EXPERT OPINION

Comprehensive cardiac rehabilitation as the keystone in the secondary prevention of cardiovascular disease

Expert Opinion of the Cardiac Rehabilitation and Exercise Physiology Section of the Polish Cardiac Society

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ABSTRACT

Comprehensive cardiac rehabilitation (CR) is a mainstay of the secondary prevention of cardiovascular disease (CVD). In the European Society of Cardiology guidelines, comprehensive cardiovascular rehabilitation has the highest class of recommendation and level of evidence as an effective method for the treatment of patients with ST-segment elevation myocardial infarction, after myocardial revascularization, with chronic coronary syndrome, for CVD prevention in clinical practice, and in patients with heart failure (HF). This document presents an expert opinion of the Cardiac Rehabilitation and Exercise Physiology Section of the Polish Cardiac Society concerning the definition, goals, target population, organization of rehabilitation services, standard clinical indications, and methods of implementation. Moreover, it describes psychosocial risk factors influencing the course of CR and secondary prevention of cardiovascular disease in patients undergoing CR.

Comprehensive CR is a process that should be implemented as soon as possible, continued without interruption, and should consist of multiple stages. Moreover, it should be tailored to the individual clinical situation and should be accepted by the patient and their family, friends, and caregivers.

Key words: cardiac rehabilitation, coronary artery disease, exercise training, secondary prevention of cardiovascular disease

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COMPREHENSIVE CARDIAC REHABILITATION: DEFINITION, GOALS, TARGET POPULATION, AND ORGANIZATION OF REHABILITATION SERVICES

In developed countries, cardiovascular disease (CVD) is the most common cause of premature death, which, in many cases, could be prevented. Primary and secondary prevention of CVD, defined as lifestyle modification with regular exercise training and optimal pharmacotherapy, is a well-established strategy to reduce morbidity, hospital readmission, and mortality due to cardiovascular causes. Cardiac rehabilitation (CR) is a mainstay of the secondary prevention of CVD. In the European Society of Cardiology guidelines, comprehensive CR has the highest class of recommendation and level of evidence as an effective method for the treatment of patients with ST-segment elevation myocardial infarction [1], after myocardial revascularization [2], with chronic coronary syndrome (CCS) [3], for CVD prevention in clinical practice [4], and in patients with heart failure (HF) [5–7]. Patients with acute coronary syndrome (ACS), decompensation of HF, and previous cardiac surgery or percutaneous coronary intervention (PCI) should be referred for an early CR program immediately after hospitalization. Each week's delay in CR requires an additional month of exercise to obtain the same level of health benefit [8, 9]. Priority patient groups that should be offered a CR program are presented in Table 1 [10, 11].

Comprehensive CR is defined as a tailored multidisciplinary intervention that includes clinical evaluation (medical history, physical examination, functional examination, questionnaires, laboratory tests, resting and exercise electrocardiography [ECG], echocardiography and other diagnostic tests if indicated), management and modification of cardiovascular risk factors, physical activity counseling, prescription of an appropriate exercise training program, dietary counseling, as well as psychological, social, and vocational support [11]. The aim of CR is also to optimize pharmacotherapy and cardiac implantable electronic devices function (pacemaker, implantable cardioverter-defibrillator [ICD], cardiac resynchronization pacemaker, ventricular assist devices, etc.), diagnose frailty syndrome, educate patients and their families about healthy behavior and first-aid principles, as well as monitor rehabilitation outcomes. Currently, the duration of CR in European countries ranges from 8 to 24 weeks, and from 3 to 4 weeks for inpatient programs [11, 12].

In facilities offering CR services, the medical team should include a physical therapist, a nurse, and an electroradiology technician in addition to medical doctors. Cooperation with a psychologist and a dietitian is important, which also applies, in larger facilities, to a rehabilitation services manager.

Comprehensive CR is a process that should be implemented as soon as possible, continued without interruption, and should consist of multiple stages. Moreover, it should be tailored to the individual clinical situation and should be accepted by the patient and their family, friends, and caregivers.

Table 1. Clinical indications for comprehensive cardiac rehabilitation [10, 11]

Post-acute coronary syndrome
Post-myocardial revascularization
Chronic coronary syndrome
Heart failure
Following implantation of cardiac implantable electronic devices, pacemakers, resynchronization devices, or implantable cardioverter-defibrillators
Following heart valve repair/replacement
Following heart transplantation
Following implantation of ventricular assist devices
Congenital heart disease
Peripheral artery disease
Following cerebrovascular events[a]

[a]Patients with paresis or aphasia require neurological rehabilitation

The CR intervention can be divided into early CR (phases I and II) and late CR (phase III).

Early comprehensive cardiac rehabilitation: phase I

Phase I CR begins during hospitalization for a cardiovascular event and is provided in an intensive care room or a postoperative, cardiology, internal medicine, or CR wards. This phase should start on admission to the hospital and should last until the patient is stable and can be discharged from the acute ward. The main goal of phase I is for the patient to achieve independence and self-care in performing daily activities, to prevent complications of immobility, and to evaluate the patient's response to exercise associated with daily activities.

Early comprehensive cardiac rehabilitation: phase II

Phase II CR may be provided in the inpatient setting (residential); in the ambulatory setting at an outpatient clinic or day rehabilitation unit; as hybrid cardiac telerehabilitation with phase I rehabilitation program in the in-hospital or ambulatory setting, followed by phase II delivered remotely at the patient's home using data transmission technology.

Inpatient phase II CR should be provided primarily to individuals at high cardiovascular risk. This may include patients:

- with complications of ACS, cardiac surgery, or PCI;
- with other cardiovascular complications or comorbidities and high cardiovascular risk with stable advanced HF (New York Heart Association [NYHA] functional class III–IV) and/or requiring short- or long-term intravenous therapy and/or with ventricular assist devices and/or other cardiac implantable electronic devices;
- immediately after heart transplantation;
- who cannot undergo a CR program at an outpatient clinic or a day rehabilitation unit [10].

Late comprehensive cardiac rehabilitation: phase III

Phase III of the CR program is most often delivered in the ambulatory setting at an outpatient clinic or a day rehabilitation unit. This phase centers on physical exercise and on educating patients and their families about a healthy lifestyle, and it should be planned, provided, and regularly monitored with consideration of the individual patient's needs, cardiovascular risk profile, and personality traits. Phase III should be lifelong as part of the healthy lifestyle intervention [13].

At each phase, different models of physical exercises (A, B, C, or D) may be prescribed depending on the individual patient's exercise tolerance and cardiovascular risk [13]. Model A is applied in patients with the best exercise tolerance and the lowest cardiovascular risk, while model D, in patients with poor exercise tolerance and high cardiovascular risk. Models B and C are used in patients with intermediate levels of exercise tolerance and cardiovascular risk.

Effects of comprehensive cardiac rehabilitation

All forms of CR provide beneficial health effects. In particular, CR

- modifies CVD risk factors by increasing physical activity, lowering blood pressure (BP), reducing or maintaining body weight, improving the lipid profile to achieve obtain guideline-recommended targets, controlling glucose levels, lowering insulin resistance;
- improves endothelial function;
- inhibits the development of atherosclerosis and its clinical sequelae, and even causes regression of atherosclerotic lesions;
- improves cardiopulmonary efficiency and exercise tolerance;
- reduces the risk of frailty syndrome;
- improves musculoskeletal function;
- improves psychophysical fitness;
- improves the quality of life;
- motivates patients to engage with treatment;
- reduces the risk of disability;
- improves family and social activity of patients;
- facilitates a return to work.

These benefits are due to the pleiotropic effects of exercise training, among other factors. When combined with patient education and optimal medical therapy, exercise training reduces the risk of acute cardiovascular events, delays disease progression, and shortens the duration of treatment after acute events and exacerbations. This results in a lower number of hospital readmissions, improved quality of life, and prolonged longevity [14, 15].

EXERCISE TRAINING IN COMPREHENSIVE CARDIAC REHABILITATION: ELIGIBILITY CRITERIA, CONTRAINDICATIONS, AND METHODS

Determining patient eligibility for comprehensive cardiac rehabilitation: general principles

Exercise training can be prescribed only to clinically stable patients. Patients are referred for CR by a physician based on medical history, physical examination, and additional tests. Medical history should include disease course, comorbidities that may affect exercise tolerance and training (e.g., diabetes, kidney failure, chronic obstructive pulmonary disease, thyroid disease, cancer, chronic inflammatory diseases, anemia, as well as musculoskeletal and neurologic disorders). Before starting the exercise training program, the patient should be assessed for current symptoms (NYHA functional classification, Canadian Cardiovascular Society classification of angina pectoris, Fontaine and Rutherford classification of peripheral artery disease) as well as cardiovascular risk (Table 2).

Patients after cardiac surgery should be assessed for the presence of postoperative complications: sternal instability, improper wound healing, postoperative infections, postpericardiotomy syndrome, and postoperative anemia. Current medical therapy is also evaluated, and modification is considered depending on the clinical sta-

Table 2. Assessment of cardiovascular risk during exercise training [13]

Risk factor	Risk		
	Low[a]	Moderate[b]	High[b]
Left ventricular systolic function	No significant dysfunction LVEF ≥50%	Moderate dysfunction LVEF = 36%–49%	Severe dysfunction LVEF ≤35%
Complex ventricular arrhythmia	Absent at rest or during exercise		Present at rest or during exercise
Ischemic signs on exercise test	None	ST-segment depression ≥1 mm–≤2 mm	ST-segment depression >2 mm
Exercise capacity[c]	≥7 MET >100 W	5–6.9 MET 75–100 W	<5 MET <75 W
Hemodynamic response to exercise	Normal		Stable or decreased SBP or HR with increased workload; peak SBP <140 mm Hg
Clinical characteristics	Uncomplicated myocardial infarction, CABG, PCI		Myocardial infarction or an invasive intervention complicated by shock or cardiac arrest; HF; recurrent ischemia after invasive treatment

[a]All criteria met; [b]Only 1 criterion met; [c]The assessment should include age and sex.
Abbreviations: CABG, coronary artery bypass grafting; HF, heart failure; HR, heart rate; LVEF, left ventricular ejection fraction; MET, metabolic equivalent of task; PCI, percutaneous coronary intervention; SBP, systolic blood pressure

tus and according to general guidelines. When referring the patient for physical training, the function of cardiac implantable electronic devices should be assessed and potential indications for implantation should be considered (pacemaker, ICD, cardiac resynchronization therapy, and ventricular assist devices).

The patient is examined by a physician before and after the CR program. Eligibility is determined on the basis of the patient's general condition, symptoms of HF, heart rate (HR) and BP measurement, presence of arrhythmia, peripheral vascular disease, as well as musculoskeletal and neurologic disorders that limit physical exercise. Medical examination should be also performed before each training session in patients at high risk of complications, after the training program has been modified, or in case of complications.

Patients are assessed for eligibility and cardiovascular risk using the following diagnostic tools:

- the ECG — standard ECG should be performed in all patients before and after each phase of CR and in the presence of symptoms that constitute an indication for ECG;
- the exercise test — recommended before the patient is referred for phase II and III CR. The exercise test is used to determine exercise intensity, exercise-related risk, as well as changes in exercise capacity after completing each phase of CR. It is also applied to determine workload for subsequent physical activity associated with work and leisure [16];
- the cardiopulmonary exercise test (CPET) — is recommended for functional assessment and rehabilitation of patients with CVD (particularly HF) as well as heart and lung transplant recipients. The CPET allows a precise assessment of exercise capacity by measuring minute ventilation as well as oxygen and carbon dioxide concentrations in exhaled air during the test [17];
- the 6-minute walk test [18] — is used in patients who cannot do the exercise test either on a treadmill or bicycle ergometer [11]. However, the treadmill stress or bicycle ergometry test should be always performedas soon as possible if there are no contraindications;
- long-term ambulatory Holter ECG monitoring — should be performed in patients who develop symptoms that constitute an indication for this type of ECG monitoring [19];
- transthoracic echocardiography — if current results after a recent cardiovascular event are not available, transthoracic echocardiography should be performed at a center providing a phase II CR program. Standard anatomical and functional parameters should be assessed. Before referral for exercise-based CR, it is important to assess the pericardium and to exclude mobile thrombi in heart cavities. Mobile thrombi constitute an absolute contraindication to exercise training. Transthoracic echocardiography is used in risk stratification of patients undergoing exercise training (Table 2). Moreover, echocardiography should be performed in patients with disease exacerbation or other indications as defined by the guidelines of European Society of Cardiology and the Polish Society of Cardiology [20, 21];
- laboratory tests — the following laboratory tests should be performed before the patient is referred for CR: complete blood count, lipid profile (total cholesterol, high- and low-density lipoprotein cholesterol, and triglycerides), fasting glucose, glycated hemoglobin HbA_{1c} in patients with diabetes, creatinine, electrolytes, uric acid, and international normalized ratio (in patients receiving vitamin K antagonists). The frequency of laboratory testing should follow the established guidelines.

Exercise training in comprehensive cardiac rehabilitation: basic concepts, contraindications, and methods

Exercise training in CR is a key treatment of patients with CVD and is prescribed at each phase of CR.

- Phase I: exercise training is started as soon as the patient with an emergency medical condition is stabilized or after an elective procedure. Depending on the disease course (complicated vs uncomplicated) and in the absence of contraindications, active rehabilitation starts after 12 to 48 hours of immobilization in patients with a stable clinical condition. Subsequent components of the training program are implemented depending on the disease course and complications during the acute phase.
- Phase II: exercise training depends on exercise capacity and the risk of complications as the most important criteria to be considered when referring the patient for one of the 4 models of physical exercise (A, B, C, or D). The training can be performed in the in-hospital setting, ambulatory setting (outpatient clinic/day rehabilitation unit), or as part of hybrid cardiac telerehabilitation.
- Phase III: exercise training is delivered as part of late CR in the ambulatory setting. The goal of exercise training is to further improve exercise tolerance, maintain treatment outcomes, and reduce the risk of disease recurrence. Exercise training at this stage should be lifelong.

To increase patient safety during training, a number of measures should be undertaken. Before training, the patient's clinical condition should be assessed, while during training, the patient should be monitored for sudden paleness, excessive sweating, blue lips, and other symptoms. Patients should be educated about any exercise-related symptoms such as chest pain, dyspnea, and dizziness as well as the need to report them to the rehabilitation team. Before and after an exercise training session as well as on each change of the body position, BP and HR should be measured. Knowledge of first-aid principles also increases patient safety.

Any emergency medical condition and unstable CVD constitute absolute contraindications to exercise training. An exercise training program should be tailored to the

individual patient's needs or temporarily discontinued (especially phases I and II) in the following conditions:

- poorly controlled hypertension;
- orthostatic BP reduction of more than 20 mm Hg with clinical symptoms;
- sinus tachycardia resistant to treatment (HR >100 bpm);
- malignant ventricular tachycardia;
- exercise-induced bradycardia;
- significant stenosis of the atrioventricular or arterial ostium;
- cardiomyopathy with left ventricular outflow tract stenosis;
- ischemic ST-segment depression of 2 mm or higher on resting ECG;
- a positive exercise test result suggesting myocardial ischemia at peak exercise;
- decompensated HF;
- acute inflammation and uncontrolled comorbidities;
- electrolyte imbalance [13, 22].

The intensity and duration of training should be tailored to each individual patient. In patients with CVD, the standard form of training is endurance aerobic exercise that involves large muscle groups. An interval or a continuous modality of training can be applied. Resistance/strength exercise is also recommended, starting with phase II of CR, after at least 1 week of supervised endurance exercise training [23].

Exercise training should adopt the FITT principle (frequency, intensity, time–duration, and type of exercise), with additional consideration of the timing in relation to meals (FITT+T).

Exercise training should be arranged to provide an energy consumption of 1000 to 2000 kcal/week [11].

- Frequency of exercise training
  For aerobic training, at least 3 days a week, preferably all days per week;
  for resistance/strength training, 2 times a week on nonconsecutive days of the week.
- Intensity of exercise
  Endurance training
  Moderate intensity: for endurance interval training: 45%–59% of peak oxygen consumption (VO_{2peak}), 50%–70% of peak exercise capacity above the first ventilatory threshold (W_{peak}), 55%–69% of peak HR, 40%–59% of HR reserve, 4–6 metabolic equivalents or a score of 12 to 14 on the 6–20 Borg rating of perceived exertion scale, or moderate-to-high intensity for continuous endurance training. High-intensity interval training is also allowed. The "speech rule" can be used as an additional tool to monitor training intensity when HR measurement is not possible.
  Resistance/strength training
  Intensity from 30% to 70% of 1-repetition maximum (1RM) for the upper body and 40% to 80% 1RM for the lower body, with 12 to 15 repetitions in one set.
- Duration of training sessions
  At least 20 to 30 minutes (preferably 45–60 minutes) per session.
- Type of training
  Aerobic training (walking, jogging, cycling, swimming, rowing, dancing), resistance/strength training, flexibility, balance, and inspiratory muscle training. Nonconventional types of training are also allowed.

During the initial phases, supervised exercise training is recommended, with a physical examination as well as HR and BP monitoring before, during, and after training. Supervision should be prolonged in patients with new symptoms, BP abnormalities, or exacerbation of arrhythmia during exercise [11].

HYBRID CARDIAC TELEREHABILITATION

Hybrid cardiac telerehabilitation offers an opportunity to provide and supervise a rehabilitation program remotely by using advanced medical and telecommunication technology [24–30].

Hybrid cardiac telerehabilitation has been approved for use by the Polish Cardiac Society [31, 32]. The setting, duration, and components of phase I hybrid cardiac rehabilitation are presented in Table 3. Phase II rehabilitation is delivered at the patient's home. It comprises 15 to 20 training sessions 3 to 5 times a week and a follow-up visit for clinical assessment, outcome evaluation, and advice on treatment and lifestyle modification. The core components of a training session in hybrid cardiac telerehabilitation are presented in Table 4.

Exercise training in hybrid cardiac telerehabilitation

Exercise training in hybrid cardiac telerehabilitation should be tailored to the individual patient according to current guidelines. The type of home-based exercise training depends on the availability of at-home physical therapy equipment. If physical therapy equipment is not available to the patient, outdoor walking is recommended.

Telerehabilitation system

A telerehabilitation system should ensure voice communication, recording and transmission of ECG parameters, BP, and body mass, as well as remote training control.

Monitoring unit

The monitoring unit should be equipped with a computer-based system enabling assessments listed in Table 4 and ensuring communication with the patient in case of alarming symptoms.

In Poland, hybrid cardiac telerehabilitation services may be provided in daily clinical practice [33], both as a separate procedure or as part of coordinated specialty care for patients after myocardial infarction [34].

Table 3. Phase I hybrid cardiac telerehabilitation: setting, duration, and components

Setting: in-hospital (cardiac rehabilitation ward); ambulatory (day rehabilitation unit/outpatient clinic)
Duration: optimally 5 days; up to 14 days in patients with comorbidities, depending on the clinical status
Scope: 1. Clinical assessment and optimization of pharmacotherapy (physical examination, additional tests including laboratory tests, ECG, echocardiography, and others if indicated) 2. Exercise capacity assessment (exercise test, CPET, or 6-minute walk test) 3. Tailored exercise training program in terms of: — duration and frequency of training sessions — exercise intensity (training HR zone, Borg rating of perceived exertion) — type of exercise training (endurance training, respiratory muscle training, resistance/strength, whole-body training including stretching) — training modality (continuous, interval) — extent of physical exercise (general, local) 4. Programming of the telerehabilitation system that includes: — exercise training program — rules, parameter recording and transmission schedule (ECG, BP, body mass) 5. mental health assessment and development of tailored psychological support program 6. education on the use of the telerehabilitation system, self-assessment during telerehabilitation, implementation of exercise training, healthy lifestyle, and CVD prevention 7. gradual implementation of the exercise training program: first supervised training sessions 8. evaluation of the patient's ability to use the telerehabilitation system and readiness for home-based CR 9. final referral of the patient for home-based CR 10. first aid training for patients and their partners/children

Abbreviations: BP, blood pressure; CPET, cardiopulmonary exercise test; CR, cardiac rehabilitation; CVD, cardiovascular disease; ECG, electrocardiogram; HR, heart rate

Table 4. Core components of a training session in hybrid cardiac rehabilitation

The core components of a training session include: 1. Permission to start a training session based on: — medical interview by phone — ECG, HR, and body mass measurement — assessment for contraindications to exercise training (see chapter: Exercise training in comprehensive cardiac rehabilitation: basic concepts, contraindications, and methods) 2. Exercise training guided by the telerehabilitation system with a programmed recording and transmission of ECG parameters 3. Summary of the training session including: — a medical interview — training evaluation: ECG (including training HR), perceived exertion according to the Borg scale, adverse events — advice on the next training session

Abbreviations: ECG, electrocardiogram; HR, heart rate

MAJOR CLINICAL INDICATIONS FOR CARDIAC REHABILITATION AND PROVISION OF REHABILITATION SERVICES

Coronary artery disease

Comprehensive CR is a mainstay of secondary prevention of coronary artery disease (CAD). It is recommended by the European Society of Cardiology (ESC) guidelines and other international societies (class IA recommendation) to improve prognosis in patients with ACS, after revascularization (coronary angioplasty, PCI, coronary artery bypass grafting [CABG]), and with CCS.

Phase II CR should start no longer than 3 months after a cardiovascular event. The recommended frequency of supervised training sessions is at least 3 to 5 times per week, with intensity tailored to the patient's individual clinical condition. At the same time, CR should include atherosclerotic risk factor modification and patient education about CAD.

Patients after acute coronary syndrome

Cardiac rehabilitation is an effective intervention in patients after ACS (class IA recommendation according to the ESC guidelines). Comprehensive CR reduces cardiovascular mortality and the risk of recurrent myocardial infarction [35]. Effective CR requires a comprehensive approach [15].

Direct outcomes of CR in patients after ACS include improved exercise capacity, modification of atherosclerotic risk factors, improved mental health, and better adherence to medical therapy.

Comprehensive CR in patients after ACS includes all 3 phases described earlier (see chapter: Comprehensive cardiac rehabilitation: definition, goals, target population, and organization of rehabilitation services). For the CR program to be effective, it has to be started no later than 3 months after hospital discharge [15].

Depending on the clinical condition and complications, phase II CR in these patients is most often provided in the ambulatory setting in a day rehabilitation unit or as hybrid cardiac telerehabilitation. In-hospital phase II CR is recommended only in patients with high cardiovascular risk, complications of ACS, HF (NYHA functional class III and IV), numerous comorbidities, or in those who cannot participate in other forms of rehabilitation due to logistical reasons and/or age. Irrespective of the setting, CR should be delivered using a comprehensive approach (Table 5) by a team of professionals (see chapter: Comprehensive cardiac rehabilitation: definition, goals, target population, and organization of rehabilitation services).

After completing phase II CR, patients after ACS are referred for outpatient care with recommendations to maintain a healthy lifestyle, including daily physical activity.

Chronic coronary syndrome

Comprehensive CR is recommended by the ESC guidelines in the treatment of patients with CCS (class IA recommendation). Indications for CR in patients with CCS include:

- stable CAD without a history of myocardial infarction and revascularization (angina symptoms or exertion dyspnea with confirmed coronary artery atherosclerosis without the possibility of revascularization);
- stable CAD long after myocardial infarction and revascularization (phase III CR);
- angina and suspected vasospastic or microvascular disease.

Comprehensive CR in patients with CSC (Table 6) facilitates implementation and maintenance of a healthy lifestyle as well as elimination of atherosclerotic risk factors, which limits the progression of atherosclerotic lesions. Comprehensive CR improves exercise tolerance,

Table 5. Components of comprehensive cardiac rehabilitation following acute coronary syndrome and percutaneous coronary intervention [11]

Components of comprehensive CR	Assessed parameters / measures
Medical interview, physical examination, and additional tests	— Clinical history: clinical course of ACS, comorbidities, evaluation of atherosclerotic risk factors — Current symptoms (NYHA class, Canadian Cardiovascular Society angina class, Fontaine and Rutherford classification for lower extremity peripheral artery disease) — Review lifestyle modifications (diet, smoking, weight control, BP self-monitoring, glucose control, subjective assessment of exercise tolerance and extracardiac symptoms) — Physical activity level: domestic, occupational, and recreation; barriers to increased physical activity — Physical examination: heart failure symptoms, arrhythmia, HR and BP control, extracardiac atherosclerotic manifestations, frailty syndrome, musculoskeletal disorders, and neurologic symptoms — Resting ECG — Echocardiography (systolic and diastolic dysfunction and other abnormalities if present). In patients with LVEF <40%, repeat echocardiography 6–12 weeks after myocardial infarction, complete revascularization, and optimal medical therapy to determine indications for primary prevention ICD implantation of sudden cardiac death — Peak exercise capacity evaluation before CR and after CR completion (exercise test, preferably CPET). If the exercise test is not feasible, perform the 6-MWT — Consider assessment of myocardial ischemia and left ventricular myocardial viability if indicated (stress echocardiography, magnetic resonance imaging, single-photon emission computed tomography, or positron emission tomography, if not performed during acute hospitalization)
Physical activity	During CR: — supervised prescribed aerobic exercise training with workload determined on the basis of exercise capacity and the risk of complications — resistance/strength training to improve exercise capacity and muscle strength Recommendations on physical activity levels in everyday life: — at least 30 min/day, 5 days a week of moderate-intensity physical activity (150 min/week), or 15 min/day, 5 days a week of vigorous-intensity physical activity (75 min/week), or a combination of both. In patients who cannot do exercise for 10 minutes, shorter sessions (i.e., <10 min) are appropriate
Patient counseling	— Expected outcome of CR — Atherosclerotic risk factors and their modification — Causes and course of the disease — Self-assessment of symptoms — Medical therapy — Diet — Physical activity, return to sexual activity — Return to work
Psychological evaluation	— Work and daily stress — Social support, social isolation — Depression, anxiety — Cognitive function assessment — Selection of patients with indications for psychotherapy and/or psychiatric treatment

Abbreviations: 6-MWT, 6-minute walk test; ACS, acute coronary syndrome; BP, blood pressure; CPET, cardiopulmonary exercise test; CR, cardiac rehabilitation; ECG, electrocardiogram; HR, heart rate; ICD, implantable cardioverter-defibrillator LVEF, left ventricular ejection fraction; NYHA, New York Heart Association

Table 6. Components of comprehensive cardiac rehabilitation in patients with chronic coronary syndrome [11]

Components of CR	Assessed parameters/measures
Medical interview and physical examination	— Review clinical history of disease, consider cardiovascular events, comorbidities, and imaging studies (echocardiography, coronary angiography) — Evaluate atherosclerotic risk factors and consider modification — Subjective assessment of exercise tolerance — Assess physical activity levels: domestic and recreational — Review medical therapy of coronary artery disease and comorbidities (modification of pharmacotherapy based on general guidelines, if indicated) — Psychological evaluation — Evaluation of social conditions — Physical examination with assessment of extracardiac atherosclerotic manifestations
Additional tests	— Resting ECG — Symptom-limited exercise test at baseline and after completion of the CR program — In selected cases, echocardiography and long-term ECG Holter monitoring-based on general guidelines)
Exercise training	— ECG and BP monitoring; duration of monitoring determined by the physician — Combined aerobic and resistance/strength training — 30–60 min/day sessions, at least 3–5 days a week — Exercise intensity (see chapter: Exercise training in comprehensive cardiac rehabilitation: basic concepts, contraindications, and methods)

Abbreviations: BP, blood pressure; CR, cardiac rehabilitation; ECG electrocardiogram

exercise capacity, and the quality of life of patients. Moreover, it reduces all-cause and cardiovascular mortality as well as rehospitalization rates [15, 36].

Heart failure

Rehabilitation in the treatment of patients with HF is recommended by several current guidelines [7, 37–39]. A tailored exercise program should be started as soon as the patient is clinically stable. The program starts with gradual mild mobilization including respiratory muscle and small muscle group exercise as an introduction to regular training sessions [4, 39]. Contraindications to exercise training and exercise-related risk factors are described in Chapter 2.

Baseline studies

Prior to starting a CR program, a medical interview and physical examination should be performed. Additionally, patients should undergo laboratory tests, 12-lead resting ECG, exercise test, and, if indicated, chest computed tomography, echocardiography, and long-term ECG Holter monitoring.

Developing an exercise training plan

An exercise training program is planned on the basis of functional assessment. The CPET is recommended as the gold standard, but, if unavailable, the standard exercise test or the 6-minute walk test should be performed. The patient's age, previous lifestyle, and individual preferences should be considered. An individualized training plan should also include exercise tolerance determined by the Borg rating of perceived exertion scale (moderate exertion is recommended: 10–14 on the 6–20 Borg scale).

A training session should include endurance, respiratory, and resistance/strength exercise with elements of stretching.

Endurance training

The most popular and accessible types of endurance training for patients with HF are cycle ergometer training, walking (on a treadmill or outdoor), and Nordic walking. Continuous endurance or interval training can be prescribed.

Continuous endurance training

In patients with significant impairment of exercise capacity, baseline low-intensity training of 5 to 10 minutes is recommended, gradually increased to 30, 45, and 60 minutes. The frequency is 3 to 5 times/week, with gradually increasing intensity. Exercise training should start at a level of 40% to 50% of VO_{2peak}, then gradually increase to 70% to 80% of VO_{2peak} or VO_2 reserve (i.e., a difference between resting VO_2 and VO_{2peak}). If CPET is unavailable, the training HR zone is determined on the basis of the exercise test. The recommended range is 40% to 70% of the HR reserve (i.e., a difference between resting and peak HR during the exercise test) [39].

Interval endurance training

Moderate to high-intensity exercises (10 sec–4 min) (50%–100% of peak exercise capacity) are interrupted by low-intensity or recovery intervals (1–3 min). A single training session usually consists of 4 sets of high-intensity and recovery intervals, as described above, preceded by a 5- to 10-minute warm-up and followed by a 5- to 10-minute cool-down [39].

Inspiratory muscle training

Inspiratory muscle training starts at an intensity of 30% of maximal inspiratory pressure, gradually increased (every 7–10 days) to achieve a maximal inspiratory pressure of 60%. Training duration should be 20 to 30 min/day, with a frequency of 3 to 5 sessions a week [39], This type of training can be performed using, for example, a Threshold Inspiratory Muscle Trainer. In addition, exercises targeting the breathing type and rate, as well as diaphragmatic breathing training, are appropriate.

Resistance/strength training and stretching

Impaired skeletal muscle function is one of the causes of poor exercise tolerance in patients with HF. A CR program that includes resistance/strength and stretching training prevents muscle atrophy and weakness, thus reducing disease-related cachexia. Training intensity is expressed as a percent of 1RM, defined as the maximum amount of weight that a person can possibly lift for 1 repetition. It is important to determine the time relationship between muscle contraction (1–3 s) and relaxation (e.g., a ratio of 1:2).

Training intensity should start at 30% 1RM, 5 to 10 repetitions, 2 to 3 sessions a week, 1 to 3 sets per session. Then, the intensity is gradually increased to 30% to 40% 1RM, 12 to 25 repetitions, 2 to 3 sessions a week, 1 set per session. In patients with good exercise tolerance, training intensity can be increased to 40% to 60% 1RM, 8 to 15 repetitions, 2 to 3 sessions a week with 1 set per session [39]. The development of an exercise training plan for patients with HF depending on exercise capacity, age, and lifestyle is presented in Table 7 [39].

Table 7. Development of an exercise training plan for patients with heart failure depending on exercise capacity, age, and lifestyle [39]

Exercise capacity	Age and physical activity			
	Age <65 years		Age ≥65 years	
	Active lifestyle	Predominantly sedentary lifestyle	Active lifestyle	Predominantly sedentary lifestyle
VO_{2peak} ≤10 ml/kg/min 6-MWT distance <300 m	CT, LIIT RMT RST	CT, LIIT RMT RST	CT, LIIT RMT RST	CT, LIIT RMT
VO_{2peak} >10 ml ≤18 ml/kg/min 6-MWT distance 300–450 m	CT, IT RMT RST	CT RMT RST	CT RMT RST	CT RMT
VO_{2peak} >18 ml/kg/min 6-MWT distance >450 m	CT, HIIT RMT RST	CT, HIIT RMT RST	CT, HIIT RMT RST	CT, HIIT RMT RST

Abbreviations: 6-MWT, 6-minute walk test; CT, continuous training; HIIT, high-intensity interval training; IT, interval training; LIIT, low-intensity interval training; RMT, respiratory muscle training; RST, resistance/strength training;VO_{2peak}, peak oxygen consumption on cardiopulmonary exercise test

Table 8. Data required to develop an exercise training program for patients with implantable cardioverter-defibrillator [7, 39, 40]

Patient-related data: — Indications for ICD implantation (primary, secondary prevention) — Previous arrhythmia (ventricular, supraventricular tachycardia), ICD interventions — Effect of previous arrhythmia on the hemodynamic status — Triggers of arrhythmia (e.g., myocardial ischemia) — Medication use (e.g., antiarrhythmic drugs) — NYHA functional class
Device-related data: — Arrhythmia detection threshold (ventricular tachycardia/fibrillation zone: HR in the ICD intervention zone) — Type of antiarrhythmic ICD intervention protocol — stimulation and defibrillation sequence

Abbreviations: HR, heart rate; ICD, implantable cardioverter-defibrillator; NYHA, New York Heart Association

The training program starts with shorter sessions with the aim to achieve at least the lower exercise training intensity. Then, the duration of training sessions and intensity are gradually increased until the upper exercise training intensity is achieved, depending on the patient's capabilities.

Patients with heart failure and a pacemaker, cardiac resynchronization therapy and/or implantable cardioverter-defibrillator, as well as left ventricular or biventricular assist device

Implantable cardioverter-defibrillator

A large percentage of patients with HF with reduced left ventricular ejection fraction undergo ICD and/or CRT implantation. In most patients, particularly those with CRT [7, 39, 40], rehabilitation significantly improves exercise tolerance. The exercise test (preferably CPET) is used to assess features of myocardial ischemia (except after CRT implantation), exercise tolerance, chronotropic response, arrhythmia, and HR control with medical therapy, including the risk of reaching antitachycardia pacing (ATP) and shock thresholds [7, 39, 40].

The training program should be set to maintain a maximum HR at a level of 20 bpm below the defibrillation threshold. The rehabilitation team should be trained on the management of ICD interventions [7, 39, 40].

Data that should be collected by the rehabilitation team to develop an exercise training program for patients with ICD are summarized in Table 8.

In most patients, exercise training can be started 6 weeks after implantation. This refers particularly to exercises for the shoulder girdle on the implantation side. It is generally agreed that electrode position is fully stabilized within up to 6 weeks after implantation. Prior to that, mild exercises for mobilization of the upper extremity on the implantation side can be performed to avoid frozen shoulder.

Any ICD intervention during CR should prompt a consultation with an electrophysiologist. Temporary discontinuation of CR should also be considered (especially if hemodynamic abnormalities are present, such as electrical storm). After ICD adjustment, patient response to exercise should be assessed. Rehabilitation can be continued if the patient's condition is stable and arrhythmia control is achieved [7, 39, 40].

Cardiac resynchronization therapy

Apart from general indications, the exercise test in patients with CRT pacemaker and CRT defibrillator (CRT-D) is used primarily to assess chronotropic response and stimulation outcome [39, 40].

Data that should be obtained to develop a CR program in patients with CRT or CRT-D are the same as for patients with ICD (as summarized in Table 8). Additionally, information on the upper tracking rate, upper sensor rate, and rate responsiveness (acceleration of stimulated heart rhythm response to exercise in patients with chronotropic incompetence) should be collected [7, 39, 40].

The exercise training program for patients with CRT, CRT-D, or CRT pacemaker is developed in the same way as for patients with HF and ICD. The CR team should be trained on the management of device-related events because the loss of resynchronization stimulation or an increase in HR above the upper sensor rate may result in a sudden decrease in cardiac output. This requires immediate discontinuation of the training session and CRT adjustment [7, 39, 40].

Left ventricular or biventricular assist devices

Available studies confirmed the beneficial effects of CR in patients with long-term mechanical circulatory support [41, 42]. Apart from the components of CR, patients are instructed on how to use the device, how to approach fluctuations in international normalized ratio, and how to take care of the driveline exit site. Patients with long-term mechanical circulatory support should undergo CR at an experienced center [41, 42]. Training intensity during phase II of CR should be determined on the basis of the Borg scale and exercise test results (preferably CPET or 6-minute walk test). Resistance/strength training is also recommended, particularly of the lower extremity muscles. Walking is a valuable complementary type of training [41, 42]. Jogging, rowing, crossfit, abdominal exercises, overhead shoulder exercises (such as weightlifting), and swimming are not recommended.

Apart from general contraindications to exercise-based CR [41, 42], exercise training in patients with ventricular assist devices should not be prescribed in the case of device complications during or after the training session (e.g., alarm activation, complex and frequent ventricular tachycardia, infection [particularly at the driveline exit site], bleeding symptoms, thrombotic complications) and ICD intervention.

Despite cardiac unloading, patients with a ventricular assist device have significantly lower exercise capacity, with VO_{2peak} lower than 50% of the normal value.

Pacemaker

In line with the general principles, the training program should be developed on the basis of exercise test results. Among other parameters, the exercise test allows an assessment of chronotropic response to exercise. Patients with chronotropic incompetence and rate-responsive pacemaker to increase HR during exercise constitute a specific population. In patients with normal left ventricular ejection fraction (≥55%), the optimum upper pacing rate limit was reported to reach 86% of age-predicted maximum HR, and in patients with reduced left ventricular ejection fraction (≤45%), it was 75% [43].

Patients after cardiac surgery

Comprehensive CR should be an integral component of the management of patients after cardiac surgery, including CABG, heart valve surgery, and heart transplantation. Participation in a rehabilitation program after CABG was associated with a 40% reduction in mortality [15].

Comprehensive CR in patients after cardiac surgery

Phase I CR is provided in the inpatient setting. It starts on the day of surgery at the intensive care unit and is then continued in a postoperative recovery room.

Rehabilitation includes:

- respiratory muscle exercises that should be started immediately after extubation;
- antithrombotic prophylaxis, arm and leg exercises, particularly those targeting the lower extremity after saphenectomy;
- pain treatment;
- wound care;
- gradual mobilization of the patient.

Phase II CR is provided in the inpatient setting (residential), as an outpatient service, or as hybrid cardiac telerehabilitation.

In the initial phase after the surgery, exercise capacity can be assessed using the 6-minute walk test. The symptom-limited exercise test should be performed as soon as possible [3].

Patients may develop postoperative complications that may require modifications in the CR program.

Comprehensive CR after cardiac surgery should incorporate:

- respiratory muscle exercises;
- antithrombotic prophylaxis, upper and lower extremity exercises (particularly those targeting the lower extremity after saphenectomy);
- pain treatment;
- wound care;
- physical therapy;
- optimal treatment of comorbidities;
- diagnosis and prevention of malnutrition;
- psychological support, especially in patients with sleep disorders, anxiety, depression, poor mental health, and reduced quality of life;
- postoperative follow-up (echocardiography, imaging studies, long-term Holter ECG monitoring) to identify complications and modify the rehabilitation program.

Comprehensive cardiac rehabilitation following coronary artery bypass grafting

In experienced centers, phase II CR can be started immediately after discharge from surgery facilities. Exercise training that may adversely affect sternal closure should be avoided [44].

In patients after CABG, the type and scope of exercise should be determined on the basis of the surgical access: standard sternotomy vs minimally invasive or lateral approach.

Some patients after sternotomy may benefit from the use of sternum support vests [45]. Upper body stretching exercises can be started 6 weeks after the surgery. Patients should sleep on the back for 2 to 3 months until sternal stability is achieved.

Comprehensive cardiac rehabilitation in patients undergoing heart valve surgery

Comprehensive CR following heart valve surgery using either a surgical or percutaneous method may improve exercise tolerance, functional independence, maximum exercise capacity, and quality of life [46, 47].

Patients after heart valve surgery require much more time to improve exercise tolerance compared with those after CABG. Exercise tolerance is considerably lower after mitral vs aortic valve replacement, especially in patients with pulmonary hypertension [48]. Recommendations on protection of the sternum after heart valve surgery with sternotomy are the same as for patients after CABG.

Patients after transcatheter aortic valve implantation (TAVI) should initially undergo a center-based CR program, which may be continued in the outpatient and home-based settings [11].

Comprehensive cardiac rehabilitation in patients undergoing heart transplantation

Patients after heart transplantation have a number of specific features that should be considered in CR, such as those resulting from heart denervation, including accelerated resting HR, chronotropic incompetence (i.e., inadequate acceleration of HR in response to exercise, delayed return to resting HR), elevated resting BP, peripheral effects of long-term HF (i.e., skeletal muscle atrophy and metabolic abnormalities, osteoporosis, reduced skeletal muscle strength, chemoreceptor and ergoreceptor hypersensitivity), side effects of immunosuppressive and corticosteroid treatment, increased risk of infection, and risk of acute and chronic graft rejection [49].

Differences in the CR program in this patient population are listed below.

- For testing protocols, small increments of 10 W/min on a bicycle ergometer, or ramp protocols, modified Bruce protocols, or Naughton protocols on a treadmill are appropriate.
- Exercise intensity should be determined based on the Borg rating of perceived exertion scale. The recommended intensity is 12 to 14 on the 6–20 Borg scale [11].
- Aerobic training should start at low intensity (<50% $VO_{2\ peak}$ or 10% below the anaerobic threshold) or peak workload (<50%) and gradually increase.
- The CR program should incorporate resistance/strength exercises, which increase muscle mass and bone density and prevent adverse effects of immune therapy.
- Hemodynamically stable patients should undergo CPET to guide detailed exercise recommendations.

Comprehensive CR was shown to be effective in reversing the pathophysiological effects of heart denervation and skeletal muscle atrophy as well as improving exercise capacity in this population of patients [50].

PSYCHOSOCIAL RISK FACTORS INFLUENCING THE COURSE OF CARDIAC REHABILITATION

Psychological and social factors may affect the treatment course and outcomes [4, 51, 52]. Before starting a CR program, a psychological evaluation should be performed with the assessment of the patient's psychosocial well-being and quality of life, psychopathological symptoms, lifestyle-related risk factors, attitude to the disease, and any current psychosocial problems.

The aim of clinical psychological evaluation is to identify risk factors as well as psychological resources of the patient in order to develop a management plan in cooperation with the patient and to determine a therapeutic intervention [53, 54]. A psychological interview and observation are the most important clinical tools for psychological assessment. To obtain clinical data, psychological questionnaires are recommended [55–65].

As part of psychological management, patients should be provided with individual or group counseling consistent with the goals of CVD prevention. The main areas of psychological education are the physiology of stress, methods to reduce emotional tension and develop coping skills, the effect of personality traits and lifestyle on treatment, the effect of depression/anxiety on somatic health, motivation to undergo treatment, and the role of social support. A CR program should also include behavioral counseling and relaxation techniques training (e.g., progressive muscle relaxation, guided visualizations, meditation and mindfulness, autogenic training).

Psychosocial risk factors in patients undergoing CR include adjustment disorders or psychopathological symptoms (depression/anxiety/high level of hostility) and lack of social support [66, 67]. Patients with adjustment disorders should receive psychological counseling and their relatives should be actively involved in the therapeutic process. In patients with the diagnosis of mental disorders (e.g., depression, anxiety disorder), medical therapy supported by psychotherapy should be used.

Psychological interventions are beneficial not only by improving treatment acceptance and the quality of life but also by reducing stress, depression, anxiety, and mortality of patients with CVD [4, 51–56]. The cognitive-behavioral approach has been shown to be the most effective in CR, but the choice of a psychological intervention should be tailored to the individual patient's needs and capabilities [68, 69].

SECONDARY PREVENTION OF CARDIOVASCULAR DISEASE IN PATIENTS UNDERGOING CARDIAC REHABILITATION

Secondary prevention should be one of the most important tasks in CR. It is achieved by health education, motivation to lifestyle changes, and modification of medical therapy [4, 11, 70].

Lipid disorders

The secondary prevention targets in all patients at very high cardiovascular risk are low-density lipoprotein cholesterol levels of less than 55 mg/dl and at least 50% reduction from baseline [11, 71, 72] A reduction in low-density lipoprotein cholesterol levels below 40 mg/dl is recommended in patients after a subsequent cardiovascular event. Statins are the drug of choice [71–73]. If treatment goals are not reached at the highest tolerated statin dose, the addition of a selective cholesterol absorption inhibitor, ezetimibe, is recommended, followed by a PCSK9 inhibitor (evolocumab, alirocumab). These drugs are also recommended in patients with statin intolerance [71, 72, 74–76].

If the patient reports skeletal muscle pain, it is important to differentiate the etiology between either the effect of training or the adverse effect of hypolipidemic treatment.

Lifestyle modification is recommended to support the treatment of lipid disorders.

Obesity and overweight

In all patients, reduction of excessive weight or maintenance of normal weight is recommended. Both overweight and obesity are associated with an increased risk of cardiovascular and all-cause mortality. The lowest all-cause mortality rates are reported in patients with a body mass index of 20 to 25 kg/m^2 (aged <60 years). Normal body weight in elderly people is higher than in young and middle-aged individuals [77]. In all patients with obesity and overweight, a healthy diet is recommended along with maintenance or reduction of energy intake to achieve a body mass index of 20 to 25 kg/m^2 and a waist circumference of 94 cm or lower in men and of 80 cm or lower in women [78]. As an adjunctive treatment, medical therapy (orlistat) or bariatric surgery can be appropriate [79]. Incretin therapy, originally used in patients with diabetes (glucagon-like peptide-1 re-

ceptor agonists), seems to be a promising approach in the treatment of obesity [80, 81].

Hypertension

In all patients, normal BP values should be maintained [82]. Most patients require the use of combination antihypertensive drugs. The choice of medication depends on the presence of comorbidities, among other factors.

Diabetes

The treatment of patients with diabetes is multifactorial and includes monitoring of glucose levels, lipid disorders, BP, and body mass. Although intensive treatment of high blood glucose levels reduces the risk of vascular complications, it is important to avoid episodes of hypoglycemia, especially in elderly patients. In all patients with diabetes and high blood glucose levels, secondary prevention should involve statin treatment with a reduction of low-density lipoprotein levels to reach the same targets as in very high-risk patients. Patients with type 2 diabetes and cardiovascular comorbidities were shown to benefit from treatment with canagliflozin [83, 84] and incretin drugs (glucagon-like peptide-1 receptor agonists) [85–87]. Intensive treatment of hyperglycemia reduces the risk of microvascular complications. The target glycated hemoglobin HbA_{1c} is less than 7%, with more stringent targets in young patients (≤6.5%) and less stringent targets in elderly patients due to the risk of hypoglycemia (<8% or even ≤9% in elderly individuals with multiple comorbidities, frailty, and a higher risk of hypoglycemia) [88].

Smoking

Smoking cessation, optimally during the CR, is one of the most important goals of secondary prevention [89]. It is important to identify smoking patients not only by medical interview, which in many cases is insufficient, but also by the measurement of carbon oxide levels in exhaled air and/or the measurement of urinary nicotine metabolites (cotinine). As an adjunctive treatment, the following tools may be used in addition to psychological support: nicotine replacement therapy (chewing gums, nasal spray, inhaler, sublingual tablets), oral preparations (bupropion, varenicline), and in some cases electronic cigarettes [90, 91]. Electronic cigarettes may be helpful but should be used as a bridge to smoking cessation rather than a long-term substitute [92]. Passive smoking is equally harmful and should be reduced [93, 94]. An active search for interventions and counseling on smoking cessation is recommended. Algorithms can be helpful, including the 5As model (Ask, Advise, Assess, Assist, and Arrange) [95, 96].

Low physical activity

Regular physical activity reduces all-cause mortality and improves mental health [97–100]. Individuals with a low level of physical activity should be encouraged to start regular aerobic training, initially at low intensity and gradually increased. In other cases, moderate-intensity exercise is recommended. This includes both recreational activity (brisk walking, Nordic walking, trekking, jogging, running, cycling, cross-country skiing, dancing, skating, rowing, swimming) as well as occupational activity (physical work). The workload is determined on the basis of the exercise test after completion of the CR program [101]. At least 30 to 60 minutes of moderate physical activity on most days of the week are recommended [4, 11, 70, 102]. Vigorous aerobic and resistance/strength training is preferable, complemented by whole-body training including stretching, balancing, agility, relaxation, and flexibility exercises. An effective way to support higher levels of physical activity is the use of activity trackers: bands, watches, and mobile applications.

Excessive psychological and emotional stress

Interventions aimed at reducing psychosocial risk factors may prevent psychosocial stress, depression, and anxiety, thus facilitating behavioral changes as well as improving the quality of life and prognosis [52, 103]. In patients with hostility, group training may be effective by increasing social adjustment as well as improving HR and BP control [104].

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