Exercise Training in Patients with Heart Disease: Review of Beneficial Effects and Clinical Recommendations

Stephan Gielen, M. Harold Laughlin, Christopher O’Conner, Dirk J. Duncker

Over the last decades exercise training has evolved into an established evidence-based therapeutic strategy with prognostic benefits in many cardiovascular diseases (CVDs): In stable coronary artery disease (CAD) exercise training attenuates disease progression by beneficially influencing CVD risk factors (i.e., hyperlipidemia, hypertension) and coronary endothelial function. In heart failure (HF) with reduced ejection fraction (HFrEF) training prevents the progressive loss of exercise capacity by antagonizing peripheral skeletal muscle wasting and by promoting left ventricular reverse remodeling with reduction in cardiomegaly and improvement of ejection fraction. Novel areas for exercise training interventions include HF with preserved ejection fraction (HFrEF) training, pulmonary hypertension, and valvular heart disease. In pulmonary hypertension, reductions in pulmonary artery pressure were observed following endurance exercise training. Recently, innovative training methods such as high-intensity interval training, resistance training and others have been introduced. Although their prognostic value still needs to be determined, these approaches may achieve superior improvements in aerobic exercise capacity and gain in muscle mass, respectively.

In this review, we give an overview of the prognostic and symptomatic benefits of exercise training in the most common cardiac disease entities. Additionally, key guideline recommendations for the initiation of training programs are summarized.

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Valvular heart disease

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**Abbreviations and Acronyms**

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<th>Definition</th>
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<tr>
<td>CAD</td>
<td>coronary artery disease</td>
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<tr>
<td>CR</td>
<td>cardiac rehabilitation</td>
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<td>CV</td>
<td>cardiovascular</td>
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<td>CVD</td>
<td>cardiovascular disease</td>
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<td>EF</td>
<td>ejection fraction</td>
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<td>EDV</td>
<td>end diastolic volume</td>
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<tr>
<td>ESV</td>
<td>end systolic volume</td>
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<tr>
<td>HIIT</td>
<td>high intensity interval training</td>
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<td>HF</td>
<td>heart failure</td>
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<tr>
<td>HFrEF</td>
<td>heart failure—reduced ejection fraction</td>
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<tr>
<td>HFpEF</td>
<td>heart failure—preserved ejection fraction</td>
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<td>LV</td>
<td>left ventricular</td>
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<tr>
<td>MI</td>
<td>myocardial infarction</td>
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<td>OMT</td>
<td>optimal physical therapy</td>
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<td>PA</td>
<td>physical activity</td>
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<td>PCI</td>
<td>percutaneous coronary intervention</td>
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<td>PAH</td>
<td>pulmonary arterial hypertension</td>
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<td>VO$_2$</td>
<td>oxygen consumption</td>
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<td>PH</td>
<td>pulmonary hypertension</td>
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“Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it.”

[Plato, Greek philosopher]

The antique wisdom on the benefits of regular exercise for health was based on the observation that well-trained individuals were less likely to become sick. Today, large-scale population-based trials have confirmed that there is indeed a correlation between leisure-time PA and all-cause mortality: 15 min of exercise per day confers a 14% mortality reduction. A 4% reduction can be added for each additional 15 min of daily exercise time.

During the last 50 years the concept that exercise reduces CV mortality was also extended to patients with manifest heart disease: 1) In coronary artery disease (CAD) patients a consistent 18–20% reduction in all-cause mortality was confirmed in meta-analyses. After an acute coronary syndrome the effects seem to be even more pronounced leading to a 40% decline in 6-month mortality. 2) In heart failure (HF) with reduced ejection fraction (HFrEF), a European meta-analysis of pooled patient data from randomized studies found a significant reduction of total mortality by 35% and of hospitalization by 28%. This was, however, not confirmed in a prospective large-scale multicenter study, probably as a result of lower-than-expected adherence to the prescribed training programme. It is clear, however, that training programs result in a 15%–25% increase in exercise capacity, a concomitant improvement of New York Heart Association (NYHA) functional class, and a reversal of left ventricular remodeling with reduction of cardiomegaly; 3) Recently, the beneficial training effects on symptoms, exercise capacity and left ventricular diastolic function were also confirmed in HF with preserved ejection fraction (HFpEF) in the ExDHF study; and 4) Training as a therapeutic concept is also being extended to patient groups which were formerly advised not to engage in recreational PA or structured exercise programs (e.g., patients with pulmonary hypertension, valvular and congenital heart disease). Clinical research in these areas is just beginning and although first proof-of-concept studies confirmed safety and efficacy it is too early to extrapolate the findings to prognostic improvements.

Exercise training has multiple physiologic effects on the CV system, most notably a reduction of resting heart rate as a result of increased parasympathetic tone, an improved vascular endothelial function with augmented flow-mediated vasodilation during exercise, an increased vasculogenesis through endothelial progenitor cells, and multiple metabolic changes in the myocardium resulting in improved tolerance for ischemia and reperfusion injury.

**Beneficial clinical and prognostic effects of exercise training in heart disease**

Contrary to former textbook recommendations, there are in fact only a few cardiac pathologies in which patients do not derive a symptomatic or prognostic benefit from regular training programs. The list of clear contraindications includes unstable angina, and recent myocardial infarction, uncontrolled cardiac arrhythmia, symptomatic severe aortic stenosis or other valvular disease, decompensated symptomatic HF, and acute myocarditis or pericarditis.

Relative contraindications usually lead to temporary suspension of training programs and should be corrected before the exercise training is reinitiated. Most relevant are uncontrolled tachy- and bradyarrhythmias, severe arterial hypertension (systolic blood pressure >200 mm Hg, diastolic blood pressure >110 mm Hg), electrolyte disorders or uncorrected severe anemia.

In this review, only key indications for exercise-based cardiac rehabilitation (CR) can be briefly discussed. We will therefore focus on (1) stable CAD, (2) post-infarction rehabilitation, and (3) HF (both HFrEF and HFpEF). As novel and upcoming indications for exercise training, we assess training in valvular heart disease, congenital heart disease, and pulmonary hypertension.

**Stable coronary artery disease**

The oldest account that physical exercise can improve the symptoms of ischemic heart disease comes from the physician, who first described the clinical syndrome of angina pectoris, William Heberden. He reported that a patient with angina pectoris was nearly cured of his symptoms after sawing wood every day for half a year. As this observation would at best qualify for a class C recommendation in modern guidelines we need to look into prospective clinical studies.

**Prognostic benefits of exercise training in coronary artery disease**

In a large, high-quality meta-analysis, Taylor and colleagues collected clinical follow-up data in 8940 patients with CAD included in 48 prospective randomized clinical exercise training studies. Exercise-based CR was associated with a significant decrease in all-cause mortality by 20% (odds ratio 0.80; 95% confidence interval 0.68 to 0.93) and in cardiac
mortality by 26% (odds ratio 0.74; 95% confidence interval 0.61 to 0.96). These figures were recently confirmed in the 2011 Cochrane database systematic meta-analysis, which included 47 studies randomizing 10,794 patients. In medium to longer term (i.e., 12 or more months of follow-up), exercise-based CR significantly reduced overall and CV mortality [RR 0.87 (95% CI 0.75, 0.99) and 0.74 (95% CI 0.63, 0.87), respectively], and hospital admissions [RR 0.69 (95% CI 0.51, 0.93)]. Recently, combined resistance–endurance training has been shown to be more effective than aerobic endurance training in improving body composition, strength, and some indicators of CV fitness. Interval training leads to equal if not greater increases in exercise capacity compared to aerobic endurance training without higher adverse event rates, however, prognostic data are still lacking.

Apart from the profound beneficial effects of exercise training in patients with manifest CAD, regular physical activity (PA) has been shown to reduce CV and all-cause mortality in a primary prevention setting. In large-scale prospective cohort studies examining the relation between leisure time PA and mortality, participants with the highest proportion of leisure PA had the lowest all-cause and CV mortality. Likewise, higher physical fitness was predictive of reduced CV and all-cause mortality. According to the meta-analysis of Kodama and colleagues, each 1 metabolic equivalent (MET) increase in aerobic capacity was associated with a 13% risk reduction of all-cause mortality and a 15% reduction in CAD events.

Role of regular exercise and optimal medical therapy in stable coronary artery disease

Prospective randomized studies have documented that in patients with small ischemic areas (<10% of the myocardium), a treatment strategy with optimal medical therapy (OMT) plus exercise is not inferior to an intervention strategy. In a small pilot study, 101 patients with significant coronary artery stenosis and exercise-induced myocardial ischemia were randomized, with the training arm including 12 months of ergometer training 20 min per day. The training group had improved event-free survival and symptom-free exercise capacity as compared to those randomized to intervention therapy.

Endurance exercise training also attenuates the progression of coronary atherosclerosis and improves endothelial function. Niebauer et al. showed that 5–6 h/week of moderate intensity exercise training (>2200 kcal/week leisure-time physical activity per week) can induce regression of coronary plaques. However, since the changes in angiographic luminal diameter are minute most of the clinical effect of training on coronary perfusion seems to be mediated by enhanced endothelium-derived vasodilation. Taken together, exercise training is not just a means to improve the patients exercise capacity and symptoms but bears the potential to modify the progressive course of the underlying disease — coronary atherosclerosis.

Post myocardial infarction

Long before the prognostic benefits of endurance exercise on the progression of CAD were appreciated, exercise-based CR programs were developed for patients after acute myocardial infarction (MI) to help them regain their previous exercise capacity and facilitate reintegration into working life. In patients with uncomplicated course post MI PA such as walking may resume as soon as the patient has left the coronary care unit (usually after 48 h of ECG monitoring). In more complicated cases with large myocardial damage, CR should start after clinical stabilization and PA can be increased slowly according to symptoms.

Meta-analyses and reviews have primarily addressed two important aspects of exercise-based CR post MI: 1) The effects on mortality and cardiac event rate (i.e., non-fatal myocardial infarctions); and 2) the effects on cardiac remodeling and left ventricular function.

Specific Cochrane Library analyses for exercise-based CR post myocardial infarction are lacking. Although there is general consensus that exercise-based rehabilitation reduces all-cause and CR mortality, the meta-analyses on which this consensus is based date back to the late 1980s — prior to primary percutaneous coronary intervention (PCI), modern antiplatelet therapy, and widespread statin use. It is therefore likely that the reported 24% reduction of all-cause mortality and 25% reduction of CV mortality following CR could be lower today. Home-based and center-based CR yield comparable beneficial results after MI. The key message, however, was that only a minority of patients post MI — in the UK for example less than 40% — actually benefit from any form of exercise-based CR. The real challenge is therefore universal access to CR for all post-MI patients.

In regard to the beneficial effects of training on left ventricular (LV) remodeling, Haykowsky et al. analyzed trials which reported ejection fraction (EF) (12 trials, n =647), end systolic volume (ESV) (9 trials, n =475) and end diastolic volume (EDV) (10 trials, n = 512). He was able to confirm that improvements in LVEF decreased as the time between the MI and initiation of the exercise program increased. The increase in LVEF was greater with longer duration of the training program. Greater reductions in ESV and EDV were observed with earlier initiation of exercise training and with longer training durations. Each week of training initiation delay required one additional month of training to achieve the same level of benefit on LV remodeling.

In heart failure

It was not before the early 1990s that exercise training was introduced as a therapeutic concept in heart failure patients by Coats and colleagues. For decades the opposite concept — reducing PA to reduce exercise-induced symptoms in HF and avoid hemodynamic overload for the diseased ventricle — had dominated the textbooks. Coats was able to show that there is no correlation between LVEF and exercise capacity in HF patients but a clear relation between skeletal muscle mass and exercise capacity. Thus, peripheral factors potentially amenable to exercise therapy became therapeutic targets for training interventions; peripheral hyperfusion resulting from impaired endothelium-dependent vasodilation, reduced strength of respiratory muscles, and profound morphologic, metabolic, and functional alterations in the skeletal muscles.
From multiple prospective randomized exercise training studies in patients with HFrEF, we know that aerobic endurance training interventions are both safe and effective.\textsuperscript{5,40-42} Endurance training induces reverse cardiac remodeling with reduced EDV, and improved systolic and diastolic function in HFrEF patients.\textsuperscript{42-44} Meta-analyses confirmed significant improvements of clinically relevant outcome parameters such as exercise capacity,\textsuperscript{43,45} quality of life, and HF related hospitalization.\textsuperscript{46}

However, it is still a matter of continuing debate as to whether endurance training effects also reduces all-cause and CV mortality. In the EXTRA-MATCH meta-analysis data based on 9 mostly European prospective randomized single-center studies including a total of 801 HFrEF patients,\textsuperscript{5} a significant 35% reduction of all-cause mortality and a 28% reduction for the combined end-point of death or hospital admission were reported.\textsuperscript{5} In the United States, the HF-ACTION study was therefore initiated as a large multi-center prospective outcome trial for endurance training in HF.\textsuperscript{6} Surprisingly, no significant reduction of all-cause mortality or hospitalization was observed in the protocol-specified analysis. After adjustment for highly prognostic predictors of the primary end point, exercise training was, however, associated with modest significant reductions for both all-cause mortality or hospitalization and CV mortality or HF hospitalization.\textsuperscript{6} However, it was argued that the lack of significant mortality reductions resulted from the low rates of compliance with the prescribed training protocol (<60%) Due to the large number of participants (2331 patients), this study was also carried over into the 2010 Cochrane systematic meta-analysis, which described no significant training effect on all-cause mortality and all-cause hospitalizations.\textsuperscript{46} To reconcile the question of prognostic training effects, a sub-analysis confirmed a dose-response relationship between training intensity (as measured by MET-h per week) and outcome improvement, indicating significant reductions in adjusted hazard ratios for all cause/cardioc mortality or all-cause/cardioc hospitalization for those exercising between 3 and 7 MET-h per week (Fig 1).\textsuperscript{46} Taken together, available data are consistent with a dose-related improvement of clinical outcomes that reaches significant levels above 3 MET-h per week of aerobic continuous exercise training.

Among new training methods introduced in HFrEF patients are high intensity interval training (HIIT) and strength training. High intensity interval training achieves greater improvements in exercise capacity and quality of life with no apparent deleterious effects to LV remodeling.\textsuperscript{49,50} Combined strength-endurance training seems to induce more pronounced increases in muscle strength and muscle mass as compared to steady-state endurance training.\textsuperscript{12,51,52} Recently, training as a therapeutic intervention also proved to be effective in HFrEF with improved exercise capacity and diastolic function after aerobic training.\textsuperscript{7} Outcome studies are ongoing.

In other disease entities

Based on the positive clinical effects in CAD, after MI, and in HF, training interventions are being tested in a number of other CVDs, in which pharmacologic options are limited and impairment of exercise capacity is pronounced. Among these disease entities are: 1) Pulmonary arterial hypertension (PAH)/Pulmonary Hypertension (PH); 2) Valvular heart disease; and 3) Congenital heart disease. In all these disease conditions there are a few clinical studies – mostly small scale with functional end-points – which indicate safety and efficacy. However, the evidence-base is too narrow to make any guideline-based recommendations for clinical application at this time.

### Pulmonary arterial hypertension (PAH)/pulmonary hypertension (PH)

In the first prospective randomized study on aerobic exercise training in patients with PH Mereles et al. found an improved 6-min walking distance (+111 m versus control, P < 0.001) as well as improved quality of life, functional class, and peak oxygen consumption (VO\textsubscript{2}).\textsuperscript{8} However, systolic pulmonary artery pressure values at rest did not change significantly after 15 weeks in the training group.\textsuperscript{8} After this first proof-of-concept trial other studies confirmed the safety and efficacy of training to improve exercise capacity. Weinstein et al. reported a significantly improved fatigue severity scale and human activity profile scores in response to 10 weeks of aerobic exercise training plus education in comparison to education alone.\textsuperscript{53} Training improves exercise capacity not only through cardiopulmonary effects but also through increased quadriceps muscle strength and endurance.\textsuperscript{54} In a small pilot study, respiratory muscle training in combination with aerobic exercise training significantly increased twitch mouth pressure during nonvolitional supramaximal magnetic phrenic nerve stimulation and 6 min walking distance over the 15 week study period.\textsuperscript{55}

The following positive results were reported in other PAH cohorts: 1) In PAH associated with congenital heart disease,
Becker-Grünig and colleagues described improved quality of life-score and peak VO$_2$ after 15 weeks of exercise training in an observational intervention study.\textsuperscript{56} 2) Thirty-five patients with invasively confirmed inoperable or residual chronic thromboembolic pulmonary hypertension received exercise training in-hospital for 3 weeks and continued at home for 15 weeks. In this observational study, significant improvements of peak VO$_2$ and NT-proBNP were noted, associated with a better-than-expected three year survival rate of 86\%.\textsuperscript{57} and 3) In 21 patients with connective tissue disease-associated pulmonary arterial hypertension heart rate at rest, peak VO$_2$, oxygen saturation and maximal workload improved significantly after in-hospital exercise training for 3 weeks followed by home-based training for 15 weeks.\textsuperscript{58} Despite these trials we still lack outcome studies which address the prognostic benefit of training in an adequately powered multicenter study model.

Valvular heart disease

Exercise training after surgical correction. Traditionally, exercise training in valvular heart disease was recommended only after surgical correction of the dysfunctional valve. Even this recommendation, however, is based on a surprisingly small number of randomized\textsuperscript{59} and non-randomized studies.\textsuperscript{60-62} Timing of exercise training seems to be critical since patients post aortic/mitral valve replacement starting late into exercise-based rehabilitation (i.e., 9 weeks post surgery) did not show greater improvements in maximal exercise capacity versus a non-randomized control group.\textsuperscript{61} In a large French registry involving 251 patients after mitral valve repair, exercise training significantly improved peak VO$_2$ by +22\%.\textsuperscript{63} Isolated cases of patients engaging in strenuous PA after aortic valve surgery indicate that high-intensity exercise training is safe and can improve LV-function.\textsuperscript{64} Taken together, patients with valvular heart disease post surgical correction seem to respond in the same manner as other established cohorts (i.e., post-AMI, post-CABG, etc.) following participation in CR.\textsuperscript{65}

Exercise training in native valvular heart disease. Few studies have specifically evaluated training interventions in patients with valvular heart disease. Therefore, recommendations are necessarily less reliable and are based on pathophysiological considerations rather than on hard clinical evidence. In patients with stable asymptomatic moderate degree valvular heart disease (up to grade II), moderate-intensity exercise is possible. There is, however, no evidence suggesting that regular exercise interventions influence the progression of established valvular heart disease. For example, once aortic valve sclerosis has developed, exercise training does not change the course of the valvular heart disease in mice.\textsuperscript{66} However, rat studies in aortic regurgitation document a reduction of cardiomegaly and a better myocardial performance index in trained versus sedentary animals.\textsuperscript{67} Clear contraindications to exercise training include critical and highly symptomatic valvular lesions on the edge to cardiac decompensation, stable aortic stenosis with a valvular orifice area <0.75 cm$^2$ and a peak pressure gradient >50 mm Hg. In general, patients with valvular heart disease and a clear (class I and IIa) indication for cardiac surgery should abstain from exercise training until after valve surgery.

Specific risks for special valvular lesions:

Mitral valve prolapse: Although considered a benign abnormality occurring in up to 5% in the general population, sudden death has been reported as a rare complication. Exercise is considered safe in patients without significant arrhythmias at rest and during exercise, without a family history of sudden cardiac death, and without any previous thromboembolic event or syncope.

Mitr al regurgitation: In patients with HF, relative mitral regurgitation is frequent and does not preclude the initiation of training therapy provided the patient is in stable condition (i.e., NYHA II-III).

Mitral stenosis: Patients with a mitral valve orifice >1.5 cm$^2$ may safely participate in normal exercise training sessions. Those with moderate to severe mitral stenosis (<1.5 cm$^2$) are usually limited by exercise-induced dyspnea and can only tolerate low levels of physical exertion. In these symptomatic patients, treatment of mitral stenosis by balloon valvuloplasty or valve replacement should be performed prior to starting a training program.

Aortic regurgitation: Patients with mild to moderate aortic regurgitation may engage in training without problems. However, LV diameters need to be reassessed every 3-6 months to watch for worsening of the valve disease.

Congenital heart disease

In most cases adult patients with congenital heart disease seek medical advice regarding exercise not because they want to enter a structured cardiac rehabilitation program, but because they want to engage in sports activities. As highlighted in a recent recommendations paper\textsuperscript{68} only a minority of patients with congenital heart disease receive formal advice on physical activity. Instead they are often-times encouraged to avoid physical exertion as a result of overprotection and uncertainty as to which activities are safe and can be recommended. In contrast to the above mentioned adult heart diseases no general recommendations can be made. An individualized evaluation of each patient is recommended.

Conclusion

Exercise training has become an established part of evidence-based clinical therapy in stable CAD, post MI, and in HFrEF. Its role is expanding in HFrEF, where it is currently the only intervention shown to be effective in randomized studies, in PAH/PH, and in stable valvular heart disease.

The greatest challenge, however, is to implement the existing knowledge regarding training benefits in CVDs as a standard in clinical practice and to increase the participation rates of patients with a clear indication for exercise-based CR in existing programs.

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Table 1 – Recommendations for exercise training therapy in key indications. The recommendations are based on the position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation.69

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Indication</th>
<th>Contraindiation</th>
<th>Recommended Training Program EACPR Position Paper</th>
<th>EACPR Position Paper Recommendation Grade</th>
<th>Symptomatic Impact</th>
<th>Prognostic Impact</th>
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<tbody>
<tr>
<td>Stable Coronary Artery Disease</td>
<td>Percutaneous coronary intervention (PCI)</td>
<td>✴ Unstable angina pectoris ✴ Acute endomyocarditis or other acute infections ✴ Recent pulmonary artery embolism or phlebothrombosis ✴ Hemodynamically relevant arrhythmia ✴ Critical obstructions of the left ventricular outflow tract</td>
<td>Medically supervised exercise training programs are recommended for patients with multiple risk factors, and with moderate-to-high risk (i.e. recent heart failure episode) for training initiation and motivation to long-term adherence ✴ Expanding physical activity to include resistance training Also refer to ‘Post-ACS and post primary PCI’ issues</td>
<td>I (B)</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>S/P Myocardial Infarction</td>
<td>✴ Acute coronary syndrome (STEMI and NSTEMI)</td>
<td>✴ Post infarction angina pectoris (due to incomplete revascularization) ✴ Heart failure (refer to recommendations for heart failure patients) Also refer to contraindications listed under stable CAD</td>
<td>Exercise training should be recommended to all patients (supervised or monitored in moderate to high-risk ones). The program should include: at least 30 min, 5 days/week, aerobic exercise ✴ At 70%–85% of the peak heart rate, or at 70%–85% of the heart rate at the onset of ischemia (defined as ≥1 mm of ST depression, in case of asymptomatic exercise-induced ischemia). Prophylactic nitroglycerine can be taken at the start of the training session) ✴ At 50% of the peak heart rate in high-risk patients because of left ventricular dysfunction, coronary disease severity, co-morbidities, ageing ✴ Resistance training</td>
<td>I (B)</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>S/P Cardiac Surgery</td>
<td>✴ S/P CABG ✴ S/P Valve surgery ✴ S/P Aortic surgery</td>
<td>✴ Wound infection after sternotomy, harvesting of saphenous veins and/or radial arteries</td>
<td>Exercise training can be started early in-hospital Programs should last 2–4 weeks for in-patient or up to 12 weeks for out-patient settings</td>
<td>I (B)</td>
<td>++</td>
<td>+ for CABG</td>
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### Chronic Heart Failure (HFREF)

- Patients with stable compensated HFREF in New York Heart Association (NYHA) functional class I–III.

- Progressive worsening of exercise tolerance or dyspnea at rest over previous 3–5 days
- Significant ischemia during low-intensity exercise (<2 METs, 50 W)
- Uncontrolled diabetes
- Recent embolism
- Thrombophlebitis
- New-onset atrial fibrillation/atrial flutter

Progression of aerobic exercise training for stable patients

Initial stage (first 1–2 weeks): intensity should be kept at a low level in patients with NYHA functional class III (50% of peak VO2), increasing duration from 20 to 30 min according to perceived symptoms and clinical status

Improvement stage: a gradual increase of intensity (60%, 70%–80% of peak VO2, if tolerated) is the primary aim. Prolongation of exercise session is a secondary goal

- Supervised, hospital-based (in- or out-patient) program may be recommended, especially initially, to verify individual responses and tolerability, clinical stability, and promptly identify signs and symptoms indicating to modify or terminate the program

- Resistance training

- Upper-body training can begin when the sternal wound is stable

- Exercise training should be individually tailored according to the clinical condition, baseline exercise capacity, ventricular function, and different valve surgery (after mitral valve replacement exercise tolerance is much lower than that after aortic valve replacement, particularly if there is residual pulmonary hypertension)

Also refer to ‘Post-ACS and post primary PCI’ issues (including resistance training)

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REFERENCES


