Moderate-Intensity Exercise Training With Elements of Step Aerobics in Patients With Severe Chronic Heart Failure

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ABSTRACT. Sturm B, Quittan M, Wiesinger GF, Stanek B, Frey B, Pacher R. Moderate intensity exercise training with elements of step aerobics in patients with severe chronic heart failure. Arch Phys Med Rehabil 1999;80:746-50.

Objective: To evaluate whether a specific program of moderate-intensity step aerobics training may be sufficient to improve the exercise tolerance of patients with severe chronic heart failure.

Patients: Twenty-six patients (22 men, 4 women; mean ± SD age, 54 ± 9yrs) with a history of severe chronic heart failure (left ventricular ejection fraction of 18% ± 8%).

Study Design: Prospective, randomized, controlled trial. Patients were randomized into exercise and control groups. All patients underwent a clinical examination and a ramp pattern cycle exercise test before and after the observation period. The exercise group underwent a moderate-intensity (50% of peak oxygen uptake) 12-week training program, progressing to 100 minutes per week of step aerobics and 50 minutes per week of cycling. The control group did not perform a training program.

Main Outcome Measures: Peak oxygen uptake, peak workload, percent of predicted power ability.

Results: Significant increases in peak oxygen uptake (15 ± 3.4 to 18.5 ± 2.9mL/kg/min; $p = .001$), peak workload (77 ± 26 to 99 ± 31 watts; $p = .000$), and percent of predicted power ability (43% ± 10% to 56% ± 13%; $p = .000$) were observed in the exercise group. No significant changes in baseline parameters occurred in the control group. There were no critical changes in heart rate or blood pressure in either group.

Conclusion: Moderate-intensity step aerobics training significantly increases peak oxygen uptake and peak workloads in patients with severe chronic heart failure.

DILATED CARDIOMYPATHY may be idiopathic or caused by ischemic heart disease, myocarditis, valvular heart disease, and toxicologic reasons and results in an impairment in pump function. Peripheral (edema, hepatomegaly) and pulmonary congestions are the well-known consequences.[1] The impaired cardiac output affects many organ systems and is summarized as the "heart failure syndrome." The main symptoms of chronic heart failure are dyspnea, fatigue, and a marked decrease in work capacity, caused not only by the impaired cardiac output but also by substantial disorders in muscle metabolism and blood supply. Thus, the patients are substantially limited in their activities of daily living.[2-5]

Long-term physical inactivity of patients with clinically stable heart failure worsens the state of health and causes greater morbidity.[6] Physical exercise training is known to contribute to increased physical fitness in such patients. Moreover, physical training can reduce body weight and improve emotional well-being and quality of life.[7,8] From physical training, vascularity of the active muscles increases[9,10] and peripheral oxygenation improves.[10-12] The neurohumoral state is influenced by a reduction of sympathetic tone.[12]

In patients with stable chronic heart failure several studies have shown that exercise training can improve exercise tolerance and increase peak oxygen uptake (VO_2).[13-19] These changes have mainly been observed with exercise regimes between 70% and 80% of peak VO_2 and a training duration of 3 hours per week over more than 8 weeks. All these studies demonstrated an increase in workload by 20% to 30% and in peak VO_2 by 20%.[13-19] Importantly, no serious clinical side effects were reported during these studies.

In contrast to these high-dose exercise studies, Kostis and colleagues[7] and Belardinelli and colleagues[20] successfully studied a low-intensity exercise training program (40% to 60% of the peak VO_2) in patients with moderate heart failure. The patients achieved an increase in the exercise capacity of 20%. In all of the cited studies, the patients involved had moderate heart failure and left ventricular ejection fractions (LVEFs) in the range of 30%. The effects of training in patients with severe and end-stage heart failure (LVEF of <20%) are not known.

The aim of this study was to evaluate whether a specific program of moderate-intensity step aerobics training is sufficient to improve the exercise tolerance and the peak VO_2 of patients with severe chronic heart failure.

METHODS

With respect to the severity of the underlying disease we designed our training program to achieve maximal safety but also maximal motivation for the patients. A prospective, randomized, controlled trial comparing a 12-week exercise training program to normal daily activities was conducted in patients with severe heart failure. The protocol of the study was approved by the local Ethic Committee of the Medical Faculty of the University of Vienna.

Patients

Twenty-nine patients (25 men, 4 women; mean ± SD age, 54 ± 9yrs) with severe heart failure referred to the outpatient clinic of the Department of Cardiology were included. Inclusion criteria were: (1) stable chronic heart failure after optimized pharmacological therapy that was unchanged during the previous 3 months (digitalis, angiotensin-converting enzyme [ACE] inhibitors, furosemide, beta-blocker, nitrate, amiodarone); (2) LVEF below 25%, measured by radionuclidventricu-

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lography[21] during the previous 3 months; and peak VO_2 between 12 and 15mL/kg/min, power ability below 50% of the predicted value in healthy age-matched individuals,[22] or both, measured in an exercise test 2 weeks before the study.

Exclusion criteria were coronary artery disease (evaluated by coronary catheterization in every patient), acute diseases (infective diseases, acute myocarditis), recent changes of the drug regimen, malignant arrhythmias, implanted defibrillator devices, orthopedic and neurologic disorders, and serious peripheral arterial occlusive disease.

Two patients with chronic renal failure, four patients with diabetes (two treated with insulin, two treated with oral medication), and four patients with pulmonary diseases (one with small airways disease and three with obstructive pulmonary disease) were included in the study. Thirteen patients had a history of hyperuricemia and hyperlipidemia. One patient had a plastic aortic valve. One patient had an implanted demand pacemaker (DDD-mode).

Protocols

After inclusion, 26 patients were assigned either to the exercise group (EG) or the control group (CG) (13 in each group) by a computer-generated randomization list (Lotus Symphony[a]). The EG underwent a 12-week exercise training program; the CG continued their normal activities of daily living with the usual restriction of additional physical exercise. All patients gave written informed consent before starting the study.

Before and after the 12-week observation period all patients underwent a clinical examination and a ramp pattern cycle exercise test. The examiner was blinded regarding the group assignment of the patients. All patients regularly visited the outpatient clinic of the Department of Cardiology and were familiar with most of the testing procedures prior to participation in the study.

Exercise Testing

Exercise testing was performed on a bicycle ergometer.[b] A ramp pattern exercise protocol was calculated individually for each patient according to the formula of Wassermann and colleagues.[23] Because we knew the patients had reduced power ability, the calculated ramp for healthy individuals was adapted by factor of 0.5 to reduce workload and thus to achieve an exercise time of approximately 10 minutes.[23] Pedaling rate was set at 50 to 60rpm. All tests were terminated as soon as leg fatigue or severe dyspnea occurred. Heart rate was recorded continuously by a 12-lead electrocardiogram (Siemens Megacart[c]), and blood pressure was recorded noninvasively every 2 minutes. Blood samples were taken at rest and in the second and third minute of recovery from the hyperemized ear lobe and were analyzed for blood lactate concentration by an enzymatic method (ESAT 6660[d]). VO_2 and carbon dioxide production (VCO_2) was measured by the breath-by-breath method (Sensormedics 2900[b]). Patients breathed through a mouthpiece connected to a mass flowmeter, measuring minute ventilation by the thermal conductivity technique. VO_2 was measured with a fast response zirkonium-oxide analyzer.[b] The system reported 10-second averages for each parameter measured. The anaerobic threshold was determined by the V-slope-method.[24] Power ability was calculated as percentage of predicted data for normal, healthy men and women. Oxygen pulse (mL/beat) and respiratory gas exchange ratio (VCO_2/VO_2) were automatically calculated by the device.

Training Program

The exercise training took a total of 12 weeks. A therapist guided the training under constant supervision of a physician, and emergency care was available immediately. An short anamnesis was taken at the beginning of each training lesson in each patient. The patients were questioned about changes at the therapy and if dyspnea, edema, or both occurred. During the first 4 weeks the exercise training was performed on 2 days per week. The exercise training lesson was divided into a short warm-up period, the endurance training period, and a final cool-down period. The short warm-up and cool-down periods each lasted 5 minutes. Initially, each endurance training period lasted 20 minutes; the endurance training period was increased to 50 minutes after 4 weeks. Once a week the endurance type training consisted of an adapted step aerobics program; the other lesson used stationary cycling. Beginning with the fifth week a third exercise lesson per week, consisting of an adapted step aerobics program, was added (table 1). The patients stepped up and down steps of 9.5cm minimum height with a special choreography. Intensity of training was set at 50% of the individual peak VO_2 and was controlled by heart rate calculated according to Karvonen's formula (±3 beats).[25] The heart rate was monitored continuously by a pulse watch (Polar Beat[e]). The patients were trained to exercise in such a way that they were well within their individual training heart rate range. This was achieved by altering the step height from 9.5 to 19cm and/or step cadence or adjusting resistance during ergometer training. After a short familiarization time, all patients were able to keep their training heart rate well within the prescribed limits. Particularly in the beginning of the program, the staff had supplementary roles of adjusting the workload and controlling the heart rate for the patients.

Summarizing the endurance training time taking effect on circulatory function, patients accumulated from 40 minutes per week to 150 minutes per week from the fifth week on.

Statistics

Continuous variables are given as mean ± SD and were compared using analysis of variance (ANOVA). Dichotomous variables were compared using Fisher's exact test. To assess effects of treatment in the two groups, two-factor ANOVA was used. The linear relation between variables was evaluated by computing Pearson's correlation coefficient. A $p < .05$ was considered significant.

RESULTS

Patients characteristics did not differ significantly in the two groups before the study (table 2). The LVEF at baseline was 17% ± 7% in the EG and 19% ± 9% in the CG. Five patients in the exercise group and six in the control group were listed for heart transplantation. Long-term medication, which was not changed during the study period, included ACE inhibitors, furosemide, mononitrates, beta-blockers, and amiodarone. All patients were in New York Heart Association functional class II or III.

The peak VO_2 was 15.9 ± 3.4mL/kg/min in the exercise group and 17.8 ± 2.4mL/kg/min in the control group (not

Table 1: Timetable of Exercise Program

Training	Cycling (min/week)	Step Aerobics (min/week)
1st Week	20	20
2nd Week	30	30
3rd Week	40	40
4th Week	50	50
5th-12th Week	50	100

Table 2: Baseline Characteristics of Patients

	Exercise Group	Control Group
No.	13	13
Age (yrs)	55 ± 9	53 ± 9
Weight (kg)	80 ± 16	79 ± 11
LVEF (%)	17 ± 7	19 ± 9
RVEF (%)	26 ± 13	23 ± 10
NYHA class II/III	6/7	8/5
Receiving long-term medication (no.)		
Digitalis	13	13
ACE-inhibitors	12	12
Beta-blockers	3	2
Carvediol	3	1
Amiodarone	1	1
Mononitrate	9	6
Diuretics	7	5

There were no significant differences between the exercise group and the control group for any variable.
Abbreviations: LVEF, left ventricular ejection fraction; RVEF, right ventricular ejection fraction; NYHA, New York Heart Association; ACE inhibitors, angiotensin-converting enzyme inhibitors.

Table 3: Results of Moderate Intensity Exercise Training in the Exercise and Control Groups

	Exercise Group			Control Group		
Variable	Pretraining	Posttraining	p	Pretraining	Posttraining	p
Peak VO_2 (mL/kg/min)	15.9 ± 3.4	18.5 ± 2.9	.001	17.8 ± 2.5	18.5 ± 3.6	.348
Work capacity (W)	77 ± 26	99 ± 31	.000	84 ± 24	89 ± 27	.305
Exercise time (sec)	574 ± 127	747 ± 137	.000	591 ± 111	626 ± 126	.170
PA	43 ± 10	56 ± 13	.000	45 ± 4	49 ± 7	.068
$ATVO_2$ (mL/kg/min)	9.1 ± 2.1	9.7 ± 1.3	.341	9.8 ± 2.1	10.2 ± 2.3	.674

Data are expressed as mean ± SD.
Abbreviations: VO_2, oxygen uptake; PA, percent of predicted power ability; $ATVO_2$, oxygen uptake at the anaerobic threshold.

significant). The power ability was 43% of predicted in the exercise group and 45% in the control group (not significant). During all exercise training sessions no critical findings in heart rate and blood pressure, no rales, and no increased dyspnea were observed that would have placed patients at high risk. Overall compliance with participation in the exercise lessons was 90%.

Three patients were excluded from the study and the statistical analysis: One patient was excluded because of noncompliance (he missed the training lessons more than 40% of time). Two patients (one from the EG and one from the CG) were excluded because of substantial changes of pharmacologic therapy: one patient received additional furosemide dosage because of peripheral edema; the other started a beta-blocker therapy because of a high blood pressure and heart rate.

Changes in Peak VO_2, Workload, and Power Ability

Peak VO_2 increased by 18% from 15.9 ± 3.4 to 18.5 ± 2.9mL/kg/min in the EG ($p = .001$) (fig 1). As indicated in table 3, the CG did not show significant changes of peak VO_2. Therefore, VO_2 values did not differ between groups after 12 weeks of therapy.

At baseline the EG achieved a workload of 77 ± 26 watts and increased to 99 ± 31 watts after 12 weeks of scheduled training ($p = .000$) (fig 2). Exercise time increased significantly from 574 ± 127 to 747 ± 137 seconds ($p = .000$) and power ability from 43% ± 10% to 56% ± 13% of the predicted ($p = .000$) (table 3). This increase of power ability corresponded to 32% of the baseline value. The oxygen-pulse increased after training from 9.9 ± 3 to 11.3 ± 4 mL/beat ($.05 < p < .10$).

The CG did not show significant changes of workload, exercise time, power ability, and oxygen pulse (table 3). The increase of workload, exercise time, and power ability was significantly different between the groups ($p < .05$).

Neither VO_2 at rest nor VO_2 at the anaerobic threshold changed significantly. Moreover, there was no significant change in respiratory gas exchange ratio for either group. Blood lactate concentration at rest and at peak exercise did not show any significant differences between groups before and after therapy. Heart rate at rest and at peak exercise remained unchanged in both groups. Furthermore, the diastolic blood pressure at rest, the peak diastolic blood pressure, the systolic blood pressure at rest, and the peak systolic blood pressure did not change in either group.

Relation Between Exercise Capacity and Peak VO_2

A significant, negative correlation ($p = .01$; $r = -.68$) was found between exercise capacity at baseline and the increase of the peak VO_2 after the 12 weeks of training (fig 3).

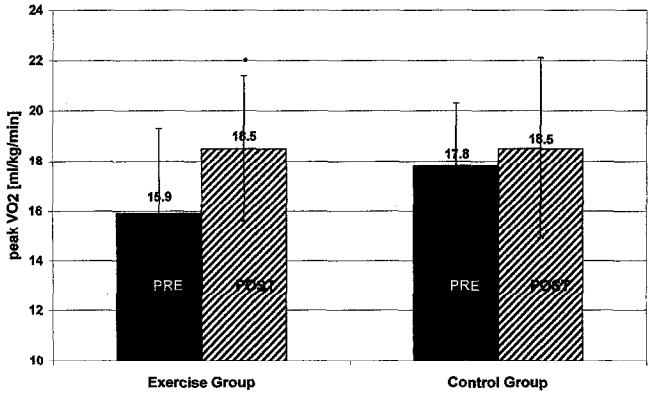

Fig 1. Peak VO_2 (ml/min/kg) before and after observation time (*$p < .01$).

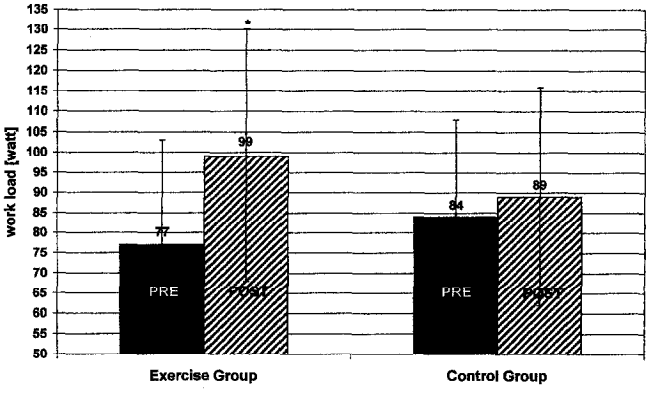

Fig 2. Workload (watt) before and after the observation time (*$p < .05$).

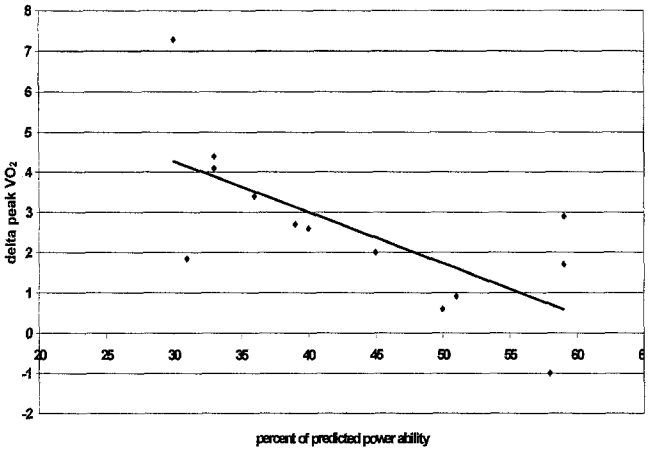

Fig 3. Relation between Δ peak VO_2 and percent of predicted power ability. A lower power ability resulted in a greater increase of peak VO_2 ($r = -.68$; $p = .01$).

DISCUSSION

These data show that moderate-intensity exercise training with elements of step aerobics can achieve a significant and clinically relevant increase of work capacity in patients with severe chronic heart failure based on dilated cardiomyopathy, with no significant coronary stenosis under full-dose medication (high-dose ACE inhibitor, beta-blocker, digitalis, furosemide).

While all patients fulfilled the clinical and exercise inclusion criteria before randomization, the prevalues for power ability, peak VO_2, VO_2 at the anaerobic threshold, and peak work rate ranged widely, with a considerable overlap between the CG and the EG. As depicted in figure 1, there was a gap between the mean baseline level of peak VO_2 in the EG and in the CG that is no longer present after therapy. If the difference in the pretreatment value was accounted for, the effect of training was not statistically significant. However, the increase in peak VO_2 was only significant in the EG. Further studies are necessary to investigate the effect of moderate step aerobics on peak VO_2.

The moderate-intensity step aerobics training (50% of peak VO_2) was chosen based on the findings of others,[13-19] who showed that this training has the potential to improve work capacity in chronic heart failure patients. Another rationale was the risk of a cardiovascular event, which threatens patients with severe chronic heart failure during physical exercise. Although the reported rate of serious incidents has been low regarding patients who trained with a higher-intensity exercise program (70% to 80% of peak VO_2),[13-19] it must be kept in mind that these patients had only moderate heart failure (LVEF between 24% and 40%). In our study we trained patients with severe chronic heart failure and a very low LVEF (17% ± 7% in the EG and 19% ± 9% in the CG), although we observed no serious side effects. Only one patient had to be treated with a higher dose of furosemide, because of peripheral edema.

Importantly, the relative improvements in peak VO_2 and workload (18% and 30%, respectively) are similar to the results of other studies, although those patients were using a higher-intensity exercise training regime.[13-19] We also found a significant, inverse relationship between the power ability before beginning the therapy in the exercise group and the increase of the peak VO_2 after the 12-week training period. In other words, patients who had a lower initial power ability were able to achieve a higher increase in peak VO_2. These results are similar to the results of Meyer and colleagues,[26] who showed a significant correlation of baseline aerobic capacity and training induced improvement in VO_2 at ventilatory threshold.

CONCLUSIONS

This study demonstrated that supervised, moderate-intensity step aerobics training is not only effective in increasing power ability, but also a safe procedure in patients with heart failure, which in this study was not based on coronary heart disease. Thus, we also suggest that such patients may be advised to perform moderate-intensity step aerobics without supervision.

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