Cardiac rehabilitation: applying exercise physiology in clinical practice

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Abstract In this paper new insights into the beneficial effects of physical training for patients with coronary artery disease are reviewed. Endurance training as part of a comprehensive cardiac rehabilitation programme in combination with strength training, smoking cessation and lipid management may slow down and in some cases reverse the progress of coronary atherosclerosis. Thus, exercise training remains an invaluable tool in the hands of the clinical cardiologist dealing with chronic coronary care.

Key words Cardiac rehabilitation · Exercise physiology · Ischaemic heart disease · Physical training

Introduction

Cardiac rehabilitation has been defined as, “The sum of interventions required to ensure the best possible physical, psychological and social conditions so that patients with chronic or post-acute cardiac disease may, by their own efforts, preserve or resume their proper place in society.” (Tavazzi et al. 1992). There are several detailed guidelines on the provision of comprehensive cardiac rehabilitation (Tavazzi et al. 1992; Wenger et al. 1999). Exercise training remains the cornerstone of these programmes, in which physical training, smoking cessation, dietary intervention, psychosocial support and stress management are combined, aiming at a lasting cardio-protective change in lifestyle as stated in a recent review (Gohlke and Gohlke-Bärwolf 1998).

Meta-analysis has shown that cardiac rehabilitation reduces cardiac mortality by up to 25% (O’Connor et al. 1989; Oldridge et al. 1988) and long-term follow-up has confirmed the protective effect of the comprehensive care against recurrent cardiac events (Hedbäck et al. 1993; Hämäläinen et al. 1989). Yet, the access to cardiac rehabilitation varies widely; in several countries only a minority of the population in need of this service is enrolled in multidimensional programmes. Women, elderly and socially deprived patients are often excluded (Evenson et al. 1998; Melville et al. 1999). Even the organization of programmes shows wide variations, indicating a demand for a clearer logistic direction including a consensus on quality assurance (Thompson et al. 1997).

Over the past decade early intervention with thrombolysis and dilatation techniques in patients with acute coronary syndromes has attracted much attention, whereas secondary prevention against coronary artery disease (CAD) and behavioural changes have not always been a priority for the clinical cardiologist. Recently the guidelines of the Second Joint Task Force of European and other Societies on Coronary Prevention contributed to renewed interest in this field (Second Joint Task Force of European and other Societies on Coronary Prevention 1998). These guidelines include recommendations for physical activity.

There are several reports in the recent literature on the novel beneficial effects of exercise training for patients with CAD.

Therefore, the aim of this review is to highlight the role of exercise training in comprehensive cardiac rehabilitation with the main emphasis on recent publications. This review is restricted to exercise training, its role in comprehensive programmes and health-economic aspects. For the remaining components of cardiac rehabilitation, i.e. dietary counselling, smoking cessation, and other lifestyle changes, we refer to previous reviews (Gohlke and Gohlke-Bärwolf C 1998; Wenger et al. 1999).
Exercise training programmes

Physical training is usually practised as part of an outpatient-based multidimensional rehabilitation programme. Patients who have had myocardial infarction (MI), coronary artery bypass grafting (CABG) and coronary angioplasty (PTCA) start, 2–6 weeks after discharge from hospital, endurance training sessions at a sub maximal level. Group training is available for 45–60 min twice/thrice weekly for three months. Patients are encouraged to increase their leisure time physical activity by walking, cycling, swimming, etc. In Central and Eastern Europe a considerable proportion of the cardiac population with cardiac disease is offered exercise training in specialized residential centres. After completing the programme long-term physical training is supported by heart-patient foundations, coronary clubs or other voluntary organizations. Encouragement from the cardiologist or the patient’s general practitioner is helpful in maintaining a physically active lifestyle, as regular exercise may attenuate the progress of coronary atherosclerosis; endurance exercise at the level of more than 2000 kcal per week is needed (Hamprecht et al. 1993; Niebauer et al. 1997; Schuler and Hamprecht 1996).

Earlier studies have shown that exercise training contributes to an improvement in cardiorespiratory fitness, with a lower heart rate and blood pressure at comparable workloads. It improves peripheral adaptation, high-density and low-density lipoprotein (HDL/LDL) cholesterol balance and affects the threshold for angina. Beneficial effects on fibrinolysis, carbohydrate metabolism, blood viscosity, weight reduction and mental health have been reported.

New insights into the effects of physical training

Exercise training affects the production of free radicals: Leaf et al. (1999) compared lipid peroxidation (i.e. expired ethane, pentane and plasma malondialdehyde) between a group of ten cardiac patients participating in exercise training and ten non-exercising patients. Physical training increased the work capacity in the training group without a concomitant increase of markers of free-radical production, indicating that more intense physical work could be performed with less oxidative stress (Leaf et al. 1999). Deskur et al. (1998) compared hydrogen peroxide levels during bicycle ergometry before and after a 3-week endurance training programme. At the initial test hydrogen peroxide levels increased by 27% whereas no increase was observed at the post-training test, indicating a beneficial effect of the programme on the generation of free radicals (Deskur et al. 1998). From the same programme Dylewicz and co-workers (1999) reported a reduction of insulin resistance in post-MI patients with hyperinsulinemia. Insulin blood levels fell from 23.9 (4.4) μIU/ml to 15.0 (1.9) μIU/ml after training; insulin binding increased by 26% (Dylewicz et al. 1999).

Hyperhomocysteinemia is a significant risk factor in patients with normal lipid levels. Exercise training reduces homocysteine levels by 12%, which may lead to 20–30% reductions in overall CAD risk (Ali et al. 1998).

Paramo et al. (1998) studied the effect on fibrinolysis of a 9-month training programme for patients after a first MI. There was a marked decrease in functional PAI-1, indicating improved fibrinolysis both at 3 months and at the end of the programme.

Nitric oxide (NO) may be a major adaptive mechanism by which chronic aerobic training affects the cardiovascular system. This was shown by Rodriguez-Plaza et al. (1997), who investigated the urinary excretion of NO metabolites in four groups: 14 highly trained marathon runners before and after a marathon race, 11 well trained runners before and after a 15-km run, 12 sedentary individuals and 13 CAD patients before and after a 6-km walk. The urinary excretion of NO metabolites was 10.10 mmol/g creatinine, 5.60 mmol/g, 1.59 mmol/g and 0.35 mmol/g in the four groups. After a 12-week cardiac rehabilitation programme the urinary excretion increased by 157% in the CAD group. This increase was correlated with the increase in exercise capacity (Rodriguez-Plaza et al. 1997).

Patients with CAD and signs of myocardial ischaemia at ergometer testing and radionuclide imaging did not show physiological adaptations at a submaximal work level after 6 months of exercise training, in spite of an improvement in their maximal work capacity. The threshold for ischaemia did not increase either (Digenio et al. 1999). However Linxue et al. (1999) reported that myocardial perfusion increased significantly after a long-term (>1 year) training programme. In 20 of the 35 training patients showed improvement in perfusion during stress 201 TI scintigraphy as compared to 3 of the 23 patients in the control group (Linxue et al. 1999).

Severe coronary disease seems to limit improvement, as shown by Klaiman et al. (1997). After a programme lasting 6–9 months, CAD patients with one- or two-vessel disease and patients with impaired left ventricular function had a significantly increased ventilatory anaerobic threshold, whereas patients with three-vessel disease did not.

The mode of physical training does play a role in the outcome assessment of the programme: when comparing a 6-week programme dominated by cycling with a programme containing both cycling and walking/jogging, Nieuwland et al. (1998) reported significant differences in the increase of peak oxygen consumption ($\dot{V}O_2$) at cycle ergometer and treadmill testing (Nieuwland et al. 1998).

Comprehensive cardiac rehabilitation may protect against sudden death (Beniamini et al. 1997) possibly through the beneficial effect of physical training (Hull et al. 1995). The mechanism for this protective effect remains uncertain, but changes in sympathetic balance
may offer an explanation. Malfatto et al. (1998) divided 53 patients after acute MI in three groups: group 1 participated in physical training without concomitant use of beta blockers, group 2 combined physical training and beta blocker therapy whereas group 3 used a beta blocker but did not participate in the training programme. The indices of heart rate variability (HRV) showed no change in group 3 over time, but groups 1 and 2 had comparable and significant increased parasympathetic tone. The authors concluded that the effects of training and beta blocker therapy are not redundant; their combination accelerates the recovery of a normal autonomic profile after MI. Identical results relating to HRV, independent of the presence of systemic hypertension, were reported by Bryniarski et al. (1997): all HRV parameters improved after 4 weeks of early post-discharge exercise training. Hypertensive and normotensive MI patients showed similar results. Among patients with chronic heart failure, a comparable outcome of physical training was demonstrated as physical training affected the circadian pattern of HRV (Adam-opoulos et al. 1995). The effect of training on the long-term prognosis of patients with congestive heart failure remains unclear, in spite of the well documented beneficial effects on exercise tolerance, anaerobic threshold, oxidative capacity, autonomic balance and on changes in skeletal muscle ultrastructure.

The role of resistance training

In cardiac rehabilitation programmes, physical training has been undertaken as aerobic endurance exercise, mainly cycling, walking, running and swimming. Many patients will have to return to a work environment where static labour is required. Therefore, strength training is being included in an increasing number of programmes as an addition to endurance training.

The major aim is to increase dynamic muscle strength, which may lead to an improvement in peak exercise performance, submaximal endurance and to reduced ratings of perceived leg effort (McCarty 1998). This is highly relevant for patients returning to physically demanding labour, but also for elderly patients and patients with congestive heart failure or after transplantation, whose activities of daily living must be enhanced.

Stewart et al. (1998) showed that weight training can be started safely 4 weeks after MI provided the patients are free from coronary ischaemia, complex arrhythmia or major anterior Q-wave MI. The combination of weight and cycle training results in greater arm and leg strength, and also an increase in \( V_{\text{O}_2\text{max}} \) and cycle time.

There is no consensus on the optimal workload for circuit weight training: protocols of varied intensity [40–60% of one-repetition maximum load (1-RM)] are safe for cardiac patients (DeGroot et al. 1998).

Adams et al. (1999) offered 8 weeks of weight training twice weekly to patients with three different levels of ejection fraction [23.6 (7.8), 40 (4.6), 58 (7.7)%], starting at 60% of 1-RM and progressing to 80% of 1-RM. All patients made significant gains in muscular strength and no adverse events were observed (Adams et al. 1999).

Beniamini et al. (1998) compared adding strength training to conventional cardiac rehabilitation with the addition of flexibility training. Strength training resulted in an increase in muscular strength, local muscle endurance and in treadmill time, as well as a loss of body fat when compared to flexibility training (Beniamini et al. 1998). Increases in strength correlate with improvements in quality-of-life parameters, i.e. self-efficacy, mood and well-being scores (Beniamini et al. 1997).

Thus, there is strong support in the literature for the value of adding high-intensity strength training to the exercise training protocols of cardiac rehabilitation.

Effect on dyslipidaemia and being overweight

The anorectic effect of physical training and increased caloric expenditure may reduce excessive body mass. Is physical training without dietary restriction sufficient to reduce excess body mass? Mertens et al. (1998) studied this question in moderately overweight patients. A 12-month programme of daily walking for 40 min resulted in an average weight loss of 4.5 kg and a 7% decrease of body fat content. Cardioprotective changes in the lipid profile were observed. The combination of a low-fat diet and physical training is commonly used in comprehensive programmes. This combination may attenuate the course of coronary atherosclerosis, as recently shown by Niebauer et al. (1997).

Combined programmes are more effective in the management of hyperlipidaemia than standard lipid counselling. Verges et al. (1998) compared the outcome of hypolipidemic treatment (referral to a dietician and a lipidologist) as part of cardiac rehabilitation with a control group of patients only seen by a dietician and a lipidologist. In the study group a significantly greater reduction of total cholesterol (23 versus 13%), LDL cholesterol (28 versus 12%), the LDL/HDL ratio (34 versus 13%) and triglycerides (33 versus 21%) was seen, whereas there was no difference in the use of hypolipidemic treatment (Verges et al. 1998). Similar findings were reported by Ades et al. (1999), who showed that the systematic lipid review and physical training in a comprehensive rehabilitation programme resulted in a threefold increase of pharmacological modifications and lower LDL cholesterol values among the participants compared to patients receiving standard care.

Exercise training and female and elderly CAD patients

There is convincing scientific evidence of the beneficial effect of physical training for women, i.e. improvement of risk factors and functional capacity (Limacher 1999). However, women tend to be enrolled in rehabilitation
programmes less often. Psychosocial variables play important but different roles in the convalescence of women and men. Thus, gender-specific tailoring of cardiac rehabilitation may render them more amenable to female CAD patients (Con et al. 1998).

Moore et al. (1998) studied exercise patterns in a group of 40 post-MI or post-CABG women for 3 months after completion of a phase II exercise programme. Although 83% had started exercising almost one-third had stopped within a month and at the end of the study only half of the women were still as physically active as recommended. The authors assume that, after acute cardiac events, women are exercising well below the recommended guidelines.

Yet the physiological benefits of a 12-month exercise programme are evident among female cardiac patients and do not differ between the fourth, fifth and sixth decades of life. In all three decades lower resting heart rates and higher peak \( \dot{V}O_2 \) could be demonstrated in a population of 330 women (Hamm et al. 1999).

The majority of CAD patients are senior citizens; several surveys have shown that the elderly often are excluded from exercise training in spite of the potential value of reconditioning. Ståhle et al. (1999) reported the outcome of a 1-year controlled follow-up of elderly patients participating in a 3-month group training programme. Significant effects on physical fitness and self-reported health-related quality of life were found at 3 months but there was a tendency to lose part of the initial results at the 1-year follow-up.

The maintenance of the ability to perform activities of daily life should be an important goal of exercise training. A combination of resistive and aerobic training may be a relevant modality: Fragnoli-Munn et al. (1998) offered 12 weeks of combined training to a group of 45 patients shortly after MI. Nineteen patients were elderly. The strength of both the younger and the older population improved similarly. Within the older patient group men were significantly stronger than women and men tended to improve their strength to a greater degree (leg strength 66 versus 29%, bench press 29 versus 10%).

New types of physical training are gaining popularity among the elderly. Among these methods, Tai Chi has reached large groups even outside the Chinese sphere. Lan et al. (1999) included 20 post-CABG men after phase-II rehabilitation in a 1-year Tai Chi programme, during which the patients exercised at 48–57% of their maximum heart rate. The control group was recommended to continue home-based exercise with similar intensity as in phase-II rehabilitation. The Tai Chi group showed higher peak \( \dot{V}O_2 \) and peak workload after 1 year, whereas the control group showed a slight decrease (Lan et al. 1999). This type of group training with little risk of orthopedic injuries could be an attractive option for elderly.

Recently the role of physical exercise for cardiac transplant patients was investigated in a group of 27 patients. After a 6-month cardiac rehabilitation pro-

gramme the training group had increased their workload (49 versus 18%) and peak \( \dot{V}O_2 \) (59 versus 18%) to a significantly greater extent than the control group (Kobashigawa et al. 1999).

Cost-effectiveness

The cost-effectiveness of comprehensive cardiac rehabilitation has been convincingly demonstrated in several studies (Ades et al. 1997; Levin et al. 1991; Oldridge 1998; Oldridge et al. 1993). Fewer cardiac events, fewer hospital admissions and a better rate of return to work outweigh the cost of these programmes. Cost-effectiveness can be estimated in total costs per year of life saved (YLS). Ades et al. (1997) calculated this cost to 4950 $/YLS at 1995 values. In comparison with other post-MI methods of treatment, cardiac rehabilitation is considered to be more cost-effective than thrombolytic therapy, CABG and cholesterol-lowering drugs. Only smoking cessation programmes are more cost-effective.

Discussion

At the hospital of Epidaurus in Ancient Greece, sports were an essential part of the medical treatment. Patients were encouraged both to participate in physical exercise and to enjoy watching sports games. This classical example has, in many hospitals, been reduced to access to a television set with a sports channel in spite of the abundant documentation of the beneficial metabolic, circulatory and mental effects of physical training. Few modern cardiologists have included exercise programmes in their arsenal of coronary intervention programmes and drug treatment. There may be different explanations for this lack of interest. During medical university studies and post-graduate training, there is little room for education in the clinical application of exercise physiology. This lack of knowledge may contribute to the limited clinical use of physical training. Patients are referred to physiotherapists or rehabilitation centres, but the professional communication between the clinician and the referral centre can be improved. Family doctors have little time for the follow-up of lifestyle changes, and the patient’s physical activity is not a high priority.

If exercise training is to be upgraded as a cornerstone in the treatment of CAD patients, clinicians will wish to know more about different types of training, specific indications, programme length and content, outcome measurements and long-term maintenance of physical activity. A consensus among exercise physiologists and cardiologists is needed on the clinical application of training programmes. Before consensus can be reached further research is needed both in the exercise laboratory and in the clinical setting. What is the minimal level of physical training for cardioprotection and for regression
of coronary atherosclerosis? What are the effective inter-
teractions of the different components of cardiac rehab-
ilitation? Can patients with mild to moderate ischaemia benefit from training programmes or is revascularization needed before entering the programme? What is the role of early high-intensity training in residential specialized centres? Is there a need for special training protocols for female CAD patients and what is the most cost-effective model for the large group of elderly patients? Is there an optimal training model for patients with heart failure and should patients with severe heart failure (NYHA gr. IV) be offered physical training at all?

Many important questions remain to be answered in order to clarify the role of applied exercise physiology. Therefore, exercise physiologists and clinicians face a rewarding challenge. In light of this, the Working Group on Cardiac Rehabilitation and Exercise Physiology of the European Society of Cardiology may offer a forum for scientific co-operation and lead the way to a contemporary Epidauros.

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