The European Journal of Heart Failure 5 (2003) 527–535

The European Journal of Heart Failure

www.elsevier.com/locate/heafai

Hydrotherapy—a new approach to improve function in the older patient with chronic heart failure

Åsa Cider[a,*], Maria Schaufelberger[a], Katharina Stibrant Sunnerhagen[b], Bert Andersson[a]

[a]*Department of Cardiology, Institution for Community Medicine, The Sahlgrenska Academy at Göteborg University, Sahlgrenska University Hospital, Goteborg, Sweden*

[b]*Department of Rehabilitation Medicine, Institution for Community Medicine, The Sahlgrenska Academy at Göteborg University, Sahlgrenska University Hospital, Goteborg, Sweden*

Received 15 April 2002; received in revised form 9 December 2002; accepted 7 January 2003

Abstract

Aims: Hydrotherapy, i.e. exercise in warm water, as a rehabilitation program has been considered potentially dangerous in patients with chronic heart failure (CHF) due to the increased venous return caused by the hydrostatic pressure. However, hydrotherapy has advantages compared to conventional training. We studied the applicability of an exercise programme in a temperature-controlled swimming pool, with specific reference to exercise capacity, muscle function, quality of life and safety. *Methods and results:* Twenty-five patients with CHF (NYHA II–III, age 72.1 ± 6.1) were randomised into either 8 weeks of hydrotherapy ($n=15$), or into a control group ($n=10$). The training program was well tolerated with no adverse events. Patients in the hydrotherapy group improved their maximal exercise capacity (+6.5 vs. −5.9 W, $P=0.001$), isometric endurance in knee extension (+4 vs. −9 s, $P=0.01$) together with an improvement in the performance of heel-lift (+4 vs. −3 n.o., $P=<0.01$), shoulder abduction (+12 vs. −8 s, $P=0.01$) and shoulder flexion (+6 vs. +4, $P=0.01$) in comparison to patients in the control group. *Conclusion:* Physical training in warm water was well tolerated and seems to improve exercise capacity as well as muscle function in small muscle groups in patients with CHF. This new approach broadens the variety of training regimes for older patients with CHF.

Keywords: Exercise; Hydrotherapy; Water immersion; Elderly; Rehabilitation; Muscle function

1. Introduction

A major problem for patients with chronic heart failure (CHF) is their limited capacity to perform daily activities. Conventional physical training, such as cycle training or peripheral muscle training, has been found to improve physical function and well being in these patients [1]. The prevalence of CHF increases with age and the majority of patients 65 years or older [2]. However, most previous studies have investigated the effect of exercise in patients who are 65 years old or younger [3]. Further, elderly patients often have other disabling diseases that diminish their ability to exercise. For example, it may be difficult or impossible for a patient with severe orthopaedic problems to cycle on an ergometer.

Hydrotherapy, exercise in warm water, is an alternative method of exercising since the buoyancy effect reduces loading. Exercises to improve mobility, strength, as well as cardiovascular fitness can easily be provided in water [4]. Immersion in warm water has been used in bathing resorts in Europe in the beginning of the last century to reduce heart failure symptoms and enhance function and well being in patients with CHF. However, it has recently been advocated that patients with CHF should refrain from exercise in water due to the increased pre-load [1,5]. Immersion in water to the sternal notch causes an increased venous return resulting in both cardiovascular and renal effects [6,7]. In healthy people the thoracic blood volume, central venous pressure, cardiac output, and diureses increases during water immersion [6]. Vagal tone measured by power spectrum

*Corresponding author. Physiotherapy Department, SU/Sahlgrenska, S-413 45 Goteborg, Sweden. Tel.: +4631-3421195; fax: +4631-3424341.

E-mail address: asa.cider@fhs.gu.se (Å. Cider).

1388-9842/03/$ - see front matter © 2003 European Society of Cardiology. Published by Elsevier Science B.V. All rights reserved.
PII: S1388-9842(03)00048-5

Table 1
Baseline characteristics of the 25 patients with chronic heart failure

	Training ($n=15$)	Control ($n=10$)	P-value
Age (years)	70.2±5.2	75±6.4	ns
Sex F/M	5/11	3/6	
Weight (kg)	75±15	74±11	ns
Duration of CHF (years)	5.3±2.6	6.0±5.2	ns
LVEF (%)	31±8.3	8/1/0/1	ns
Etiology of CHF (IHD/DCM/VD/HT)	12/2/1/0		
NYHA class (II/III)	3/12	1/9	
Beta blockers (n)	13	7	
ACE-inhibitors (n)	13	8	
Diuretics (n)	12	10	

F/M, female/male; LVEF, left ventricular ejection fraction; NYHA New York Heart Association Classification, IHD, ischemic heart disease; DCM, dilated cardiomyopathy; VD, valvular disease; HT, hypertension; ACE, angiotensin converting enzyme; ns=$P\geqslant 0.2$.

analysis increases [8]. Neurohormonal effects of water immersion, such as a decrease in renal sympathetic activity, a reduction in angiotensin II and aldosterone levels, and an increase in renin activity are also seen in patients with CHF as well as healthy people [7,9]. Water temperature, water depth and the posture of the body influence the physiological reactions to immersion [10]. Tei et al. [11] assessed the effect of warm water immersion (41 °C swimming pool) and found an improvement in hemodynamics in patients CHF. Water immersion resulted in increased pre-load, ejection fraction, stroke volume, and cardiac output, and decreased peripheral resistance.

Patients with CHF are suffering from reduced quality of life due to several factors; these include a decreased physical function, dyspnea and fatigue [12]. Previous studies have shown conflicting results, with improved exercise capacity not always being associated with improved quality of life [13].

The purpose of this study was to assess the applicability of an exercise programme in a temperate controlled swimming pool in older patients with CHF. The hypothesis was that training in warm water could be a feasible alternative of physical training for patients with CHF, resulting in enhanced physical performance, muscle function and quality of life.

2. Methods

2.1. Patients

Twenty-five patients (8 women) with stable CHF in NYHA functional class II–III, ejection fraction <45%, and 60 years of age or older were recruited. Medication for heart failure had to be stable for the previous 3 months. Exclusion criteria were diabetes, peripheral arterial disease, chronic pulmonary disease and status post stroke, or other disabling diseases that might interfere with the exercise protocol. After baseline testing, the patients were randomised, using a 2:1 ratio, in a stratified order to 8 weeks of hydrotherapy ($n=15$), or to a control period ($n=10$). The patients were stratified according to age over 70 years, NYHA-class III and female gender. Baseline characteristics of the study population are given in Table 1. The study complied with the declaration of Helsinki. The Ethics Committee of Göteborg University approved the research protocol and informed consent of the subjects was obtained.

2.2. Test procedures

2.2.1. Exercise tolerance

Ergometer exercise tests were conducted in an upright position. A ramp protocol was utilised with a 10-W increase every minute until exhaustion. Peak oxygen uptake (V_{O_2} peak) and peak carbon dioxide production (V_{CO_2} peak) was measured breath-by-breath using a V-max system (Sensor Medics, USA). Inspiratory flows and expiratory oxygen (O_2) and carbon dioxide (CO_2) concentrations were determined. All patients were familiarised with the test procedure through a submaximal exercise test (13 on RPE-scale) 1 week prior to the first test session.

2.2.2. Six-minute walking test

A standardised 6-min walking test [14] was used to assess exercise capacity related to activities of daily living. The patients were asked to walk as far as possible during 6 min on a pre-marked 30-m walkway. Heart rate was recorded using a Sport-tester (Polar Electro Oy, Kempele, Finland). Perceived exertion and rate of dyspnea was rated using the Borg scale [15]. The test was carried out twice separated by 1 h of rest at the baseline test procedure. The value of the second test was used in the study.

2.2.3. Muscle strength and endurance

For measurement of the torque, a KINetic COMmunicator II (Kin-Com) (Chattanooga Group Inc., P.O. Box 489, Hixson, TN), was used. This equipment is a hydraulically driven and microcomputer-controlled device that operates in an isokinetic mode, i.e. an equal speed and a perfect adjusted resistance through the whole movement. The test was preceded by a 5-min warm-up on a test bicycle. The subjects sat with a hip angle of 90°, and the tested leg was attached to the lever arm of the dynamometer. The left and the right leg were randomly tested first. Knee extension and isometric strengths were measured at a 60°-knee angle. Isokinetic concentric and eccentric strength were measured at 60 and 180°/s for knee extensors for both legs. Isometric endurance was measured on the right leg as the time the person could keep 40% of his voluntary maximum strength at 60°-knee angle, with a follow-up of 5 min to evaluate the recovery process with a maximum voluntary isometric contraction every minute. On the left leg, isokinetic endurance was evaluated as the reduction of torque (in percent) between the first and the last three extensions in a series of 50 maximal contractions with an angle of 180°/s. Handgrip strength was recorded using Grippit® (AB Detector, Göteborg, Sweden). The maximum grip force and the mean value of the 10-s sustained grip was assessed. The test procedures have been described previously [16]. Unilateral isotonic heel-lift [17], bilateral isometric shoulder abduction and unilateral isotonic shoulder flexion were also measured as described in Appendix A.

2.2.4. Assessment of quality of life

Quality of life was measured using two instruments, the Short Form-36 Health Survey Questionnaire (SF-36) [18] and the Minnesota living with heart failure questionnaire (LHFQ) [19].

2.2.5. Training programme

The training programme comprised of 45-min sessions in a heated pool (33–34 °C), three times a week over an 8-week period.

The patients trained as a group following a low to moderate exercise level, i.e. 40–70% of maximal heart rate reserve. The basis posture was standing with water just below neck level. The exercise regime was designed to include muscles utilised in activities of daily living such as walking, dressing and household activities. The programme focused on peripheral muscle training but central circulatory exercises were also included. The purpose was to improve aerobic capacity, peripheral muscle strength and endurance. The physiotherapist used music to facilitate the correct pace of exercise. A heart rate recorder, Sport-tester (Polar Electro Oy, Kempele), was used to monitor the intensity. Details of the exercise programme are given in Appendix B. The control group was instructed to live their life as normal for 8 weeks and were not allowed to increase their habitual physical activity during this period.

2.2.6. Statistics

The SPSS® 9.0 for Windows (Chicago, IL) was used to analyse the data.

Ratio and interval data are given as mean (±1 S.D. or 95% CI) and ordinal data as median and range. Wilcoxon's rank sum test was used for comparisons of paired observations within each study-group. The Mann–Whitney U-test was used to assess differences between groups. A sign rank test was used to compare ordinal data. A P-value $\leqslant 0.01$ was considered significant as a method to correct for multiple comparisons. An intension to treat design was used on all data, except for the compliance rate in the exercise group.

3. Results

The training program was well tolerated, and there were no serious adverse events. Three patients reported mild fatigue after exercising during the first 2 weeks of the training period. One patient who had a history of paroxysmal artrial fibrillation had to finish the exercise programme due to a new episode of arrhythmia. The average adherence (total number of attended sessions) was 95%. Heart rate reserve during training is presented in Fig. 1.

3.1. Exercise tolerance

Patients in the hydrotherapy group showed a greater improvement in their maximal exercise capacity (+6.5 vs. −5.9 W, $P=0.001$), maximal oxygen uptake (+1.0 vs. −2.0 ml/kg/min, $P=0.02$) and 6-min walk test (+29.7 vs. +6.3 m, $P=0.055$) compared to the control group (Fig. 2 and Table 2).

3.2. Muscle function

Patients in the hydrotherapy group significantly improved their ability to perform heel-lift, shoulder flexion and shoulder abduction (Fig. 3). There was also a significant improvement in isometric endurance in knee extension. There was no significant difference between the two groups in isokinetic peak torque at 60°/s and in isokinetic endurance in the right leg. There were no other significant differences regarding isokinetic and isometric strength in knee extension or in handgrip strength (Table 3).

3.3. Quality of life

Quality of life improved significantly within the training group as measured by the total score and the physical dimension of the LHFQ (Table 4). In SF-36 there was no significant improvement after 8 weeks of training (Fig. 4). There were no statistically significant inter-group differences.

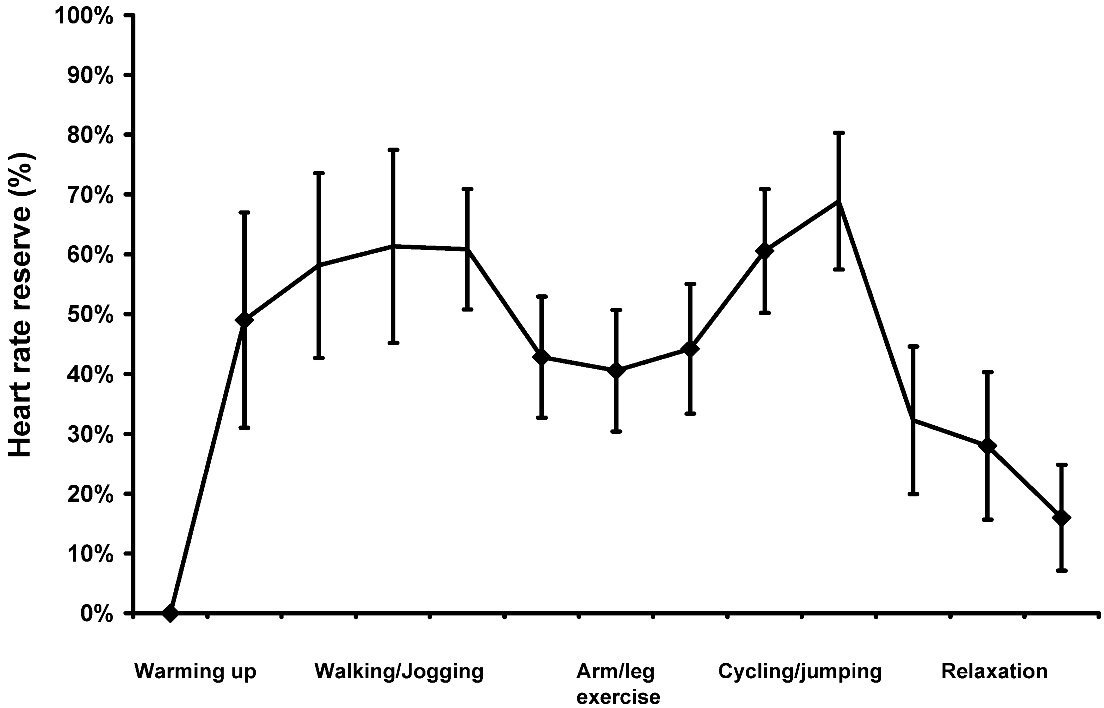

Fig. 1. Average (CI 95%) heart rate reserve (%) during the training session ($n=15$) in the swimming pool.

4. Discussion

This is the first study to demonstrate that hydrotherapy can improve maximal performance as well as muscle function in small muscle groups in patients with CHF. Furthermore, the training programme was well tolerated and associated with an improvement in quality of life.

4.1. Adherence

The adherence was high. One patient was excluded from the training programme because of an episode of paroxysmal atrial fibrillation. As the patient had a history of paroxysmal atrial fibrillation we do not believe the water training was the cause of the tachycardia. The

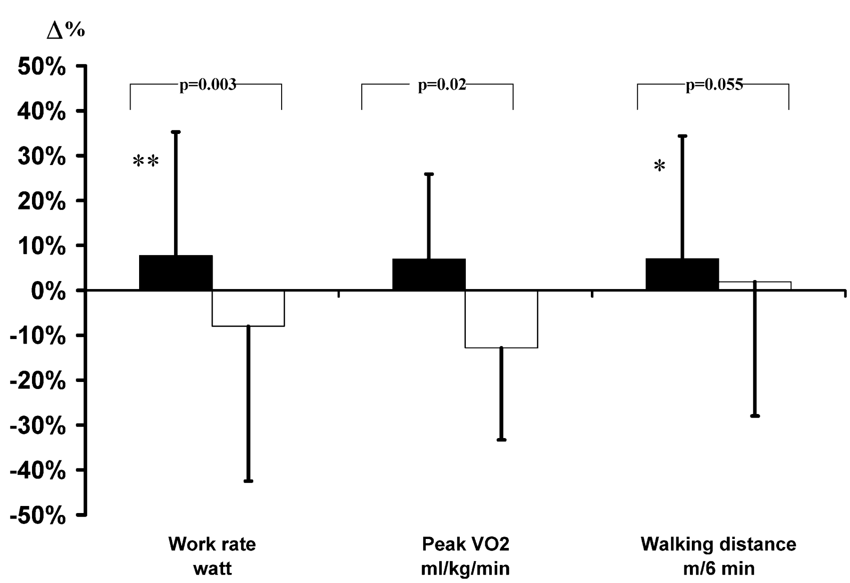

Fig. 2. Changes in exercise performance achieved after training ($*P \leqslant 0.05$, $**P \leqslant 0.01$, within group comparison with baseline). Training group (■) ($n=15$), and control group (□) ($n=10$).

Table 2
The effect on exercise capacity after training in water

		Before	After	*P*-value within the group	*P*-value vs. the control group
Exercise capacity (W)	T	84±23	91±24	0.01	<0.001
	C	74±25	70±22	0.1	
Oxygen uptake (ml/kg/min)	T	14.3±2.7	15.3±3.2	ns	0.02
	C	14.3±3.0	12.5±2.7	0.1	
Six-min walk (m)	T	421±115	450±94	0.02	0.055
	C	329±98	335±95	0.4	

T, training group ($n=15$), C, control group ($n=10$), ns $=P \geqslant 0.2$.

patients enjoyed the training sessions and wished to continue exercising in water after the study period was over. Since exercise and physical activity improve function [20], it is of great importance that life long exercise adherence be maintained. Long-term adherence appears to be difficult to maintain without professional support [21]. Therefore, it could be beneficial to offer patients a wider variety and more engaging training options. Hydrotherapy is often a very well appreciated way of exercising for older people [22].

4.2. Exercise capacity

In our study there was a 6% increase in peak V_{O_2} in the training group and a 16% decrease in peak V_{O_2} in the control group. Several other studies have described an increment of 10–30% in peak V_{O_2} after aerobic exercise on a level of 40–80% of V_{O_2} peak in patients with Ref. [1]. The explanation for this might be that we included elderly patients in our study. A similar decrease in peak V_{O_2} was seen in another study with elderly patients [23]. The improvement in the 6-min walk test was comparable with several previous studies conducted on land in patients with CHF [21,23–25].

4.3. Muscle function

The lack of improvement in knee extensors might be explained by the difficulty to achieve enough resistance in water to improve quadriceps strength and endurance. The quadriceps muscle is a large muscle group and it can be difficult to construct sufficient resistance for such a large muscle group in water. This has also been seen in patients with polio exercising in water [26]. There was a significant improvement in isometric endurance in knee extensors. This result is difficult to explain since very few of the exercises were focusing on isometric exercises. However, an increase in peripheral vasodilatation would increase oxygen supply to the skeletal muscles, which might facilitate this muscular improvement. Our training programme focused both on peripheral muscle training and on central circulatory exercises in order to improve poor muscle function as well as aerobic capacity. In a recent paper McKelvie

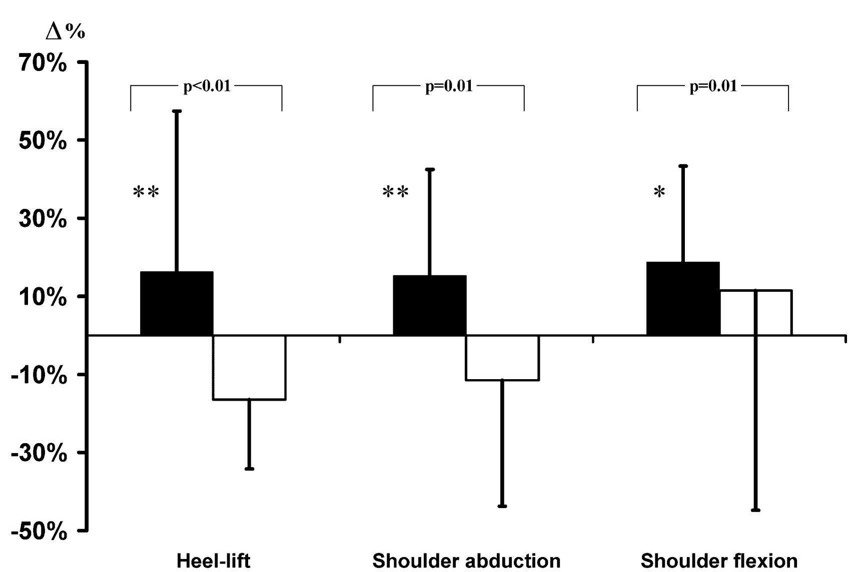

Fig. 3. Changes in muscle function achieved after training (*$P \leqslant 0.05$, **$P \leqslant 0.01$, within group comparison with baseline). Training group (■) ($n=15$) and control group (□) ($n=10$).

Table 3
The effect on muscle function after training in warm water

Knee extension in Kin-Com		Before	After	*P*-value within the group	*P*-value vs. the control group
Isokinetic					
Peak torque	T	133±39	134±39	ns	0.03
(60°/s N m) right leg	C	105±31	98±36	0.07	
Peak torque	T	138±44	137±41	ns	ns
(60°/s N m) left leg	C	128±51	114±35	ns	
Peak torque	T	76±27	94±29	0.1	0.06
(180°/s N m) right leg	C	76±25	73±26	ns	
Peak torque	T	90±27	94±29	ns	ns
(180°/s N m) left leg	C	72±24	79±25	ns	
Endurance decline in %	T	53±7	50±8	0.05	ns
of normal value left leg	C	50±10	46±9	0.1	
Isometric					
Peak torque	T	151±50	153±51	ns	ns
60° (N) right leg	C	119±41	117±41	ns	
Peak torque	T	158±54	163±54	0.09	ns
60° (N) left leg	C	128±31	140±47	ns	
Endurance (s)	T	97±24	101±33	ns	0.01
right leg	C	106±27	97±23	<0.05	
Hand strength					
Peak force (N)	T	315±96	328±92	0.1	ns
Right hand	C	284±89	288±108	ns	
Peak force (N)	T	288±88	298±74	ns	ns
Left hand	C	269±90	283±105	ns	
Clinical endurance tests					
Heel-lift (n.o)	T	22±9	26±10	<0.01	<0.01
	C	16±3	13±2	0.06	
Shoulder flexion (n.o)	T	29±7	35±10	<0.01	0.01
	C	31±18	35±24	ns	
Shoulder abduction (s)	T	78±21	90±23	0.02	0.01
	C	71±23	63±16	0.09	

T, training group ($n=15$); C, control group ($n=10$), ns=$P\geqslant 0.2$; n.o, number of.

[27] advocated the combination of aerobic exercise and peripheral muscle training to achieve optimal training effects in patients with CHF. The decrease in ergometer performance and muscle function tests in our control group may be explained as a consequence of normal disease progression in elderly patients and/or a random error in a small study population.

4.4. Quality of life

In our study we observed a significant improvement in the total score and in the physical dimension of LHFQ. According to the LHFQ, which is a disease specific instrument, our patient's physical function improved. On the contrary, Owen [23] could not show

Table 4
The effect on disease specific quality of life after training in warm water

LHFQ		Before	After	*P*-value within the group	*P*-value vs. the control group
Total score	T	33.3±15.9	24.5±16.9	0.01	ns
	C	32.7±21.7	27.8±16.8	0.1	
Physical dimension	T	15.0±5.1	10.6±6.4	0.01	ns
	C	16.8±9.8	15.0±8.7	ns	
Emotional dimension	T	6.5±4.1	5.3±5.7	ns	ns
	C	6.0±6.2	5.1±5.0	ns	

LHFQ, Minnesota living with heart failure questionnaire; T, training group ($n=15$); C, control group ($n=10$); ns=$P\geqslant 0.02$.

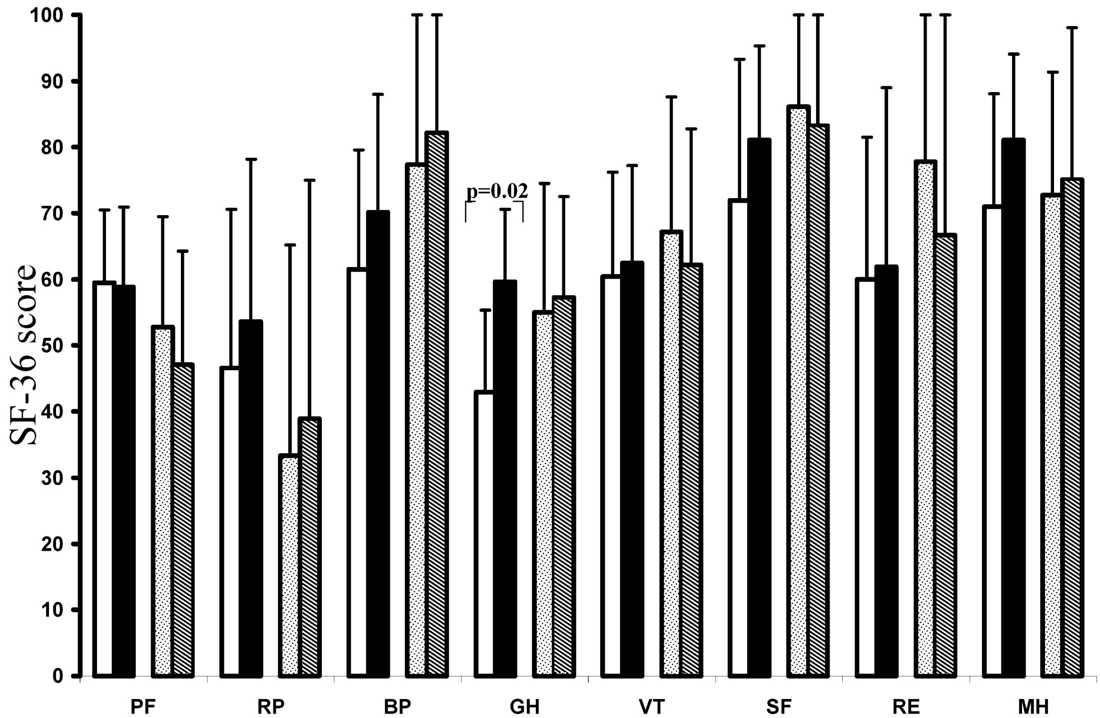

Fig. 4. The results of health related quality of life measured by SF-36. Training group ($n=15$) before (□) and after (■), control group ($n=10$) before (▒) and after (▧). Physical functioning (PF), role limitations due to physical problems (RP), bodily pain (BP), general health (GH), energy/vitality (VT), social functioning (SF), role limitations due to emotional problems (RE), mental health (MH).

any improvement after 5 months of exercise in elderly patients. Others have shown an improvement in SF-36 scores after an exercise programme on land [28]. These conflicting results are probably attributable to small study populations.

4.5. Effects of warm water immersion

It might beneficial for patients with CHF [11] that hot water immersion is also associated with other effects than increased pre-load, i.e. increased stroke volume, cardiac index, ejection fraction, reduced peripheral resistance, increased diuresis, as well as positive effects in neurohormonal secretion. We have preliminary results showing that water immersion at 33–34 °C induces an increase in stroke volume, ejection fraction and cardiac output in elderly patients with CHF [29] However, data on changes of stroke volume and cardiac output during water immersion in healthy older persons are conflicting. Small or absent increments have been reported [30,31]. One report has compared hot water immersion with sauna studying afterload reduction in patients with CHF. Similar effects as we found were recorded in both the healthy control group and the patients with CHF. However, the investigators used a very hot water temperature of 41 °C [11]. A change in renal and neurohormone levels in both healthy subjects and in patients with CHF has also been reported, as a result of water immersion. The plasma concentration of antidiuretic hormone was decreased and diuresis was increased during water immersion to the sternal notch. Likewise, the concentration of renin, angiotensin II, aldosterone and the renal sympathetic outflow were decreased by water immersion [7,9].

In summary, the physiological reactions caused by warm water immersion, resemble those used in modern pharmacological treatment of CHF, except for the increased pre-load. The reduced peripheral resistance in combination with an increased cardiac function and positive effects on the neurohormonal profile might explain that water training in thermo-neutral water seems to be a safe and effective exercise alternative for patients with CHF.

4.6. Study limitations

Clinical muscle endurance testing has not been evaluated for reliability and validity in patients with CHF, but similar tests have been evaluated in healthy people and patients with rheumatic diseases [32]. Due to the limited size of our study, the results could not be generalised for all patients with CHF. Although we randomised the patients and tried to stratify for age, NYHA-class, gender and baseline function.

4.7. Conclusions

Physical training in warm water was well tolerated and seems to be associated with significant improvement in exercise capacity and muscle function in small muscle groups in patients with CHF. Hydrotherapy may be a useful alternative for many elderly patients with CHF and simultaneously other disorders that impede mobility. Furthermore, our elderly patients might be more representative of the general CHF population than many previous studies.

Acknowledgments

This study was supported by Vårdalstiftelsen VD-98, Askers foundation, The Cardiac research found SU/Sahlgrenska, Renee Eanders foundation, and Hjalmar Svenssons foundation, LSR memorial foundation, and Gustav V memorial foundation. We wish to express our deep appreciation to Ms Marita Hedberg, BSc, for assistance with the muscle function test, Ms Bente Grüner Sweälv and Margareta Scharin Täng, BSc, for assistance with echocardiographic measurements.

Appendix A: Clinical muscle endurance test

Unilateral isotonic heel-lift. Touching the wall for balance with the fingertips and the arms elevated to shoulder height, the subjects performed a maximal heel-lift on a 10° tilted wedge, one lift every other second using a metronome (Taktell Piccolo, West Germany). The contra lateral foot was held slightly above the floor. The number of maximal heel-rises was counted for each leg.

Bilateral isometric shoulder abduction. The patients sat comfortably on a stool with their back touching the wall and with a 1-kg weight in each hand. They were asked to elevate both shoulders in 90° abduction and to keep this position as long as possible.

The time the patients could keep the shoulders in 90° angle of abduction was recorded.

Unilateral isotonic shoulder flexion. The patients sat comfortably on a stool with their back touching the wall holding a weight (2 kg for women and 3 kg for men) in the arm, which should be tested. The pace, 20 contractions per minute were held using a metronome. The patient were asked to elevate one shoulder from 0 to 90° flexion as many times as possible.

Appendix B: Exercise programme

The exercise programme performed in warm water for patients with heart failure. Music pace (beats per minute).

Warming up

1. Walking forwards, backwards and to the side with increasing speed (108 b/min).
2. Walking and jogging in combination with arm movements in alternating directions (120 b/min).

Flexibility and endurance training

1. Standing: bilateral arm movements in front of the body ‘drawing a lying eight.’ Arms stretched out at surface in front of the body, shoulder extension and flexion (60 b/min).
2. Arms stretched out at surface in abduction, small fast abduction movements was performed with the arms bilaterally. Elbows and upper arms held towards thorax. Flexion movements with wrist flexors and lower arms and then the opposite in extension (60 b/min).

Aerobic exercise

1. Jumps in place: contra lateral knee towards contra lateral elbow. Body twisting with the arms working under surface in the opposite direction. Jog in place with high knees while swimming breaststrokes with the arms (130 b/min).

Endurance and strength training

1. Eight exercises each performed for 2 min (60 b/min).
   - Sitting: reciprocal knee flexion and extension using a chair with water level to the sternal notch.
   - Standing: unilateral knee extension and flexion with a hip angle of approximately 45°.
   - Standing: unilateral hip flexion and extension (fast small movements).
   - Standing: reciprocal shoulder flexion and extension with paddles.
   - Standing: bilateral shoulder abduction (90°) fast small movements with weights.
   - Standing: reciprocal shoulder flexion and extension with floating weights.
   - Standing: bilateral elbow extension (upper arms held towards thorax) with floating weights.
   - Standing: unilateral heel-lift with water level to waist.

Aerobic exercise:

1. Jumps in place: contra lateral knee towards contra lateral elbow. Bicycling forwards and backwards with the legs in a supine position (120 b/min).
2. Jumps in place: ski jumps with reciprocal arm movements. Walking/Jumping side to side (120 b/min).

Stretching

1. Stretching exercises for leg and arm muscles.

Relaxation:

1. Supine position with floating devises and soft classical music.

References

[1] Recommendations for exercise training in chronic heart failure patients. Eur Heart J 2001;22(2):125–35.

[2] Cowie MR, Mosterd A, Wood DA, et al. The epidemiology of heart failure. Eur Heart J 1997;18(2):208–25.

[3] Piepoli MF, Flather M, Coats AJ. Overview of studies of exercise training in chronic heart failure: the need for a prospective randomized multicentre European trial. Eur Heart J 1998;19(6):830–41.

[4] Hall J, Skevington SM, Maddison PJ, Chapman K. A randomized and controlled trial of hydrotherapy in rheumatoid arthritis. Arthritis Care Res 1996;9(3):206–15.

[5] Meyer K. Exercise training in heart failure: recommendations based on current research. Med Sci Sports Exerc 2001;33(4):525–31.

[6] Hall JBD, O'Hare P. The physiology of immersion. Physiotherapy 1990;76(9):517–21.

[7] Epstein M. Renal effects of head-out water immersion in humans: a 15-year update. Physiol Rev 1992;72(3):563–621.

[8] Perini R, Milesi S, Biancardi L, Pendergast DR, Veicsteinas A. Heart rate variability in exercising humans: effect of water immersion. Eur J Appl Physiol 1998;77(4):326–32.

[9] Gabrielsen A, Bie P, Holstein-Rathlou NH, et al. Neuroendocrine and renal effects of intravascular volume expansion in compensated heart failure. Am J Physiol Regul Integr Comp Physiol 2001;281(2):R459–R467.

[10] Sramek P, Simeckova M, Jansky L, Savlikova J, Vybiral S. Human physiological responses to immersion into water of different temperatures. Eur J Appl Physiol 2000;81(5):436–42.

[11] Tei C, Horikiri Y, Park JC, et al. Acute hemodynamic improvement by thermal vasodilation in congestive heart failure. Circulation 1995;91(10):2582–90.

[12] Berry C, McMurray J. A review of quality-of-life evaluations in patients with congestive heart failure. Pharmacoeconomics 1999;16(3):247–71.

[13] Leidy NK, Rentz AM, Zyczynski TM. Evaluating health-related quality-of-life outcomes in patients with congestive heart failure. A review of recent randomised controlled trials. Pharmacoeconomics 1999;15(1):19–46.

[14] Lipkin DIAS, Crake T, Poole-Wilsson PA. Six minute walk test for assessing exercise capacity in chronic heart failure patients. BMJ 1986;292:653–5.

[15] Borg G. Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in a new cycling strength test. Int J Sports Med 1982;3(3):153–8.

[16] Cider Å, Tygesson H, Hedberg M, Seligman L, Wennerblom B, Sunnerhagen KS. Peripheral muscle training in patients with clinical signs of heart failure. Scand J Rehabil Med 1997;29(2):121–7.

[17] Gaffney FA, Grimby G, Danneskiold-Samsoe B, Halskov O. Adaptation to peripheral muscle training. Scand J Rehabil Med 1981;13(1):11–6.

[18] Ware JE Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30(6):473–83.

[19] Rector TS, Cohn JN. Assessment of patient outcome with the Minnesota Living with Heart Failure questionnaire: reliability and validity during a randomized, double-blind, placebo-controlled trial of pimobendan. Pimobendan Multicenter Research Group. Am Heart J 1992;124(4):1017–25.

[20] Experience from controlled trials of physical training in chronic heart failure. Protocol and patient factors in effectiveness in the improvement in exercise tolerance. European Heart Failure Training Group. Eur Heart J 1998;19(3):466–475.

[21] Belardinelli R, Georgiou D, Cianci G, Purcaro A. Randomized, controlled trial of long-term moderate exercise training in chronic heart failure: effects on functional capacity, quality of life, and clinical outcome. Circulation 1999;99(9):1173–82.

[22] Burns SB, Burns JL. Hydrotherapy. J Altern Complem Med 1997;3(2):105–7.

[23] Owen ACL. Effect of an exercise programme for elderly patients with heart failure. Eur J Heart Failure 2000;(2):65–70.

[24] Tyni-Lenne R, Gordon A, Jensen-Urstad M, Dencker K, Jansson E, Sylven C. Aerobic training involving a minor muscle mass shows greater efficiency than training involving a major muscle mass in chronic heart failure patients. J Card Fail 1999;5(4):300–7.

[25] Tyni-Lenne R, Gordon A, Europe E, Jansson E, Sylven C. Exercise-based rehabilitation improves skeletal muscle capacity, exercise tolerance, and quality of life in both women and men with chronic heart failure. J Card Fail 1998;4(1):9–17.

[26] Willen C, Sunnerhagen KS, Grimby G. Dynamic water exercise in individuals with late poliomyelitis. Arch Phys Med Rehabil 2001;82(1):66–72.

[27] McKelvie R. Exercise training in heart failure: how? Heart Failure Rev 1999;3:263–73.

[28] Quittan M, Sturm B, Wiesinger GF, Pacher R, Fialka-Moser V. Quality of life in patients with chronic heart failure: a randomized controlled trial of changes induced by a regular exercise program. Scand J Rehabil Med 1999;31(4):223–8.

[29] Gruner SB, Sharin TM, Cider Å, Andersson B. Is it safe to exercise in water for patients with chronic heart failure? (Abstract). Euroecho 2000.

[30] Claybaugh JPD, Davis J, Akiba C, Pazik M, Hong S. Fluid conservation in athletes: responses to water intake, supine posture, and immersion. J Appl Physiol 1986;61:7–15.

[31] Derion T, Guy HJB, Tsukimoto K. Ventilation perfusion relationships in the lung during head-out of water immersion. J Appl Physiol 1992;72:64–72.

[32] Mannerkorpi K, Svantesson U, Carlsson J, Ekdahl C. Tests of functional limitations in fibromyalgia syndrome: a reliability study. Arthritis Care Res 1999;12(3):193–9.