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Review

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Importance of characteristics and modalities of physical activity and exercise in the management of cardiovascular health in individuals with cardiovascular disease (Part III)

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Abstract

The beneficial effect of exercise training and exercise-based cardiac rehabilitation on symptom-free exercise capacity, cardiovascular and skeletal muscle function, quality of life, general healthy lifestyle, and reduction of depressive symptoms and psychosocial stress is nowadays well recognized. However, it remains largely obscure, which characteristics of physical activity (PA) and exercise training frequency, intensity, time (duration), type (mode), and volume (dose: intensity × duration) of exercise – are the most effective. The present paper, therefore, will deal with these exercise characteristics in the management of individuals with cardiovascular disease, i.e. coronary artery disease and chronic heart failure patients, but also in patients with congenital or valvular heart disease. Based on the current literature, and if sufficient evidence is available, recommendations from the European Association on Cardiovascular Prevention and Rehabilitation are formulated regarding frequency, intensity, time and type of PA, and safety aspects during exercise in patients with cardiovascular disease. This paper is the third in a series of three papers, all devoted to the same theme: the importance of the exercise characteristics in the management of cardiovascular health. Part I is directed to the general population and Part II to individuals with cardiovascular risk factors. In general, PA recommendations and exercise training programmes for patients with coronary artery disease or chronic heart failure need to be tailored to the individual's exercise capacity and risk profile, with the aim to reach and maintain the individually highest fitness level possible and to perform endurance exercise training 30–60 min daily (3–5 days per week) in combination with resistance training 2–3 times a week. Because of the frequently reported dose–response relationship between training effect and exercise intensity, one should seek sufficiently high training intensities, although more scientific evidence on effect sizes and safety is warranted. At present, there is insufficient data to give more specific recommendations on type, dosage, and intensity of exercise in some other cardiovascular diseases, such as congenital heart disease, valve disease, cardiomyopathies, channelopathies, and patients with implanted devices.

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Introduction

Cardiovascular disease (CVD) is still the leading cause of death in the industrialized world[1] and is one of the most common causes of long-term disability. Accumulating evidence over the last 50 years indicates that exercise may postpone or counteract, at least partially, the debilitating consequences of CVD and prevent complications provoked by the inactive state. It has been demonstrated in coronary artery disease (CAD) patients that aerobic fitness (exercise capacity) is closely related to long-term survival.[2–4] Comparing patients with a peak exercise capacity below 4.3 metabolic equivalents (METS) (<15 ml O_2 per kg per min) with patients reaching 4.3–6.3 or >6.3 METS (>22 ml O_2 per kg per min) respectively, hazard ratios for total mortality declined from 1.0 to 0.66 and 0.45.[5] Furthermore, the beneficial effect of exercise training and exercise-based cardiac rehabilitation in CAD patients has been shown with respect to symptom-free exercise capacity, quality of life, general healthy lifestyle, and reduction of depressive symptoms and psychosocial stress. Studies included patients of either sex, older patients as well as patients after elective percutaneous coronary intervention (PCI), coronary artery bypass grafting, and acute myocardial infarction (AMI).[3,6–38] In CAD patients with stable angina pectoris, treatment including medication and regular exercise training can be regarded to be equivalent or even superior to medication and elective interventional strategies with respect to exercise capacity, myocardial perfusion, and clinical events.[39–41] The mechanisms responsible for the positive prognostic effect of exercise training include reduction of major cardiovascular risk factors,[31] improvement of endothelial function and inflammatory status by a variety of mechanisms,[42–55] improvement of diastolic function,[56] reversal of left ventricular remodelling after AMI,[57] and potentially an improved electrical stability of the diseased heart.[58–61]

More and more scientific evidence on the beneficial effect of physical exercise also has been accumulated in patients with chronic heart failure (CHF). Moderate regular physical activity (PA) and exercise training programmes, tailored to the individual's exercise capacity, have been shown to be safe and effective in improving exercise capacity and quality of life and may also improve life expectancy in heart failure patients.[62–66] So far, mainly the effect of aerobic endurance training has been evaluated, supporting a structured exercise programme to be part of the routine management of patients with CHF. The mechanisms involved in the benefit of exercise training are similar to that observed in CAD patients, including beneficial effects on major cardiovascular risk factors, autonomic control restoration, and improvements of lung and skeletal muscle function, left ventricular systolic and diastolic function, and endothelial function.[67]

Although the above-mentioned studies indicate the great importance of PA and exercise training in the treatment of both CAD and CHF patients, it remains largely obscure, which characteristics of PA or exercise training – frequency, intensity, time (duration), type (mode) (frequency, intensity, time, type – FITT), and volume (dose: intensity×duration) of exercise – are the most efficient at achieving the desired effect. The present paper, therefore, will review the impact of these exercise characteristics in the management of individuals with CVD, i.e. CAD and CHF patients, but also in patients with congenital or valvular heart disease. This paper is the third in a series of papers, all devoted to the same theme: the importance of the exercise characteristics. Part I[68] is directed to the general population and Part II[69] to individuals with cardiovascular risk factors. For a more in-depth account of the characteristics of PA and exercise plus further detail of the relevant physiology, we would refer the reader to these papers.[68,69]

The guidance offered in this series of papers is aimed at medical doctors, health practitioners, kinesiologists, physiotherapists, and exercise physiologists, but also at politicians, public-health policy makers, and the individual members of the public.

Characteristics of PA and exercise training in CAD

Modes of exercise training in chronic stable CAD

Before recommendations are made, there are several aspects that require consideration. There is the question about which *treatment targets and outcomes* have been considered in the different studies, i.e. secondary prevention, change in exercise tolerance, reduction of risk profile, increased health-related quality of life and reduction of healthcare cost. It is also well documented that the positive physiological and clinical effects of exercise training can only be maintained if training is performed *lifelong*, while the benefit disappears after only 1 month of detraining.[43,53,70–73] The little data available suggests that *adherence* to a prescribed PA intervention is only 65% at 6 months after implementation, which is similar to the adherence on medication.[74] There exists a large variety of factors that may influence the individual adherence to long-term therapies including rehabilitation programmes.[75,76] Practicability and enjoyment may be regarded of special importance for a long-term maintenance of exercise training.[76–80] *Individually tailored physical exercise* therefore includes baseline assessment of a patient's fitness, the motivation to change lifestyle habits ('be active!'), the intensity of the exercise prescribed to reach the level of the target set, and finally a structured follow up, i.e. 'exercise prescription'.[74] Long-term exercise programmes following structured rehabilitation programmes also may support adherence to PA.[8,25,81,82] Regarding the *setting* used for exercise training, the optimal location for carrying out exercise training in CAD patients is not yet clarified. In terms of health-related quality of life, adherence and healthcare cost in low-risk patients after myocardial infarction or revascularization, home-based exercise training and education appears to be equally effective as centre-based rehabilitation.[17,83–85] However, this may not be true in patients at moderate or high risk.[86] Therefore, well-randomized and controlled studies based on well-specified outcome measures, including exact measurements of exercise capacity, are needed.

Aerobic endurance training. The beneficial clinical effects of regularly performed aerobic endurance training in stable CAD patients are scientifically well established. Thus aerobic endurance training represents the basis of any exercise prescription in these patients.

Modes of endurance training. Walking is especially suitable at the beginning of aerobic exercise training in previously untrained patients.[87–91] In these patients walking is likely to represent an aerobic exercise of relative moderate intensity. It also may be suited for older patients and patients with low fitness levels.[92,93] The beneficial effect of brisk walking in terms of CAD risk reduction is well documented,[94] and in men who underwent an exercise rehabilitation programme, improvement in walking distance was a strong and independent predictor of favourable prognosis.[95] With respect to fitness, the beneficial effect is proportional to training intensity and it increases with increasing the walking velocity.[96,97] Nordic walking (fitness walking using specially designed poles) includes more muscle areas resulting in increased oxygen uptake and energy expenditure. Especially older patients may profit from the increased security using poles.[98,99]

Running/jogging is confined to patients with higher cardiovascular fitness levels, and – due to the high training intensity – represents the most effective form of dynamic exercise to increase fitness and decrease cardiovascular risk.[90,91,94]

Bicycle exercise training has the advantage that training intensity and external conditions can be easily adjusted to cater for a broad range of fitness levels. Monitor display and computerized – controlled exercise training – may help patients at risk and/or in patients with low self-confidence and high anxiety.

Other types of exercise, i.e. rowing, dancing, cross-country skiing, hiking, or swimming, have also been used successfully but require extra vigilance to ensure the intensity is within the aerobic range and compatible with the individual patient's fitness level.

Continuous vs. interval training. The bulk of evidence with respect to efficacy and safety has been gained from the continuous form of aerobic exercise training lasting 10–30 minutes.[100] However, with respect to reverse remodelling and improvement of myocardial function, high-intensity interval training was superior to moderate continuous exercise in a small study enrolling 27 patients with severely depressed left ventricular systolic function following myocardial infarction.[57] In CAD patients, interval training has been shown to improve cardiovascular fitness, endothelial function, and left ventricular function even to a greater extent than conventional moderate-intensity continuous training.[101] In patients undergoing PCI, high-intensity interval training was associated with a reduction of late lumen loss in stented coronary segments, an improvement of endothelial function, and an attenuation of inflammation.[102] Interval training therefore appears to be a promising form of exercise in CAD patients, but additional randomized and well-controlled studies have to be performed to determine optimal training protocols.

Training intensity. Improvement of exercise performance during training programmes is positively associated with the intensity and frequency of exercise training.[24] Two studies even indicated that to stop progression of CAD a minimum of 1600 kcal per week of leisure-time PA appears to be necessary, whereas expenditure of 2200 kcal per week may induce regression.[103,104] High-intensity aerobic treadmill exercise (80–90% of peak oxygen uptake, VO_{2peak}, defined as the highest VO_2, averaged over 20–30 s, achieved at resumed maximal effort during an incremental exercise test)[105] for 10 weeks improved early diastolic relaxation in patients with stable CAD.[56] High-intensity training also improved heart rate variability in patients following PCI.[102] In contrast, a mild exercise training over 10 weeks (three supervised training sessions per week of 60 minutes each and with a training intensity up to 50% of VO_{2peak}) failed to improve endothelium-dependent or -independent vasomotor function in forearm resistance vessels.[106] Most studies evaluated the effect of continuous training with an intensity of 40–80% of VO_{2peak} resulting in an effective increase of exercise capacity by 11–36%.[24,27,107,108]

Duration and frequency of training sessions. In CAD patients, 40 minutes of exercise training at 65% of peak heart rate 3 days a week is at least as effective for improving body anthropometrics, blood plasma lipid profile, and exercise capacity as 60-minute sessions at a comparable intensity.[109] However, after 18 months of follow up, the adherence was low in both groups (27% for the total population) emphasizing the basic problem to maintain patients adherence.[109] In CAD patients treated with statins, high-frequency and long-duration exercise training (daily 6×15 minutes ergometer training at submaximal intensity in addition to a 1 hour per week group exercise session) resulted in a decreased expression of atherogenic adhesion molecules. The effect was sadly blunted by a maintenance exercise programme with only moderate frequency and duration (daily 30-minute home-based ergometer training and 1 hour per week group exercise).[49]

In patients with CAD, high-frequency exercise training (10 sessions per week of 2 hours each) was more effective in terms of ventilatory aerobic threshold and quality of life, but VO_{2peak} also improved with low-frequency programmes (two sessions per week of 2 hours each).[110] In CAD patients, high-frequency exercise training also generated a greater beneficial effect in quality of life during a cardiac rehabilitation programme of 6 weeks as compared to low-frequency exercise training. In addition, frequency of training sessions also had an independent positive effect on psychological outcomes. This benefit provided by a high-frequency exercise training programme, however, does not apply to every patient,[111] as higher levels of compliance in low-to-moderate exercise may outweigh the physiological advantages of exercise training from high duration and frequency. Further long-term studies are needed to investigate this issue.

Prescription and implementation of aerobic endurance training. There are two important aspects to be considered when advising people on the appropriate intensity of exercise. Firstly, the absolute training intensity, which simply expresses the energy cost of an activity. For instance the energy cost of light walking, a low-demand activity, is 2–4 METs. However, in a person of 80 years of age with associated comorbidities (e.g. chronic obstructive pulmonary disease), 3 METs may represent 80% of the actually functional capacity of this individual and is therefore considered as an intensive exercise in this individual (relative intensity). Walking – which is a suitable and common activity for many people – may be of different intensity, not only because the patient is walking at different speeds, but also because of different fitness levels of the patients. Golfing has been shown to be a low–intensity sport for the young and fit, a medium-intensity activity for the middle-aged, and a high-intensity aerobic activity for the elderly.[112] Relative training intensity also may vary with external conditions such as ground, climate, and altitude. It is therefore important to consider the absolute and relative nature of activity when prescribing exercise training.

Exercise prescription for CAD patients therefore is based on a thorough clinical evaluation including risk evaluation, echocardiogram, and exercise testing, and should take into account the fitness of the patient, individual preferences, and/or disability status and comorbidity[74] and the environment and external conditions. The individual training intensity is determined as a percentage of symptom-free maximal exercise capacity as measured by the VO_{2peak} and/or by determining the first ventilatory threshold [ventilatory anaerobic threshold (VAT): during exercise, aerobic energy supply alone is not sufficient anymore to cover the needs of muscular work, and thus requires the addition of anaerobic energy production to meet muscular energy demands; from this point, bicarbonate buffering of lactic acid generates excess of CO_2 production, steepening the VCO_2/VO_2 relationship; the VAT corresponds to about 50–60% of VO_{2peak}[105,113]] during cardiopulmonary exercise testing. In clinical practice, maximal work load in watts (Joule per sec) without signs of ischaemia and/or cardiac or respiratory failure and under actual medication may be used for an approximation of exercise capacity. Training intensity is prescribed as percentage of maximal workload and/or percentage of maximal heart rate (training heart rate, THR) achieved during the test. Another option is to determine heart rate reserve (HRR; maximal heart rate minus resting heart rate). For calculation of the THR, HRR is multiplied by 0.5 (low intensity) to 0.9 (high intensity) and then added to the resting heart rate (Karvonen formula). In CAD patients treated with beta-blockers, THR ideally is determined either as percentage of VO_{2peak}[114] or by measuring VAT.[105,113] Training programmes performed at the VAT are shown to be safe and effective in improving exercise capacity.[115] In patients with chronotropic incompetence, or atrial fibrillation and in some patients with pacemakers, heart rate-driven exercise training is not applicable and exercise prescription should be done on the basis of maximal work load. Measuring of VAT may also be helpful, at least, in patients in whom training intensity is difficult to assess. This is supported by the observation that in CAD patients flow-mediated vasodilatation increases up to a training intensity near the VAT, but decreases again at peak exercise.[116]

Learning how to approximate the relative intensity during any given exercise can increase the adherence of the patient to the prescribed training programme. Heart rate monitoring is the most effective approach, if the patient knows his/her maximum and THRs. For long-term training surveillance, the Borg scale (rate of perceived exertion, RPE) may be used in addition to approximate the relative intensity for each individual. However, some limitations have to be recognized: first, perception of exertion individually differs as being influenced by psychological factors such as depression, increased ambition, history of exercise, and group dynamics; second, RPE requires multiple trials before the patient possesses the relevant skills and confidence to use it effectively; and finally, the individual perception of exertion does not necessarily correlate with myocardial function.

Following the simple rule: 'hear your breathing but be able to talk' may also be helpful, as this indicates medium-intensity exercise.[117–120] Prescription of exercise should be evaluated and progressed based on the individual's responses during training. In addition, determination of the heart rate recovery index (heart rate at a standardized workload – heart rate after 2 minutes) is a practical tool to follow up fitness progression (Table 1).

Dynamic resistance training. The two primary concerns with resistance training in cardiac patients are the avoidance of injury (particular local muscle strain) and the potentially uncontrolled elevation of blood pressure, which could increase the risk of adverse cardiovascular events. However, blood pressure increases during exercise may be attenuated by a warming-up period and primarily depends on controllable factors including the magnitude of the isometric component, the load intensity, the amount of muscle mass involved, the number of repetitions, and the load duration.[121] Accordingly, low-to-moderate-intensity and dynamic resistance training is associated with only a moderate increase in blood pressure, comparable to moderate endurance training.[122] Furthermore, left ventricular function remains stable during moderate-intensity resistance training, even in patients with stable CHF.[123]

Resistance training in CAD patients increases muscle strength and endurance[124–126] and positively influences cardiovascular risk factors, metabolism, cardiovascular function, and quality of life without being

Table 1. Implementation of aerobic endurance exercise training in patients with cardiovascular disease

Stage	Aim and intensity	Duration	Frequency
Initial	Low intensity, i.e.: 40–50% VO_{2peak} 60% HR_{max} 40% HRR Below 1st VAT RPE < 11	Starting with 5 minutes (in the exercise phase) and progress up to 10 minutes	Minimum: 3–5 days per week Target: daily
Improvement	Gradually increase the exercise intensity from low to moderate up to target values, depending on exercise tolerance and clinical status 50, 60, 70 (80%) VO_{2peak} 65, 70, 75 HR_{max} 45, 50, 55, 60% HRR 1st to 2nd VAT RPE 12–14	Gradually prolong the exercise training from 10 to 20 (up to 30–45) minutes	Minimum: 3–5 days per week Target: $\geq$ 5 days a week
Maintenance	Long-term stabilization of the exercise intensity and exercise duration achieved during the improvement stage; gradually increase exercise duration and frequency and thereafter intensity	Gradually prolong the exercise training from 20–45 (up to >60) minutes, if tolerated	Target: most days a week

HR, heart rate; HRR, heart rate reserve; RPE, rate of perceived exertion; VAT, ventilatory (an)aerobic threshold.

associated with an increased cardiovascular event risk during exercise.[121] By activation of the skeletal muscle metabolism, insulin sensitivity and peripheral lipolysis are increased.[127–129] Resistance training also supports weight loss, reduction of waist to hip ratio, total body fat, and blood pressure regulation.[130,131] However, whether resistance training is associated with an improvement of prognosis in CAD patients is not known so far.[121,132]

Importantly, increasing the patient's ability to handle dynamic resistance training and increases in muscle mass not only results in an improved muscle strength but also in an improved level of coordination and balance which may increase the adherence, especially of older patients, to aerobic exercise (i.e. less barriers, improved participation[133]).

Modes of resistance training. The appropriate training method depends on each patient's clinical status, cardiac stress tolerance, and comorbidities, as well as what is likely to be continued by the patient during long-term follow up (compliance and adherence). On the basis of available data, all clinically stable patients without exercise-induced ischaemia and/or without clinical signs of exercise-induced heart failure may be included into dynamic resistance training programmes. With regard to the blood pressure response in CAD patients, only dynamic resistance training (in contrast to isometric strength training) should be applied.

Intensity, duration, and frequency of resistance training. Dynamic resistance training should be performed as interval training and single and/or dual limb movements should be applied and adjusted in respect of the patient's physiological response and level of skill.[119] Dynamic resistance training should be individually supervised especially at the beginning of the training, as a correct technique is mandatory. The intensity of the resistance training can be determined by measuring the one repetition maximum (1-RM), and an appropriate prescription should be within the range of 30–50% of 1-RM, as within this range blood pressure elevations are only moderate. Patients with low performance or older patients should start with a 1-RM of <30%.[134] Trained patients may start with a 1-RM of 50%, increasing first the number of repetitions and series and thereafter the intensity up to 60–70%. Higher training intensities may be considered in well-trained patients with good exercise capacity and low cardiac risk who have already completed a 4–6 week resistance exercise training programme. After each set of exercises, adequate recovery pauses of at least 1 minute should be implemented.[119,135] The higher the intensity, the greater the recovery period is required between sets.

In patients starting dynamic resistance training, a frequency of three sessions (training units) per week is preferable to gain the appropriate skills and is also considered most effective at increasing strength. Once trained, and in order to maintain the desired level of strength, patients can reduce to two sessions per week.[136,137] Between each session, there should be 1 day of 'relative rest' from resistance training for the respective muscle groups.

Combination of aerobic endurance and resistance training. In women with CAD, both aerobic endurance training and resistance training are beneficial with respect to physical quality of life and VO_{2peak}. However, within 1 year of follow up, physical quality of life is significantly higher with combined training.[138] A combination of endurance and resistance training (up to 60% of 1-RM), delivered early after AMI in men, is associated with an increase in VO_{2peak} and muscle strength to the same extent as endurance training alone and does not induce negative left ventricular remodelling.[139]

Special aspects of exercise training in CAD patients

Following elective PCI or bypass surgery. In patients after elective coronary stenting, submaximal exercise training based on the Borg scale and starting as early as the next day after the intervention does not increase the incidence of major complications.[140] Exercise training following elective PCI therefore may be started immediately after healing of the punctured vessel.

In patients after coronary bypass surgery, a structured cardiac rehabilitation programme may best provide the specialized supervision required by time course and management of wound healing, thoracic instability within the first 6 week after median thoracotomy, potential postoperative infections, Dressler syndrome, arrhythmias, and impaired ventricular function. Most important is to avoid thoracic shear and pressure stress during the first 6–8 weeks after thoracotomy.[121]

Age, sex, and ethnicity. Age, sex, and ethnic origin do not appear to be major determinants of individual responses to regular PA. Disparities in cardiovascular risk in the USA are primarily related to socioeconomic status and less to race/ethnicity.[141,142]

Older people are less likely to meet general recommendations of leisure-time PA,[108] and in patients with CVD, age appears to be an independent predictor for not attending cardiac rehabilitation programmes.[35,143] This may be explained by associated comorbidities, in that elderly patients more often have multiple comorbidities such as peripheral vascular disease, orthopaedic disease, and arthritis that – in addition to skeletal muscle deconditioning – negatively influence exercise capacity and prognosis.[144] Exercise modification in respect of comorbidity may be required to improve health outcome and maintain adherence.[145]

However, older patients (>65 years of age) also strongly benefit from structured exercise training (including resistance training) with respect to aerobic exercise capacity, attenuation of age-related loss of aerobic fitness, body strength, physical function, heart rate recovery, improvement of cardiovascular risk factors, psychological measures (depression, anxiety, somatization, hostility), quality of life, and participation, and, finally, a reduction of hospitalization.[18,143,146–150] Finally, in patients >65 years, exercise-based rehabilitation has been shown to be associated with lower risks of death and AMI, and this beneficial effect increased with the number of training sessions.[34] Individual exercise modification according the comorbidities leads to an improved health outcome without affecting adherence to the rehabilitation programme.[145] Moreover, there is growing evidence that managing associated comorbidities is associated with a better prognosis.[144]

Women who participate in exercise-based cardiac rehabilitation are older and do have a significantly lower exercise capacity at the beginning of the programme compared to men (woman VO_{2peak} 14.5 ± 3.9 vs. men 19.3 ± 6.1 ml per kg per min, $p < 0.0001$[28]). Although exercise training is similarly effective in women as in men, the proportion of women in clinical studies is low as is the actual participation in exercise-based rehabilitation programmes.[16,23,24,35,151,152]

Women with CAD benefit from both aerobic endurance training and the combination of aerobic endurance and resistance training, although – with respect to a continuous improvement of physical quality of life – the latter may be superior.[7,22,28,133,138,153] Rehabilitation programmes tailored for women may improve attendance and adherence[154] and may be superior in improvement of quality of life, if compared to traditional rehabilitation programmes.[154] Additional research examining the efficacy of gender-specific and gender-sensitive cardiac rehabilitation programmes, however, remains a major task.

Systematic studies on a potential role of ethnicity with respect to implementation and effect of exercise training programmes in CAD patients are rare. Pre-training levels in patients with AMI may vary considerably between the different ethnic groups and thereby influence exercise implementation and maintenance.[108,155] For implementation of exercise training in patients with different ethnicity, some principles may be followed:[156]

- identify and address individual barriers that affect access to and participation in exercise training,
- develop communication strategies that are sensitive to language and information requirements,
- consider cultural or religious values that either promote or hinder behavioural changes

Summary

All clinically stable CAD patients, of either sex and independent of age and ethnicity, should undergo an individually tailored exercise programme. After acute coronary syndromes, bypass surgery, and/or PCI, implementation of exercise programmes should start as early as possible and are best provided within multidisciplinary cardiac rehabilitation programmes that include clinical assessment and follow up of the patients as well as individual PA counselling, i.e. ‘exercise prescription’. The general aim is to reach and maintain the individually highest fitness level possible, at least to maintain an endurance training programme of 30–60 min daily (3–5 days per week) in combination with resistance training 2–3 times a week. A dose–response approach between training frequency and exercise intensity, should seek sufficiently high training intensities. This requires individual tailoring of exercise prescription in accordance with pre-existing risks and limitations. These should include: exercise-induced ischaemia or arrhythmias, cardiac function, clinical status after surgery, limiting comorbidities and extent of disability, baseline fitness levels, individual preferences on exercise modalities, potential psychological, social, and/or cultural barriers, gender, and age.

Characteristics of PA and exercise training in CHF and cardiomyopathies

Modes of exercise training in CHF patients

As in CAD patients, compliance and adherence to the training programme are essential to achieve optimization of the effect. In addition, the beneficial effects are rapidly lost if exercise training is not maintained.[62] The poor adherence to the prescribed training programme was considered the main cause of the lack of benefit in prognosis observed in the HF-ACTION trial, the largest randomized controlled trial conducted till now on exercise training in heart failure.[64] Increasing long-term adherence to exercise training therefore is a major task, and ways to overcome the barriers against exercise implementation in CHF patients should be addressed in future investigations.[67]

Similarly to CAD patients, also the optimal setting still needs to be identified. In low-risk and clinically stable patients, home-based exercise training appears to be as safe and effective as centre-based rehabilitation, although long-term adherence may be uncertain.[64] However, in recently stabilized CHF patients, as well as in patients with comorbidities, a centre-based and supervised setting may be preferred.[157] Further studies are needed to clarify this aspect.

The bulk of the evidence in this section, and, in turn, our recommendations for exercise in heart failure, relates to heart failure patients with low ejection fraction and not those with preserved ejection fraction [e.g. heart failure with preserved ejection fraction (HEPEF) and normal ejection fraction heart failure]. More research is needed to demonstrate the efficacy of exercise in this emerging patient population.

Relative exercise training intensity and training prescription are also general aspects that need to be clarified. In general, the assessment of exercise capacity by maximal or symptom-limited cardiopulmonary testing with metabolic gas exchange is the most appropriate and objective tool to tailor the exercise training programme. It allows clinicians to determine the first and second ventilatory thresholds and VO_{2peak}, and to avoid adverse events by inadequate training stimuli.[105,158]

The Borg scale and/or the THR as assessed during conventional exercise testing also may be used for exercise prescription and for monitoring exercise intensity. However, the method of THR may be inadequate in patients with severely reduced exercise capacity, chronotropic incompetence and intake of negative chronotropic medication, comorbidities with impact on exercise performance, atrial fibrillation, or after heart transplantation.

For testing protocols in CHF patients with a low functional capacity, small increments 5–10 watts per minute on bicycle ergometer or modified Bruce or Naughton protocols are indicated.[67] In clinical practice, the 6-minute walk test has been shown to be feasible for evaluation of functional capacity; however, this test is less well standardized and dependent on the motivation of the patient and the encouragements provided during the test.[159]

Aerobic endurance training

Modes of endurance training. In general, the feasible modes of endurance training are similar in CAD and CHF patients.

Continuous training: Aerobic endurance training (e.g. on a cycle–ergometer or a treadmill) is the most investigated training modality in CHF patients, and therefore is recommended as baseline activity.[63–66] A lifestyle approach by including common activities into daily routine (i.e. walking instead of driving, climbing stairs rather than taking the elevator, engaging in active recreational pursuits, etc.) is also effective and should be recommended.

Alignment of activity modes with individual preferences and interests is most likely to increase patient's adherence for sustained activity.[157] Particular types of training (e.g. dancing, yoga) have been shown to be well accepted and beneficial in terms of functional capacity.[160,161] In a small study including stable patients with preserved exercise capacity ($VO_{2peak} > 15$ ml per min per kg) water gymnastics and swimming also have been shown to be safe.[162] Exercise modes such as running or jogging traditionally are regarded to be contraindicated in CHF as these potentially are very strenuous and often performed without supervision. However, further investigations in asymptomatic CHF patients [New York Heart Association (NYHA) classes I–II] are needed to clarify this point.

Interval training: There is some evidence that interval training may be superior, if compared to continuous training. In a small study,[57] 18 CHF patients were randomized to either high-intensity interval training (4×4 minutes bouts of high-intensity exercise at 90–95% of peak heart rate interrupted by recovery periods of 3 minutes at low intensity plus 5–10 minutes of warming up and cooling down, 2–3 training sessions per week) or continuous training at 70% of peak heart rate for 12–16 weeks. Interval training showed greater improvements in aerobic capacity, endothelial function, and quality of life.[57] A randomized multicentre trial (SMARTEX-HF study)[163] is currently enrolling CHF patients to compare efficacy and safety of high-intensity interval training with continuous exercise training at moderate intensity. This trial is expected to give a more solid basis for recommendations on training modes in future.

Training intensity. The lower and upper limits of aerobic training intensity in CHF patients have not been established yet. Aerobic training intensities as low as 40% of VO_{2peak} ($\approx 25\%$ $VO_{2reserve}$) have been effective in improving physical capacity in CHF patients with significantly reduced pre-training VO_{2peak}.[164,165] An aerobic training intensity corresponding to a value approaching the VAT (i.e. around 50–60% of VO_{2peak}) has been proposed as the safe upper limit.[166] There is increasing evidence, however, that CHF patients also may be trained at intensities close to the second ventilatory threshold [respiratory compensation point (RCP) or critical power: during moderate-to-intense exercise intracellular bicarbonate is no longer sufficient to buffer exercise-induced lactate production and has to be supported by increased ventilation that is in excess to VCO_2 (hyperventilation with respect to CO_2 metabolically produced); the second ventilatory threshold is equivalent to 65–80% of VO_{2peak}, corresponding to the so-called 'critical power', as the upper intensity limit for prolonged aerobic exercise[105,113]] without additional risk.[167–169] Further investigations therefore are needed to determine optimal training intensity.

If an assessment of aerobic metabolism by cardiopulmonary exercise testing is not available, relative effort intensities in the 'moderate' domain have been used: these are expressed as $\%HR_{peak}$ or %HRR, or according to the Borg or RPE scales.[158,170] However, the equivalence of %HRR vs. $\%VO_{2\ reserve}$ has been questioned in CHF patients both on and off beta-blockers.[171,172]

Duration and frequency of training sessions. Aerobic training sessions between 15 and 40 minutes have been shown to be safe and effective, with shorter durations preferred at the beginning of the training programme and in patients with lower exercise capacity, fatigue, and/or recent haemodynamic instability. Session duration should be progressed according to patients' tolerance, trying to reach at least a 30-min session duration.[63–66] In these studies, a minimum of three sessions per week has been found to be beneficial in stable patients in NYHA classes I–III. They underwent 3–5 sessions per week without adverse effects. Even in patients with recent haemodynamic instability starting an individually tailored training programme of three sessions per week has been shown to be safe.

Training frequency usually is kept quite constant, whereas changes in training intensity and duration are routinely used to increase the weekly training stimulus. On the other hand, CHF patients with low exercise-related risk may perform two 30-minute bouts of moderate-intensity training per day spread over 3–5 days per week without additional risk.[64]

Prescription and implementation. Similar to CAD patients, exercise prescription and implementation is based on full clinical assessment, including risk stratification and exercise testing, and the individual training intensity is determined according to a percentage of symptom-free maximal exercise capacity as measured by cardiopulmonary exercise testing (Table 1).

In clinical practice as well as in the HF-ACTION trial,[64] at the beginning of the training period, training intensities close to the lower limit of the moderate-intensity range have been suggested ($\approx$40–50% VO_{2peak}, 50–60% HR_{peak}, 40–55% HRR, and 2.5–3.0 or 11–12 in the Borg and RPE scales, respectively). However, intensities in the low-intensity range (<40% $VO_{2peak)}$ can also be considered in selected patients with significantly reduced exercise tolerance and/or high exercise-related risk.[164]

Dynamic resistance training. As in CAD patients, there is growing evidence that dynamic resistance training may be beneficial in CHF patients. Dynamic resistance training has been shown to improve daily function and quality of life, to counteract loss of skeletal muscle mass and strength, to have anti-inflammatory effects, and to improve of insulin resistance.[121,173–175] The central haemodynamic responses appear to be comparable to aerobic endurance training.[174] However, the scientific basis of this conclusion is uncertain, referring to predominantly small studies with limited design. Furthermore, the heterogeneity of the study interventions, especially with regard to type, intensity, and volume of exercises makes it difficult to give a conclusive summary.[176] Finally, no study with sufficient power has been designed so far to address the safety aspects of dynamic resistance training in CHF patients, although no adverse events have been reported.

Prescription and implementation. On the basis of the available scientific data, in all clinically stable CHF patients dynamic resistance training may be included into the training programme as a supplement to aerobic endurance training (Table 2). Training intensity, frequency, and duration should be tailored to each patient's clinical status, exercise tolerance, and comorbidities. Training intensity should be determined on the basis of the 1-RM, as described for CAD patients. Furthermore, resistance training should be performed as interval training, and single and/or dual limb movements/exercises should be applied and adjusted in respect of the patient's physiological response and level of skill. On the basis of expert opinion, in CHF patients, dynamic resistance training should be medically supervised and guided only by experienced and competent exercise therapists or physiotherapists.

Respiratory muscle training. Respiratory muscle training involves respiratory muscle specific-training devices to improve respiratory muscle function, thereby improving respiratory functional status and reducing the extent of dyspnoea. Respiratory muscle dysfunction predominantly has been observed in patients with advanced CHF.[177,178]

Modes. Respiratory muscle training usually involves inspiratory muscles, and training is performed at a percentage of maximal inspiratory muscle strength (PI_{max}). Strength devices are pressure threshold load trainers. Devices targeting endurance include isocapnic hyperpnoea endurance trainers and incremental inspiratory endurance trainers with a computer-biofeedback.

In CHF patients with low capacity, respiratory endurance training has been shown to improve respiratory muscle function, reduce dyspnoea, and increase

Table 2. Implementation of dynamic strength training in patients with cardiovascular disease

Stage	Aim	Intensity	Repetitions per muscle group	Training frequency
Initial (pre-training)	Implementation of exercise; improvement of self-perception and coordination; learning to correctly perform exercise	<30% 1-RM RPE ≤11	5–10	2–3 training units per week, 1–3 sets each unit
Improvement stage I	Improvement of aerobic endurance and coordination	30–50% 1-RM	10–15	2–3 training units per week; 1–3 sets each unit
Improvement stage II	Increase muscle mass; improvement of coordination	40–60% 1-RM (>60% in selected patients)	10–15	2–3 training units per week; 1–3 sets each unit
Improvement stage III	Increase in muscle strength	60–80% 1-RM (in selected patients in good clinical condition and with heavy physical employment or those returning to sport)	8–10	2–3 training units per week; 1–3 sets each unit

General recommendations: if possible training should include all muscle groups. Training should change between agonist and antagonist muscle groups. Between training of each muscle group, there should be a pause of more than 1 minute; 1-RM, one repetition maximum; RPE, rate of perceived exertion; Information modified according to Bjarnason-Wehrens et al.[121] and Williams et al.[122]

functional capacity (VO_{2peak}) as well as quality of life.[179] Due to conflicting results, the application of strength devices is less established.

In conclusion, the implementation of respiratory muscle training in CHF is based on limited evidence, and further studies are needed in order to establish this training modality.

Prescription and implementation. Respiratory muscle training may be used in CHF patients with low functional capacity.[177] Using inspiratory endurance trainers, an intensity of 60% of sustained PI_{max} with a duration of 20–30 min and a frequency of three times a week for a minimum of 8–10 weeks has been proposed. If a pressure threshold trainer is used, respiratory training is usually started at 30% of PI_{max} and readjusted every 7–10 days up to 60% of PI_{max}. Training duration again should be 20–30 min per day, 3–5 times a week, and for a minimum of 8 weeks.

Special aspects of exercise training in CHF patients

CHF with preserved ejection fraction. Aerobic endurance exercise training improves the diastolic filling pattern in healthy subjects by increasing peak diastolic filling rate during exercise.[180] Exercise training also reduces diastolic dysfunction in patients with dilated cardiomyopathy.[181] However, only a few and small studies have been performed in patients with CHF symptoms but with preserved ejection fraction (HFPEF). A 12 weeks, home-based walking intervention improved quality of life in 23 elderly HFPEF patients.[182] Similarly in 53 elderly HFPEF patients, a supervised training programme of 16 weeks (aerobic endurance, walking, and cycling, three sessions per week) improved exercise capacity and quality of life.[183] Performing a 16-week combined endurance/resistance exercise programme, VO_{2peak} and quality of life was improved in patients with systolic CHF as well as in HFPEF patients.[184] A recent randomized controlled study in 64 patients, aged on average 65 years, revealed improved exercise capacity (+16%) with atrial reverse modelling and improved left ventricular diastolic function.[185]

On the basis of these limited data and the fact that such patients will present at heart failure clinics, individually tailored exercise training can be recommended in HFPEF patients. Large randomized controlled studies are still needed to evaluate clinical outcomes and the effectiveness of various training modalities.

Hereditary cardiomyopathies and sports. Patients with genetically determined cardiomyopathies (i.e. hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, channelopathies) often are young and do engage in regular PA. Systematic clinical studies on the differential effect of exercise training in these populations do not exist. There is experimental evidence of a protective effect of exercise training in hypertrophic cardiomyopathy, but whether this also is relevant in a human setting is unproven.[186] On the other hand, there is circumstantial evidence that exercise, especially if abrupt and/or highly intensive, may increase the likelihood of ventricular tachyarrhythmias, leading to cardiac arrest. Therefore, based on actual pathophysiological knowledge of arrhythmogenic cardiomyopathies and current clinical experience, high-intensity, strenuous, and competitive exercise sessions are not recommended in these patients, and participation in sport activities have to be judged on an individual basis according to the current guidelines.[186]

Implantable cardioverter defibrillator and cardiac resynchronization therapy. In patients with implantable cardioverter defibrillator (ICD) and/or cardiac resynchronization therapy (CRT) devices, exercise training may substantially increase exercise capacity and improve haemodynamic measures and quality of life.[58,187–190] Non-sustained ventricular tachycardia in the presence of an ICD device do not constitute a contraindication to aerobic exercise training.[189] There is a wide clinical concern, however, that exercise sessions, especially if abrupt and/or highly intensive, may be associated with larger proclivity of ICD discharges. On the basis of limited scientific data, expert experience, and some practical considerations, the following recommendations have been made:

- Avoidance of inappropriate ICD shocks are mandatory, and therefore the maximal THR should be at least 10–20 beats below the ICD intervention heart rate.
- Skilled movement patterns and familiarization with exercise regimes and equipment are associated with less anxiety and improved exercise ability in these patients.
- In patients with symptomatic arrhythmias or a history of ICD discharges, exercise modalities, in which a short loss of consciousness is dangerous (i.e. swimming, activities associated with an increased risk of falling) are contraindicated.
- Any activities with pronounced arm-shoulder movements or intense mechanical strain of the ICD pouch are to be avoided, especially <2 months after ICD implantation.
- In CRT patients, tracking rate and rate response during maximal or near maximal effort may need adaptation. In cases where biventricular pacing is lost and patients ‘suddenly’ fall back to a non-resynchronized state with wide QRS complexes, a significant and acute drop in cardiac output may occur. Where this happens the patient should immediately stop the exercise session and have the device and programme reviewed.

Left ventricular assist device. The native heart–left ventricular assist device (LVAD) complex responds physiologically and demonstrates a circulatory reserve with the capability to meet demands of daily activities. Long-term support by LVAD has become possible and patients can now be managed by outpatient clinics. Early initiation of exercise therapy in these patients has been reported to be associated with improvements in exercise capacity. Exercise training also may improve functional status at a later period after LVAD implantation, thereby supporting LVAD as a destination therapy.[192]

Scientific data on content, setting, duration, and safety of exercise training in LVAD patients are rare. Beneficial results have been reported for various training modalities within different settings, but no standard exercise training programme has been set.[193–196] In a single patient study, exercise training was started 3 weeks after LVAD implantation (HeartMate 1000 IP) with daily 20–30 minutes of bicycle training at 50% HRR. Within 6 weeks of training, VO_{2peak} increased by 64%.[194] An interval exercise programme within the low-intensity range (training sessions progressively increasing from 20 to 40 minutes, 3–5 times a week) was also successfully tested.[193]

In summary, supervised exercise training in LVAD patients appears feasible and may be implemented as early as possible to prevent complications related to bed rest and immobilization.[197] However, to safely and successfully perform exercise training, some special needs have to be closely followed.[196]

- Exercise supervisors should be aware on the different mechanisms of the devices to adapt cardiac output. In continuous flow devices, the flow rate may be automatically adapted to the native cardiac cycle. In contrast, in pulsative flow devices, device rate and cardiac output depends on passive filling of the device.
- Exercise programmes that irritate the driveline outlet as well as any shaking movements or strong vibrations strictly have to be avoided.
- LVAD patients are completely dependent on power supply.
- Due to the numerous potential complications, the LVAD patient should closely be monitored for any signs of activity intolerance, exercise-related complications, or LVAD dysfunction.

- Cardiac rehabilitation programmes should not be started before the patient or their carer/advocate are successfully trained to independently handle the device.
- The rehabilitation team should be specialized and trained on the specific assist device before starting rehabilitation. Close communication between heart centre and the rehabilitation team is mandatory.

Heart transplantation. In spite of continuous advances in survival, exercise capacity in cardiac transplant recipients remains 30–40% below normal.[198–200] Several factors contribute to reduced exercise capacity, including reduced heart rate response of the denervated heart, marked deconditioning prior to transplantation, a potential negative effect of chronic steroid therapy, partial persistence of skeletal muscle abnormalities, and an undesired body weight gain following transplantation.[199,200]

Few scientific data support the general clinical experience that exercise training is beneficial and highly desirable in transplant patients. An outpatient exercise training of 10 weeks has been shown to improve VO_{peak} from 16.7 to 20 ml per min per kg.[201] In a small randomized study, a 6-month exercise-based structured cardiac rehabilitation was associated with a significantly greater increase of exercise capacity as compared to the control group (increase in VO_{2peak} 49% vs. 18%).[202] A recent randomized controlled study in long-term heart transplants on the effect of high-intensity exercise training revealed improvements in exercise capacity (+18% in exercise group compared to −5% in controls) and endothelial function (+37% vs. −5%) after 8 weeks of training.[203]

Few randomized studies also evaluated the effect of dynamic resistance training (starting with sets of 15 repetitions at 50% of 1-RM, then gradually increasing intensity by steps of 5–10%). Training frequency was 2 days per week with eight or nine exercises on upper and lower extremities and 1 day per week with lumbar extensor training. This training mode was safe and, despite long-term glucocorticoid therapy, the bone mineral density largely could be restored within 6 months of dynamic resistance training.[204–206] Clearly more research is required to develop evidence-based training modalities for patients after heart transplantation.[207,208]

Based on limited scientific data and a large body of experience the following recommendations may be given:

- Initially, respiratory physiotherapy with active and systematic mobilization of the upper and lower limbs is advised.
- After maximal symptom-limited cardiopulmonary testing, aerobic endurance exercise should be started as soon as possible. This may be during the second or third week after transplantation. At start of exercise training, the training intensity should be <50% of VO_{2peak} and 10% below the VAT and may be guided by the Borg scale (to achieve 12–14 in the 6–20 scale) and/or the 'breathing rule'. Exercise duration should be at least 20–30 minutes per day.
- In stable transplant patients, high-intensity exercise training may be potentially indicated but more data are warranted before definite recommendations can be formulated.

Age and sex. Due to the lower baseline exercise capacity and more common orthopaedic problems, the question raises whether elderly CHF patients require special training modalities. However, a number of clinical studies have applied bicycle ergometer training, treadmill training, and resistance training in patients of different ages without reporting significant problems.[209–211] In a study with 200 CHF patients aged >60 years, a nurse-specialist-coordinated training programme, consisting of aerobic endurance training in combination with high repetition/low resistance training, increased maximal 6-minute walking distance by 16% and reduced unplanned hospital admissions by 10.6% during a follow up of 24 weeks.[212] In the Leipzig Exercise Intervention in CHF and Aging Study (LEICA), both ≤55 years and ≥65 years old CHF patients showed an increase in VO_{2peak} by 26% and 27% respectively after 4 weeks of an intensive aerobic endurance training (four×20 minutes on 5 days per week[213]). Hydrotherapy (three×45 minutes per week) also has been shown to be effective in older CHF patients by increasing VO_{2peak} and 6-minute walking distance.[214]

On the basis of these still-limited scientific data, elderly and old patients with clinically stable CHF should have regular exercise training in most days of the week, including dynamic resistance training. Adaptations of training programmes may be required according to various comorbidities. If exercise adaptation is not feasible to accommodate comorbidities, hydrotherapy may be used as an alternative.

If compared to men, participation rates of women in exercise-based cardiac rehabilitation programmes as well as in clinical studies are still low.[215] Limited physicians and family support, comorbidities, and musculoskeletal disabilities may be some reasons for this finding.[216–218] Low participation rates in structured exercise programmes, however, is a critical observation, as women are functionally more impaired by CHF than their male counterparts and therefore are at a higher risk for disability. Most likely as a result of the lower muscle mass, VO_{2peak} and the 6-minute walk distance were significantly lower in women, if compared to men with similar ventricular function and health status. On the other hand, female CHF patients participating in training programmes show a similar relative improvement in exercise capacity to that of men, and this has been shown to be accompanied by increases of skeletal muscle glycolytic and oxidative enzyme activities and by an improvement in quality of life.[216] It is therefore strongly recommended to include women suffering from CHF in structured exercise-based rehabilitation programmes.

Summary

PA and aerobic endurance exercise training programmes tailored to the individual's exercise tolerance are recommended for all patients with systolic CHF in NYHA classes I–III. The recommendation is less well established for patients with heart failure symptoms with preserved systolic function (HFPEF) but an exercise approach is supported to improve exercise capacity and quality of life.

For aerobic endurance training, effective and safe protocols are well described. The combination with other training modalities, such as resistance and respiratory training, is less well documented, but the actual data are promising.

Individually tailored and medically guided exercise programmes also are recommended for patients after cardiac transplantation and for patients with special devices such as LVAD, ICD, and/or CRT.

Patients with special cardiomyopathies such as hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and channelopathies often are young, and regular PA and low-intensity training programmes should be advised as a part of their healthy lifestyle. Participation in sport activities, however, has to be judged individually and further medical assessment and supervision is strongly advised. High-intensity, strenuous, and competitive sports are contraindicated.

Characteristics of PA and exercise training in patients with heart valve disease

Acute and chronic clinical effects of physical exercise in patients with valvular heart disease have not been systematically studied so far. The actual knowledge of favourable and/or potentially detrimental effects of various kinds of physical exercise therefore mainly refers to pathophysiological considerations and clinical experience. Effects or potential risks of exercise training differ depending on kind and severity of the valvular heart disease. Exercise training therefore has to be individually tailored and thereby may prevent premature detraining and inability of the patients and preserve quality of life.

There are very limited data from several small studies including patients after valve surgery. The patients evaluated were predominantly in good clinical condition and without significant limitation of exercise tolerance. These studies show an improvement of exercise tolerance comparable to CAD patients.[24,219,220] On the basis of actual pathophysiological knowledge and clinical experience, high-intensity, strenuous, and competitive sports, however, are not recommended in these patients, and participation in sport activities have to be judged on an individual basis. For recommendations in participation in leisure sports activities, we refer the reader to a previous EACPR recommendation paper.[220]

Characteristics of PA and exercise training in patients with congenital heart disease

Recommendations for PA, exercise training, and recreational sports for children and adolescents with congenital heart disease (CHD) have been published.[221,222] The recent recommendations for exercise participation from EACPR/European Congenital Heart and Lung Exercise Group/Association for European Paediatric Cardiology[222] for patients with CHD differ not only according to the underlying disease, but also according to the different age groups (e.g. children, adolescents, and adults). For details for patients with common congenital heart defects, the reader is referred to the recommendations.[222] General exercise training recommendations are provided below, but it should be clearly stated that the importance of different exercise characteristics and modalities are not studied yet in CHD patients. The actual knowledge of favourable and/or potentially detrimental effects of various kinds of physical exercise therefore mainly refers to pathophysiological considerations and clinical experience.[221,222]

Even more, in prepubertal children (age <12 years), general advice regarding PA is less based on FITT factors than in adults since the typical activity pattern of young children is intermittent of nature with short bouts of high-intensity exercise interchanged by periods of rest. They have an inborn motivation to be physically active and should be advised to participate in a large variety of activities to develop proper exercise habits, motor coordination, aerobic capacity, muscle strength, mental development, and quality of life. Only severely disabled children withdraw themselves from PA if they do not feel comfortable. Except in very rare arrhythmic diseases, the presence of disability should not be seen as a reason for restricted PA and exercise. In general, children and adolescents with CHD should be advised to comply with public-health recommendations of daily participation in 60 minutes or more of moderate-to-vigorous PA that is developmentally appropriate and enjoyable and involves a variety of activities.[223] Moreover, they are advised to perform less than 2 hours of sedentary activities per day.[223]

In adolescents and adults without deconditioning, a quite high exercise intensity (60–85% of VO_{2max}) will be needed to have a significant improvement in VO_{2peak}.[224] In patients with moderate or severe deconditioning, it is recommended to start at a low intensity (40–50% of VO_{2peak}) and gradually increase to intensity to about 60% of VO_{2peak}.[225] Exercise sessions should be at least 30 minutes, 3–5 times per week. In deconditioned persons, it should start with 10 minutes and be continually increased up to 30–60 minutes. The type of activities could include all activities in which large muscle groups are used. Exercise programme duration of at least 12 weeks is recommended.[226] The exercise should be developmentally appropriate and enjoyable and should include a variety of activities to make the programme as attractive as possible.[227]

In addition, patients are advised to comply with public-health recommendations of daily activity with at least 60 minutes for adolescents and 30 minutes for adults of moderate-to-vigorous PA.[223]

There is no evidence regarding the effects of resistance training in patients with CHD.

Precautions and safety for individuals with established CVD

Part of the preventive strategy of the EACPR is to ensure that the benefits of PA and structured exercise programmes are safely realized also in individuals with established CVD.[228] The risk of adverse cardiovascular events during exercise is about two times higher in patients with underlying CVD compared to apparently healthy individuals.[229] In cardiac rehabilitation programmes, the incidence of complications requiring resuscitation vary from 1/6000 to 1/112,000 person-hours of exercise.[24,229–231] Recently, an incidence of nine events requiring resuscitation in a 21-year period during an ambulatory cardiac rehabilitation programme (1/29,214 patient-hours of exercise) has been reported.[24] Exercise-induced ischaemia during exercise testing (ST-depression ≥ 1 mm) and the intake of anti-arrhythmic drugs were the only predictors of these complications. The incidence of these events in the setting of a sport club for cardiac patients in the same 21-year period was 1/16,533. All these events occurred during the more intense conditioning training (1/13,592), and not during less intense leisure sporting activities, such as walking, volleyball, aquatics, and swimming. In almost all patients ($n = 12$), these events occurred several years after the initial cardiovascular event requiring cardiac rehabilitation.[24]

Individual exercise prescription

To maximize the benefits and minimize the risks of exercise, individually prescribed activity (type, intensity, duration, frequency) for each individual according to his/her underlying cardiac abnormality and the individual cardiorespiratory fitness level (according to a maximal exercise test), must be performed.[228] The intended level of PA as well the training goals have to be taken into consideration.

Criteria for such risk stratification of patients with underlying CAD and subsequent recommendations for participation in regular leisure-time PA and/or sports have been published previously by the EACPR.[232] According to these recommendations, patients with established CAD, with a low probability of cardiac events according to risk stratification, should be recommended non-supervised leisure-time PA of mainly aerobic type, at an intensity on the ventilatory and ischaemic/arrhythmic threshold, while competitive sports participation is limited to a low-static, low-dynamic type of sports.[232] For patients with other underlying cardiac abnormalities, such as cardiomyopathies,[186] channelopathies,[233] congenital heart diseases,[221] and structural valve disease,[220] recommendations for risk stratification and participation in exercise/sporting activity have also been produced by the EACPR. Patients with CHF should also be risk stratified according to the severity of the underlying disease and the individual fitness level using a maximal exercise test.

Supervision during physical training of individuals with underlying CVD

There is no scientific evidence available that clarifies what form, frequency, and intensity medical controls should be carried out, and therefore recommendations are based on expert opinion. On this basis, regular medical follow-up examinations outside of a training programme, as well as medical supervision and monitoring during training, are undertaken in order to reduce the likelihood of an event in patients at risk. The frequency of checking and monitoring the individual patient depends on the severity of the underlying disorder. It is generally believed that medical supervision and patient monitoring is indicated during cardiac rehabilitation in inpatient or outpatient programmes. When the patient is taking part in home-based training or using regular training facilities outside the healthcare setting, regular medical follow ups, including fitness assessments and patient's education on how to react in case of new or increased symptoms, are recommended in order to reduce cardiovascular events. After an acute event (i.e. acute coronary syndrome) or after heart surgery, follow-up examinations typically take place within the first weeks after hospital discharge, preferably within a structured rehabilitation programme, and thereafter every 6–12 months. Training recommendations given must be based on the results of these follow-up examinations.

Safety precautions in case of cardiac emergency

As soon as the training is considered to be organized and open to the public, mandatory safety equipment should be present, regardless of the risk stratification of the individual. The major determinant of survival in case of sudden cardiac death is the time to defibrillation, which should not exceed 3–5 minutes. Automated external defibrillators (AED) have been advocated in public places, frequented by a critical number of individuals, and when the time to defibrillation otherwise exceeds 5 minutes.[234] Recent EACPR recommendations on cardiac safety in sports arenas include similar recommendations,[235] but at present no European recommendation on cardiac safety at health and fitness facilities exists. It is therefore recommend that, in case cardiac patients may frequent these facilities, AEDs should be available and that the staff should be educated in cardiopulmonary resuscitation.

Summary

In general, there is strong evidence that exercise training and a sufficient level of PA have beneficial health effects in patients with CVD.

After acute coronary syndrome, PCI, or bypass surgery, implementation of individual tailored exercise programmes should start as early as possible and are provided best within multidisciplinary cardiac rehabilitation programmes that include clinical assessment and follow up of the patients as well as individual PA counselling. The general aim is to reach and maintain the individually highest fitness level possible and to perform endurance exercise training 30–60 min daily (3–5 days per week) in combination with resistance training 2–3 times a week. Because of the frequently reported dose–response relationship between training effect and exercise intensity, one should seek sufficiently high training intensities, although more scientific evidence on effect sizes and safety is warranted.

Roughly the same recommendations can be formulated in patients with systolic CHF in NYHA classes I–III, as well as in patients with heart failure symptoms but preserved systolic function. In CHF patients effective and safe protocols for aerobic endurance training are well described. However, the lower and upper limits of the aerobic training intensity in these patients still remain to be established. Also the combination with other training modalities such as dynamic resistance training is less well documented. From this background, aerobic endurance training of low-to-moderate intensity is recommended, and dynamic resistance training may be prescribed in addition. However, in CHF patients, PA and exercise training programmes are strongly recommended to be medically guided and tailored to the individual's exercise tolerance and risk profile. The latter also applies for patients after cardiac transplantation and in patients with devices such as LVAD, ICD, and/or CRT. In patients with special cardiomyopathies such as hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and channelopathies, systematic clinical studies on the effects and risks of physical exercise do not exist. These patients often are young, and regular PA and low-intensity training programmes should be advised as a part of their healthy lifestyle. Participation in training programmes with higher intensity and in sport activities have to be individually judged on the basis of the current pathophysiological knowledge and clinical experience.

In patients with valve disease, after valve surgery and in congenital heart disease current available data are insufficient to give specific recommendations on type, dosage, and intensity of exercise. The current recommendations are mainly based on the actual knowledge of favourable and/or potentially detrimental effects of various kinds of physical exercise and refer therefore mainly to pathophysiological considerations and clinical experience. High-intensity, strenuous, and competitive sports may be contraindicated in a variety of diseases and clinical situations. Participation in exercise programmes and sport activities therefore have to be judged individually and medical exercise prescription and supervision are strongly advised.

With regard to safety, appropriate individual exercise prescription, based on clinical examination and exercise testing, and the presence of safety measures, such as the availability of AEDs in rehabilitation and fitness facilities, are mandatory.

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