system should be low (9).

The heart rate during peripheral training sessions was reduced in the training group. This is evidence of an effect on circulatory regulatory mechanisms, but the effect was not transferred to bicycle exercises, as demonstrated by the unchanged heart rate and maximal oxygen uptake after training. As the central circulatory demand during the training programme in the present study was low, it is assumed that the observed reduction in heart rate was due to adaptive factors in the exercising muscles and/or adaptive factors related to the central motor command for those exercises. While improvement in heart rate responses to low levels of work would be of no major functional importance to a fit, healthy subject, it would be of benefit to a patient with CHF. Similar results and conclusions were reached in the study by Gaffney and coworkers (9). As shown previously, training effects are usually difficult to transform from one modality to another.

We had expected to find more differences related to muscle function between the intervention and control group. Gaffney and coworkers found that peripheral training improved the muscle strength in healthy subjects (9), a result we could not reproduce. This may be due to either the placebo effect, i.e. the effect of the interest we show the patients by including them in the study group, and/or the fact that the training is not specific and intensive enough to improve the strength in the quadriceps muscle. The quadriceps table is used for only 10% of the total training session. The fact that the patients managed to increase their ability to lift weights by 14–58% shows that the training has a positive effect on the peripheral muscle function, but we may not have chosen the right method for evaluating the possible improvement in muscle strength and endurance.

Heel-lifts are often used in clinical work to evaluate muscle strength. The training group significantly improved their heel-lift performance probably due to improved anaerobic capacity in the local muscles (9). The same improvement is not seen in plantar flexion in KIN-COM, probably because of the testing procedure.

Previous exercise training studies (3, 4) of patients with CHF whose central circulation was affected, have shown a change in HRV, suggesting a shift in the sympatovagal balance towards parasympathetic predominance. Our study shows no significant impact on vagal or sympathetic tone, as expressed by HRV. This could support the hypothesis that the change in the autonomic balance mainly is due to training of the central circulation system.

Quality of life was not changed significantly during the training period in the training group. An unexpected phenomenon was seen in the control group, which showed an improved quality of life in NHP part II in the items social life, hobbies and holidays. This can in part be explained by that the NHP is too crude for such a small study group.

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