6. Exercise Prescription for Specific Populations

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6.1. Acute Coronary Syndromes

Acute coronary syndromes (ACSs) represent a spectrum of clinical presentations, including acute ST-segment elevation myocardial infarction (STEMI), acute non-ST-segment elevation myocardial infarction (NSTEMI), and unstable angina (UA) and are typically associated with the rupture of an atherosclerotic plaque and partial or complete occlusive thrombosis [1]. Exercise-based cardiac rehabilitation has been evaluated comprehensively in patients referred after acute MI. A meta-analysis of 36 randomized control trials, including 6111 patients after myocardial infarction, demonstrated that cardiac rehabilitation was clearly associated with a 36% reduction in cardiac deaths, a 26% reduction in total mortality, and a 47% reduction in reinfarction rate [2]. The recent meta-analyses conducted by Anderson and Ji have supported these findings [3,4]. Potential mechanisms responsible for mortality reduction entail an reduced sympathetic, then enhanced parasympathetic tone or ischemia-induced preconditioning [5]. Cardiac rehabilitation following acute coronary syndromes has received a class I indication (i.e., mandatory) in the international guidelines. It is typically delivered in the form of an outpatient program, whereas a residential cardiac rehabilitation program is recommended for:

- Patients with event- or procedure-related complications;
- Patients with severe left ventricular dysfunction;
- Patients with frailty;
- Patients who cannot attend outpatient sessions.

A phase II program following acute coronary syndrome should incorporate patient assessment, including the evaluation of the arterial puncture site; functional capacity and angina threshold assessment based on a symptom-limited exercise test; exercise training; dietary counseling; body mass control; lipid management; blood pressure management; smoking cessation; and psychosocial support. The scope of early mobilization was described earlier in this book. Phase II should begin as soon as possible after an acute event. Patients diagnosed with myocardial infarction or unstable angina who have undergone percutaneous coronary intervention should optimally commence a cardiac rehabilitation program within the first 14 days after hospital discharge, and this period can be prolonged in the case of patients with multiple risk factors, with a complicated course of disease, or who are at high risk [6].

Phase II with medically supervised exercise training typically includes 2–3 sessions per week for outpatients and 5–6 sessions per week for residential and hybrid cardiac rehabilitation patients. Each session usually lasts 30–60 min. General rules of exercise training following the FITT-VP formula have been described elsewhere [7]. Moderate-intensity aerobic exercise (45–59% of peak oxygen consumption, 55–69% of peak heart rate, 40–59% of heart rate reserve, 4–6 METs, or 12/20–14/20 on the Borg scale) is initially recommended for low-risk patients. Intermediate- and high-risk patients should begin exercise at an intensity of 40% of heart rate reserve [7,8]. High- and maximal-intensity interval training for patients following acute coronary syndromes has recently been an object of research. After 2 weeks of moderate-intensity training (as an adaptation phase), patients exercised at 95–100% of their heart rate reserve (maximal-intensity training) or at 85% of their heart rate reserve (high-intensity training) 3 days per week for 4 weeks. The primary outcome was maximal oxygen uptake. The secondary outcomes were major cardiovascular complications. After six weeks of aerobic interval training, maximal oxygen uptake increased significantly in both groups, with a greater increase seen in maximal-intensity effort. Furthermore, no major cardiovascular or musculoskeletal complications were noted [9].

6.2. Chronic Coronary Syndromes

Chronic coronary syndromes are defined as occurring in patients with stable angina, patients who are symptomatic >1 year after initial diagnosis or revascularization, and patients with angina and suspected vasospastic or microvascular disease [7]. The most frequently observed clinical picture of stable coronary artery disease is the occurrence of recurrent, transient episodes of chest pain at a certain level of exertion that can be relieved with rest or nitroglycerin. Thus, stable angina reflects a mismatch between demand and supply [10]. The beneficial effect of regular physical exercise as part of a multifactorial intervention in terms of improving symptom-free exercise tolerance and myocardial perfusion in patients with stable coronary artery disease and the deceleration of the disease progression over time have been documented [11,12]. One of the most influential accounts came from a study by Humbrecht. A randomized study was designed with the aim of comparing the effects of exercise training versus standard percutaneous coronary intervention with stenting on clinical symptoms, angina-free exercise capacity, myocardial perfusion, cost-effectiveness, and the frequency of a combined clinical end point (death of cardiac cause, stroke, coronary artery bypass graft surgery, angioplasty, acute myocardial infarction, and worsening angina with objective evidence resulting in hospitalization). A total of 101 male patients aged $\leq$70 years were enrolled following routine coronary angiography and randomized to 12 months of exercise training—i.e., 20 min of bicycle ergometry per day—or to percutaneous coronary intervention. Compared with the coronary intervention group, 12 months of regular physical exercise in patients with stable coronary artery disease resulted in a superior event-free survival (with 70% in the PCI group and 88% in the training group). The exercise intervention was associated with a higher exercise capacity and maximal oxygen uptake after 12 months than in the PCI group (the maximal exercise tolerance increased significantly by 20%, while maximal oxygen uptake increased by 16%). It is noteworthy that no adverse events were recorded during the training sessions in any patient [13].

Exercise-based cardiac rehabilitation is recommended by the American College of Cardiology/American Heart Association and the European Society of Cardiology for patients diagnosed with chronic coronary syndromes to help them manage risk factors and to reduce recurrence of the disease; however, the referral and program participation rates remain suboptimal compared with those seen in patients after acute coronary syndromes. This relates particularly to patients with multiple risk factors, women, and the elderly [14,15]. The progress of early mobilization and exercise training for patients with stable angina depends on the clinical situation the coronary intervention has been performed for, the patient's clinical status after the procedure, their revascularization level, and the presence of complications related to the puncture site (i.e., bleeding, hematoma, fistula, infection). A moderate- or moderate-to-high-intensity exercise regimen is typically utilized [6,16]. Supervised exercise training principles were described earlier in this book in a dedicated chapter.

6.3. Coronary Artery Bypass Graft Surgery

All patients undergoing coronary artery bypass graft surgery should be referred to a cardiac rehabilitation program due to its beneficial effects, as confirmed in numerous studies [17,18]. In an observational trial of 846 patients after coronary artery bypass graft surgery (CABG), 69% of whom participated in a cardiac rehabilitation program, after a mean follow-up of 9 years, a 46% relative risk reduction and a 12% absolute risk reduction in all-cause mortality were reported. These findings were independent of age, sex, prior myocardial infarction, or the presence of diabetes [19]. In another study including 3975 patients after CABG, an all-cause mortality reduction of 20% with in-patient cardiac rehabilitation and 40% with supervised exercise training were observed [20]. The principles of in-patient prehabilitation followed by post-operative early mobilization and combined aerobic, resistance, and inspiratory muscle training have been extensively studied [21]. The details of phase I cardiac rehabilitation were depicted earlier in this book. Phase II of cardiac rehabilitation should optimally begin four weeks after coronary artery bypass graft surgery and may commence earlier in a center experienced with patients who have undergone cardiac surgery. The duration of the exercise training program should be individualized, depending on the patient's profile (i.e., age, fitness level, risk factors, adherence), but at minimum, it should include at least 24 sessions [22]. Patients undergoing coronary artery bypass graft surgery are typically older, present with comorbidities, and have a lower functional capacity level. Prior to commencing exercise training, a functional capacity assessment should be performed in the form of a six-minute walk test, symptom-limited exercise test (optimally four weeks after surgery), or submaximal exercise test (with a target of 70% of maximal heart rate). The maximal exercise test should not be executed within the four weeks following CABG. The exercise training program following CABG results in numerous cardiovascular and peripheral adaptations, including improved blood flow in exercising muscles, enhanced oxidative capacity of the working skeletal muscles, and the correction of endothelial dysfunction in the skeletal muscle vasculature. The supervised exercise training prescription should be based on clinical conditions, exercise capacity, left ventricular performance, and the type of surgery performed [6]. Thus, the postoperative rehabilitation principles are determined by many factors. The authors recommend enrolling patients after CABG into corresponding aerobic ABCD training models, as described earlier, in relation to their clinical outlook, their echocardiographic left ventricular performance, the presence of arrhythmia or ischemia, their functional capacity level, the presence of surgery-related complications, and their comorbidities (Table 43). As described earlier in a chapter concerning risk stratification, all characteristics listed must be present for patients to remain low-risk, whereas even one of characteristics listed places patients as moderate- or high-risk. The principles of strength training following cardiac surgery, including adequate timing and the acceptable load, can be found earlier in this work in the chapter dedicated to resistance training.

Table 43. Rehabilitation models for patients after cardiac surgery.

Risk Factor	Low Risk A Model	Intermediate Risk B Model	High Risk C or D Model
Left ventricular systolic function	Preserved LVEF 50% or more	Moderately impaired LVEF 36%–49%	Severely impaired LVEF 35% or less
NYHA class	NYHA I	NYHA II	NYHA III, IV
Complex ventricular arrhythmia	Absent at rest and during exertion		Present at rest and during exertion
Atrial fibrillation	Absent	Present, ventricular rate controlled	Present, ventricular rate uncontrolled
Ischemic ECG changes on exertion	Absent	ST-segment depression 1–2 mm	ST-segment depression 2 mm or more
Functional capacity	7 METS or more 100 watts or more 6 MWT > 400 m	5–6.9 METS 75–100 watts 6 MWT 250–400 m	<5 METS <75 watts 6 MWT < 250 m
Exertional hemodynamic response	Normal		Lack of increase or decrease in systolic blood pressure or heart rate during increasing intensity
Clinical data and complications			
Time from surgery	>3 weeks	2–3 weeks	<2 weeks
Type of the surgery	Mini invasive		Complex, multistage
Wound healing	Proper healing	Healing difficulties	Infected wound
Sternum	Stable	Re-fixation	Unstable
Pericardial and pleural effusion	Small effusion		Large effusion
Pneumonia, bronchitis	Absent		Present
Anemia	Mild		Severe
Comorbidities			
Diabetes mellitus	Controlled		Uncontrolled
Hypothyroidism Hyperthyroidism	Controlled		Uncontrolled
Renal failure	GFR > 60 mL/min	GFR 31–60 mL/min	GFR < 30 mL/min
Disability	Mild		High degree

Abbreviations: CABG—coronary artery bypass grafting; ECG—electrocardiogram; GFR—glomerular filtration rate; LVEF—left ventricular ejection fraction; METS—multiples of resting metabolic equivalent; 6 MWT—six-minute walk test; NYHA—New York Heart Association. Source: Adapted from [23].

6.4. Valve Surgery

6.4.1. Rationale

The epidemiology of valve disease has changed, and degenerative valve disease dominates nowadays in operating theaters, indicating the ageing surgical population and the challenges of the rehabilitation process [24]. Benefits of the cardiac rehabilitation program after valve surgery in terms of short-term physical capacity improvement and an earlier return to work have been documented, with a beneficial effect on peak oxygen uptake seen at 4 months—i.e., 24.8 mL/kg/min, compared with 22.5 mL/kg/min for a usual care group [25]. Therefore, a cardiac rehabilitation program should be offered to all patients after valve surgery, including those who have undergone percutaneous interventions, i.e., following percutaneous valve replacement, repair, the implantation of clips, etc. [7]. A multidisciplinary team should be involved in the cardiac rehabilitation program after valve surgery, particularly for patients with a postoperative course complicated by heart failure [26]. Valve surgery is typically performed during the symptomatic period, typically at the advanced stage of heart failure; thus, the improvement in the functional capacity and the left ventricular systolic function is extended over time [6]. Exercise tolerance after mitral valve replacement is much lower than that after aortic valve replacement, particularly in the presence of residual pulmonary hypertension [26]. Transcatheter aortic valve implantation (TAVI) has recently been implemented as the procedure of choice for elderly patients with severe aortic stenosis and a high perioperative mortality risk for surgical aortic valve replacement. Moreover, TAVI seems to also be non-inferior to surgical valve replacement in patients at intermediate surgical risk [27,28]. Existing data on transcatheter aortic valve replacement and exercise-based cardiac rehabilitation programs are limited (mainly due to the low enrollment, compared with surgical replacement, and a lack of consistency). In an observational trial evaluating the effects of eight weeks of combined endurance and resistance training in a group of elderly TAVI patients, compared to those given usual care without structured exercise, significant improvements in exercise capacity, muscular strength, and quality of life in the exercise group were observed. In addition, the exercise training did not affect negatively prosthetic valve function, whereas, in a recent trial, exercise training resulted in preserved long-term improvements, compared to usual care, in oxygen uptake at the anaerobic threshold but not in peak oxygen uptake, muscular strength, or quality of life [29,30].

6.4.2. Exercise Prescription

The general rules of the cardiac rehabilitation program implemented after valve surgery are analogous to those described for post-CABG. The individual rehabilitation plan is based on [6,31]:

- The patient's clinical status before the surgical correction of valve disease (symptom duration, hemodynamic abnormalities, cardiac rhythm, thrombo-embolic complications, orthopedic and vascular disorders);
- The type of surgery;
- The surgical wound status;
- The presence of early postoperative complications.

Phase I of cardiac rehabilitation taking place in the intensive care unit and in cardiac surgery departments is typically prolonged compared with post-CABG. Phase II is recommended to be implemented within a few weeks after surgery and should optimally last for 8–12 weeks. For patients with heart failure complications in their postoperative course, a residential program should be offered, if available. Patients who have undergone an uncomplicated replacement of their aortic and mitral valves can begin phase II after two and three weeks, respectively [32].

The initial assessment before commencing exercise training should involve echocardiographic assessment—i.e., assessment of the transvalvular pressure gradient, grade of valvular insufficiency, and presence of pericardial effusion [7]. Typically, the low to moderate aerobic training intensities are utilized initially. The Borg scale is a useful adjunct in the case of patients with atrial fibrillation. The anticoagulation regimen is of special importance after the implantation of mechanical valves, and patients should be educated about adequate anticoagulation rules.

6.5. Heart Failure

6.5.1. Rationale

The low exercise tolerance observed in patients with heart failure is a consequence of their diminished exertional response of cardiac output, impaired vasodilation, and increased systemic vascular resistance [33,34]. Based on physical capacity levels, patients diagnosed with heart failure can be classified into three groups [35]:

- Patients with significant impairment of functional capacity (peak oxygen uptake in CPET < 10 mL/kg/min, 6 MWT distance < 300 m);
- Patients with moderate impairment of functional capacity (peak oxygen uptake 10–18 mL/kg/min, 6 MWT distance 300–450 m);
- Patients with good functional capacity (peak oxygen uptake > 18 mL/kg/min, 6 MWT distance > 450 m).

All patients diagnosed with heart failure at NYHA class I-III, irrespective of their left ventricular ejection fraction value, should be referred to a cardiac rehabilitation program [36,37]. Improvements in exercise capacity, symptoms, and quality of life and reductions in the hospital re-admission rate after participation in a cardiac rehabilitation program in patients with heart failure have been documented [38,39]. The quantitative beneficial effects of cardiac rehabilitation have been depicted and include [40,41]:

- An increase in maximal oxygen uptake by 2.1 mL/kg/min;
- An increase in exercise duration by 2.3 min;
- An increase in peak work rate by 15 watts;
- An increase in walking distance at 6 min walk test by 40 m.

6.5.2. In-Patient Phase

In-patient rehabilitation should begin as soon as possible after hospital admission [40]. Once a patient's clinical stability is attained, gradual mobilization (calisthenics exercises with simple movements, without weights or equipment) should commence to increase body strength and flexibility. The resistance training of small muscle groups should be also implemented, with the initial intensity kept below 30% of the one repetition maximum. Inspiratory muscle training is essential [42]. The plan suggested depends on patients' hemodynamical status and the stage of the disease (as presented in Table 44).

Table 44. In-hospital early mobilization model for patients with heart failure.

Period	The First	The Second	The Third
Duration	1–3 days	4–6 days	>6 days
Exercise Duration	2–3 × 10 min	2–3 × 15–20 min	1 × 20–25 min
Mobilization Program	Passive sitting in bed	Sitting in the bed with legs outside, standing	Sitting, Standing
Respiratory Exercises	Prolonged exhaustion, exercises with resistance	Intensive inspiration and exhaustion with resistance	As in the second period

Table 44. *Cont.*

Period	The First	The Second	The Third
Exercises	Passive, active assisted exercises of the lower extremities, stretching, active dynamic exercises of of small to major muscle groups	Passive, active assisted exercises of the lower extremities, dynamic exercises of the upper and lower extremities, balance exercises	Increase in: repetitions, sets, pace
Moving		Walking around a room (10–15 m)	Increased distance of walking, intermittent walking of 30–60 m/ 3–5 times daily Climbing up stairs (up to 2 flights of stairs)

Source: Adapted from [23].

6.5.3. Phase II Initial Assessment

There is no consensus regarding the optimal timing for the initiation of exercise training, with the typical practice for most cardiac rehabilitation centers being beginning at least one month after a decompensation episode [43]. Knowledge of the underlying cause of heart failure, recent pharmacotherapy, and the current functional capacity level before commencing an exercise program is essential. Detailed physical examination should assess signs of pulmonary congestion or peripheral edema. The initial exercise intensity should preferably be based on cardiopulmonary testing (the gold standard for patients with heart failure), utilizing the Naughton or modified Bruce protocol on a treadmill or an incremental or ramp protocol on a bicycle ergometer with a load increase of 5–10 W/min [7]. The exercise intensity should be set with relation to the ventilatory threshold, as was extensively discussed in the exercise intensity chapter of this book. If CPET is unavailable, intensities of 40%–70% of heart rate reserve and Borg scale values of 10–14 are recommended.

Contraindications to the commencement of exercise training for individuals with heart failure include [32,35]:

Absolute contraindications:

- Acute coronary syndromes within 2 days;
- Lack of clinical stability within the previous 12 h, including increased shortness of breath over the previous few days, resting heart rate above 120–130/min,

uncontrolled blood pressure (SBB above 180 mmHg, DBP above 120 mmHg), hypotension, resting angina, new resting ischemic ECG changes, new onset of unstable hemodynamically atrial fibrillation, an advanced atrioventricular block without a pacemaker, and acute heart failure;
- Uncontrolled diabetes mellitus;
- Acute systemic illness or fever;
- Recent pulmonary embolism or thrombophlebitis;
- Active endocarditis or pericarditis;
- Valve insufficiency for surgical treatment;
- Moderate and severe aortic stenosis;
- Complex arrhythmias without treatment;
- Intracardiac thrombus;
- Uncontrolled thyroid function.

Relative contraindications:

- Body mass increase over 1.8 kg in the last 1–3 days;
- Intravenous inotropes infusion;
- Drop in blood pressure with exertion;
- NYHA class IV;
- Resting heart rate > 100 bpm in the supine position;
- Complex ventricular arrhythmias at rest or during exertion;
- Oxygen saturation < 85–90%;
- Severe pulmonary hypertension (mean pulmonary arterial pressure > 55 mmHg);
- New left bundle branch block.

Training should be stopped with a subsequent intensity modification in the case of excessive fatigue, a significant increase in systolic blood pressure with symptoms of exercise intolerance, a blood pressure drop with exercise, the presence of exercise-induced supraventricular or ventricular arrhythmias, a significant reduction in oxygen saturation, or after ICD intervention.

6.5.4. Exercise Prescription

The principles of exercise were described in detail in this book in a chapter dedicated to exercise prescription for high-risk patients. The initial duration and frequency of aerobic training should be based on the functional capacity level [35]:

<3 METs (<0.5 watt/kg): 5–10 min exercise in a few sessions per day;
3–5 METs (0.5–1.2 watt/kg): 15 min sessions 1–2 times a day;
>5 METs (>1.2 watt/kg): 20–30 min once a day.

For patients with very low functional capacity, frequent short bouts of low-intensity exercise are suggested initially ("start low and go slow"). Regular body weight monitoring is important so as not to ignore fluid retention. Moderate-intensity continuous endurance training is recommended as a baseline protocol. If interval training is prescribed, low-intensity bicycle ergometer training with 30 sec hard segments at 50% of workload and 1 min recovery segments below 20 watts is utilized [7].

With training progression, the primary goal in an interval regimen is to increase the duration up to 30 min and change the work-to-recovery ratio of 1:2 to 1:1 (by increasing the duration of active segments and/or shortening the recovery time). In continuous exercise, after attaining the duration of the conditioning phase of 40–60 min, exercise intensity should be increased subsequently. Selected patients can progress on to HIIT [44].

Resistance training usually includes a work-to-rest ratio of 1:2—i.e., 30–60 s of exercise with a subsequent 1–2 min rest. Resistance training progression should be phasic [7,35]:

- Stage 1 to learn the technique includes: 5–10 repetitions at 20–30% of one repetition maximum (Borg < 12), 2–3 sessions per week, 1–3 sets.
- Stage 2 to improve endurance includes: 12–25 repetitions at 30–40% of one repetition maximum (Borg 12–13), 2–3 sessions per week, 1 set.
- Stage 3 to increase muscle mass includes: 8–15 repetitions at 40–60% of one repetition maximum (Borg < 15), 2–3 sessions per week, 1 set.

Full training progression requires at least 3–4 weeks.

Inspiratory muscles training is essential, particularly during the in-patient phase. Typically, 30% of the maximum inspiratory mouth pressure is recommended initially, being increased every 7–10 days, with a target of 60%. Such training lasts for 20 min daily, 3–5 days a week, for 8 weeks [42].

The European Association of Cardiovascular Prevention and Rehabilitation summary of exercise training for patients with heart failure is presented in Table 45 [35].

Table 45. EACPR exercise training prescription for patients with heart failure.

Functional Capacity Level	<65 Years Active	<65 Years Sedentary	>65 Years Active	>65 Years Sedentary
VO_2 peak < 10 mL/kg/min or 6 MWT < 300 m	Continuous endurance Respiratory Resistance Low-intensity interval	Continuous endurance Respiratory Resistance Low-intensity interval	Continuous endurance Respiratory Resistance Low-intensity interval	Continuous endurance Respiratory Low-intensity interval
VO_2 peak 10–18 mL/kg/min or 6 MWT 300–450 m	Continuous endurance Respiratory Resistance Interval	Continuous endurance Respiratory Resistance	Continuous endurance Respiratory Resistance	Continuous endurance Respiratory
VO_2 peak > 18 mL/kg/min or 6 MWT > 450 model	Continuous endurance Respiratory Resistance High-intensity interval	Continuous endurance Respiratory Resistance High-intensity interval	Continuous endurance Respiratory Resistance High-intensity interval	Continuous endurance Respiratory Resistance High-intensity interval

Abbreviations: EACPR—European Association of Cardiovascular Prevention and Rehabilitation; VO_2—oxygen uptake; 6 MWT—six-minute walk test. Source: Reprinted from [35].

6.6. Implantable Cardiac Electrical Devices

6.6.1. General Remarks

A growing number of patients referred to cardiac rehabilitation have implanted cardiac electrical devices—i.e., a permanent pacemaker (PPM), cardiac resynchronization therapy (CRT), or an implantable cardioverter-defibrillator (ICD). Patients with PPM, CRT, or ICD are considered eligible for cardiac rehabilitation programs [45,46]. Exercise training in this group of patients can be implemented safely, and evidence shows that cardiac rehabilitation can almost double physical capacity after CRT implantation [47,48]. The exercise training of patients with implanted cardiac electrical devices requires special attention from cardiac rehabilitation staff, as apart from the supervision of the exercise training, adequate knowledge about the proper functioning of the devices is essential [49]. During phase I of cardiac rehabilitation, attention is required to prevent extensive movements on the side of the implant to avoid strain and lead fracture. Upper-body-strength-targeted exercise may cause the dislodgement of implanted lead; thus, resistance training is not recommended for 4–6 weeks after device implantation [7]. Upon admission to phase II, an initial assessment should involve evaluation of the indication for the implantation; assessment of the presence of underlying heart disease, including events that have occurred; wound inspection; and the determination of the device position. Device interrogation is essential, particularly of the firing mode for ICD or CRT with a defibrillator (CRT-D). As heart rate during exercise should not exceed the ICD therapy threshold, the upper limit of the training heart rate should be set between 10 and 20 beats/min below the detection threshold [50]. Other important device parameters include sensing, pacing threshold, pacing percentage, and arrhythmia record. Functional capacity assessment should be performed as a symptom-limited test, preferably a cardiopulmonary exercise test, in order to provide additional information about chronotropic response to exercise, exercise-induced arrhythmias, and maximum tracking rate [51]. Exercise prescription for cardiac electrical devices recipients may follow the rules for heart failure patients, considering the upper limits of the device, and should incorporate the continuous endurance or interval model, last for 30–60 min, and be performed 3–5 days a week. Resistance training can begin after 6 weeks and include 2–3 sets of 10–12 repetitions per set at 40–70% of one repetition maximum and a rate of perceived exertion of 12–15, with attention paid to shoulder movements on the side of the implant.

6.6.2. Special Considerations

Permanent Cardiac Pacemaker

Before the start of phase II, stimulation parameters should be analyzed. Patients should notify cardiac rehabilitation staff about any symptoms that may be related to incorrect stimulation (such as palpitations, syncope, or dizziness).

Cardioverter-Defibrillator

An initial assessment should include the patient's history of ICD shocks and the relation of dysrhythmias and ICD shocks to exertion. Continuous ECG monitoring is mandatory during exercise sessions involving ICD recipients, and the upper limit of the training heart rate should be set 10–20 bpm below the fire rate. Exercise training is contraindicated in the presence of uncontrolled ventricular arrhythmias. If ICD intervention occurs during exercise training, the session must be stopped, and ICD control and the consultation of an electro-cardiologist are mandatory. Exercise sessions should be resumed rapidly after a change in pharmacotherapy and/or the reprogramming of the device to avoid ICD discharge becoming a psychological barrier to physical activity [52].

Cardiac Resynchronization Therapy

Exercise training should follow the rules of training for individuals with heart failure (in the case of CRT device with defibrillation function—i.e., CRT-D—the additional rules for ICD recipients apply). The cardiac rehabilitation team should know the type of device inserted (CRT or CRT-D) and the upper tracking limit value (stimulation with conduction 1:1). Some important points should be taken into accounts during exercise in CRT recipients—e.g., that exercise can induce sinus tachycardia above the upper tracking limit, leading to the inadequate tracking of the sinus rhythm, or that changes in atrio-ventricular conduction can cause a loss of resynchronization [53].

6.7. Heart Transplantation

6.7.1. General Remarks

Heart transplantation is considered the gold-standard treatment for selected patients with end-stage heart failure despite optimal medical therapy [37]. Aerobic exercise training revokes the pathophysiological consequences related to cardiac denervation and prevents immunosuppression-induced adverse effects in heart transplant recipients [54]. Postulated exercise-induced beneficial effects include oxygen extraction, an increase in cardiac output, and reduced neurohormonal activity [55]. Numerous studies have demonstrated a significant increase in cardiorespiratory fitness following heart transplantation—e.g., in a trial of 27 cardiac transplant recipients randomized to supervised exercise training, a 4.4 mL/kg/min (49%) increase in maximal oxygen uptake was reported at 6 months, compared with the increase of 1.9 mL/kg/min (18%) seen in the control group [54,56]. Cardiac rehabilitation, however, is challenging in the early post-operative period, due to patients' physical deconditioning, muscular atrophy, and low exercise capacity. The denervation of the donor's heart results in [32]:

- An increased resting heart rate;
- Heart rate increase occurring (slowly) only by increased circulating catecholamines due to the lack of sympathetic denervation, and this increase is slow;
- The prolonged return of the heart rate to resting values after exercise;
- Silent ischemia, with denervation preventing the transplant recipient from experiencing chest pain.

6.7.2. Exercise Prescription

In-hospital phase [37,56].

Early mobilization should be initiated as soon as possible after hemodynamic stability is achieved and after the patient has been weaned from intravenous therapy [40]. Walking progressively increasing distances is typically implemented alongside the monitoring of vital signs and perceived exertion. At discharge, patients who have undergone heart transplantation should be able to walk for a period of

40–60 min, inducing moderate fatigue, 4–5 times a week [7]. In addition, the exercise regimen should include resistance (low loads), flexibility, and respiratory training [6]. Recommendations concerning personal hygiene and the importance of reducing the risk of infection should be discussed with the patient. These include good dental hygiene, frequent hand washing, avoiding contact with potential sources of infection (i.e., persons with active infection; decaying plants, fruits, or vegetables; swimming pools). Patients should be notified about the clinical symptoms of potential acute transplant rejection—i.e., changes in blood pressure, changes in heart rate, increased body mass, or impaired fitness level [7]. Prehabilitation principles prior to cardiac surgery were described earlier in this book.

Phase II

Initial assessment should entail in particular:

- Heart failure etiology and duration;
- Transplant rejection episodes and details of immunosuppressive treatment, including side-effects;
- Result of recent heart biopsy;
- Wound healing;
- Heart failure signs and symptoms.

Functional capacity assessment utilizing cardiopulmonary exercise test, if available, is recommended as the gold standard, with small increments of 10 Watts or modified Bruce/Naughton protocols implemented on a treadmill. Exercise tests can be performed safely four weeks after heart transplantation, as can exercise training programs for heart transplant recipients.

Exercise prescription for heart transplant recipients should comprise all components and occur at a residential cardiac rehabilitation department, in cooperation with the cardiac surgery department [57]. Aerobic training can begin in the second or third week after heart transplantation and should incorporate prolonged warm-up and cool-down phases with relation to the pathophysiological consequences of the denervation of the heart. An initial exercise intensity of 10% below the anaerobic threshold in the case of CPET or below 50% of the maximal workload attained during the exercise test is recommended; however, due to the denervation of the heart rate, the patient's perceived level of exertion and respiratory rate should guide exercise rather than their specific heart rate [8]. Resistance training is essential to reverse muscular atrophy and should include 2–3 sets of exercises with 10–15 repetitions per set at 50% of one repetition maximum, with breaks of at least 1–2 min occurring between the sets. Training progression should be conducted to 70% of 1-RM.

The AACVPR exercise prescription for heart transplant recipients is presented in Table 46 [6].

Table 46. AACVPR exercise prescription after heart transplant.

Type	Frequency	Intensity	Time
Warm-up, cool-down, range of motion, low-intensity aerobic	Each session	RPE < 11	>10 min
Aerobic first 6 weeks after surgery: walking, cycle ergometer at 6 weeks, including combination arm and leg ergometer, elliptical, rower, arm ergometer, jogging	5–7 sessions/week, 3 supervised, 2 or more independent	RPE 12–16 (if heart rate response to exercise has normalized, 50%–80% of HRR)	Begin with >5–10 min per session, increasing in 5 min steps to 30–60 min per session
Strength	2 or 3 sessions/week on nonconsecutive days	First 6–8 weeks after surgery: <10 lbs for upper extremities; otherwise, RPE 12–16	1–3 sets, 8–15 slow repetitions per set

Abbreviations: AACVPR—American Association of Cardiovascular and Pulmonary Rehabilitation; RPE—rating of perceived exertion. Source: Reprinted from [6].

6..8. The Elderly

6.8.1. Rationale

Ageing leads to a growing number of elderly patients with cardiac disease and increased rates of comorbidities, cognitive impairment, and frailty [58]. Although the reduced exercise capacity and risk profile of the elderly indicate their need for cardiac rehabilitation, they are often excluded from large meta-analyses and subsequently are insufficiently represented in cardiac rehabilitation programs [3]. In observational studies, cardiac rehabilitation has been found to improve functional capacity, the cardiovascular risk factor profile, and patients' quality of life. Other registries have demonstrated the reduced rates of mortality and hospitalization in the elderly, but the observational nature of these studies may be associated with selection bias [59]. The main aims of cardiac rehabilitation in the elderly are the maintenance of mobility and independence and the prevention of frailty.

6.8.2. Initial Assessment

Elderly patients typically present with a low functional capacity and reduced muscle power, which make them prone to falls. Other frequently observed comorbidities and problems related to ageing include the presence of osteoarthritis; chronic obstructive pulmonary disease; dementia; problems with sight, hearing, and balance; and urine incompetence [60]. Entry assessment should include, particularly in patients over 75 years of age, multidimensional geriatric evaluation (MGA) to exclude the possibility of disability, frailty, and cognitive problems [61]. MGA has been incorporated in programs to determine the presence of medical, psychosocial, functional, and environmental problems in elderly patients. Specific measures of MGA include:

- Basic activities of daily living—e.g., Katz activities of daily living (for an assessment of self-care and mobility);
- Instrumental activities of daily living—e.g., Lawton instrumental activities of daily living (used to assess activities such as shopping, cooking, or solving financial issues);
- Social support (social network);
- Mental health—e.g., Geriatric Depression Scale (degree of anxiety, depression, etc.) or Mini-Mental State Examination (for the assessment of cognitive function);
- Gait and balance—e.g., the get up and go test (used to assess the risk of falls);
- Nutritional adequacy—e.g., multi-nutritional assessment;
- Grip strength;
- Comorbidities.

The Fullerton test, or Senior Fitness Test, is frequently utilized to assess the strength, flexibility, coordination, speed, balance, and endurance of elderly patients [62]. It includes the 30 s chair stand test, arm curl test, chair sit-and-reach test, back scratch test, eight-foot and go test, and six-minute walk test (or two-minute step test).

The 30 s chair stand test is suitable for the assessment of lower body strength and reflects daily activities such as climbing stairs or getting out of a chair. The number of full stands completed in 30 s with arms folded across the chest is counted. The norm is eight or more unassisted stands for both men and women.

The arm curl test is suitable for the assessment of upper body strength and reflects daily tasks such as lifting and carrying things. The number of biceps curls completed in 30 s is counted (with hand weights of 5 lbs. (2.2 kg) for women and 8 lbs. (3.6 kg) for men). The norm is 11 or more.

The chair sit-and-reach test is utilized for the assessment of the lower body flexibility. From a sitting position at the front of the chair with one leg extended and hands reaching toward the toes, the distance between the fingers and the tips of the toes is measured. The norm is less than 4 inches (10 cm) for men and less than 2 inches (5 cm) for women.

The back scratch test is used for the assessment of upper body flexibility, aiming to reflect daily activities such as combing one's hair or reaching for a seat belt. With one hand reaching over the shoulder and the other up in the middle of the back, the number of inches between the extended middle fingers of both hands are counted. The norm is less than 4 inches (10 cm) for men and less than 2 inches (5 cm) for women.

The eight-foot and go test assesses agility and dynamic balance. The number of seconds required to get up from a seated position, walk 8 feet (2.44 m), turn back, and return to a seated position is counted. The norm is less than 9 s for both men and women.

The six-minute walk test and the two-minute step test principle were described earlier in this book, with norms of >320 m and 65 steps or more, respectively.

6.8.3. Exercise Prescription

If frailty and cognitive problems can be excluded, an exercise program with an individually tailored intensity and based on an aerobic component associated with resistance, flexibility, and balance training is executed. Aerobic training following the "start low and go slow" formula is recommended, with the duration of the first few sessions being as short as 15 min [16]. Training should include adequate durations of warm-up and cool-down phases. Low-intensity exercises are safe and reduce injury risk, but older patients can also benefit from moderate-intensity training. The initial workload can be increased after a few weeks of conditioning to moderate intensity, if tolerated. Due to age-related chronotropic incompetence, heart-rate-lowering drugs, and sedentary lifestyles, the maximal heart rate of elderly patients is typically lower than that of younger patients; therefore, what can be considered light exercise for younger patients can be considered moderate exercise for elderly patients. Heart rates cannot be utilized to determine workload in the case of atrial fibrillation, and the Borg scale is utilized with the goal of 11–13 [63]. A session duration of 30 min, 3–4 times a week, with a total program duration of 12 weeks is recommended. Resistance training on alternate days of aerobic session utilizing a multi-weight machine is recommended to stabilize body position when lifting weights [64]. A very low load should be used initially and increased, if tolerated, to a moderate intensity, with 8–12 repetitions. The set can be repeated once or twice, with a 10 min break between the two. If the patient has not attended several consecutive sessions, resistance training should be resumed at 50% of the previous load. A light to moderate intensity (30–70 and 1-RM) is recommended. Patients should avoid rapid postural changes so as not to evoke orthostatic hypotension. Flexibility and neuromotor exercises are integral parts of exercise programs for the elderly—e.g., tai chi, which incorporates both components, can be performed twice a week for 10–15 min.

6.8.4. Frailty

Frailty is a geriatric syndrome characterized by impairment in physical, psychological, and social abilities. Frailty has been demonstrated as a strong predictor of mortality, morbidity, and hospitalization [65]. Several models for frailty screening have been proposed, with MGA, the phenotypic Freid model, and the deficit accumulation model being widely adapted [66]. The Freid phenotype model includes nutritional status (non-intentional weight loss of at least 4.5 kg in the previous year), self-reported physical exhaustion, low energy expenditure (kcal expended per week), mobility level (gait speed for a few meters of walking), and muscular strength (assessed by handgrip). Each component is scored as 1 if present, with a total of 1–2 points for a pre-frail state and frailty recognized in those who score 3 or more points. The true incidence of frailty in cardiac rehabilitation is unknown; however, cardiac rehabilitation is recommended for frail patients with a resistance component in addition to endurance, balance, and flexibility components to improve their physical capacity and muscular strength, reduce their risk of falls, and preserve their independence [67]. Exercise sessions should be individually tailored to the patient's level of functional impairment. Patients with frailty usually cannot perform baseline exercise stress tests or cardiopulmonary tests; therefore, the intensity of aerobic training, performed on alternate days of resistance exercise, should be set at a heart rate slightly lower than that attained during the 6-min walk test. For patients who are unable to perform the 6 MWT, bed mobilization and walking with support remain training targets [68].

Resistance exercise improves muscular strength and reduces the risk of falls in patients with frailty. The strength program protocol proposed by Vigorito et al. is summarized in Table 47 [69].

Table 47. Resistance training recommendations for frail patients [69].

Type of exercise	Reduced Number of Muscle Groups Involved, Particularly Lower Extremities
Intensity	50–70% of 1-RM
Number of repetitions per exercise	4–8
Number of sets	1–2
Frequency	1–2 per week
Duration	Up to 40 min
Program length	Up to 3 months

Source: Adapted from [69].

6.9. Peripheral Arterial Disease

6.9.1. Rationale

Peripheral arterial disease (PAD) is a progressive disease caused by atherosclerosis and results in limited blood flow and oxygen delivery to the lower limbs, as well as skeletal muscle dysfunction [70]. The most recognizable symptom of PAD is intermittent claudication (IC), occurring in 30% of patients with PAD [71]. Exercise-based cardiac rehabilitation reduces symptoms, prolongs claudication distance, and improves the quality of life in patients with peripheral arterial disease by the improvement in the metabolism of skeletal muscles, blood redistribution, and rheological changes [72]. Although cardiac rehabilitation leads to significant improvements in walking distance, no clear evidence regarding mortality reduction has been demonstrated [73].

6.9.2. Exercise Testing

Exercise tests are typically performed on a treadmill. The following are recorded [74]:

- Time and distance to the onset of claudication;
- Time and distance until the moment walking is ceased due to unbearable pain;
- Functional capacity in METS.

Thus, both the pain-free walking distance and cardiorespiratory fitness level should be evaluated. The graded stress test is the preferred mode of testing, with the maximal distance (and time), rather than the onset of claudication, recorded. Numerous testing protocols exist [75]:

- Walking at a speed of 3.2 km/hour and inclination change by 3.5% every 3 min (Hiatt protocol);
- Walking at a speed of 3.2 km/hour and inclination change by 2% every 2 min (Gardner–Skinner protocol);

The ankle–brachial index (ABI) is the ratio of the blood pressure at the ankle level to the blood pressure measured in the upper arm. ABI is used to objectively classify the severity of peripheral arterial disease, with ABI < 0.5 corresponding to low physical activity and reflecting significant stenosis, ABI 0.2–0.49 corresponding to rest pain, and ABI less than 0.2 reflecting tissue necrosis [7]. A decrease in the ankle–brachial index in response to the treadmill test reflects significant stenosis [76].

6.9.3. Exercise Training

Weight-bearing exercises such as walking are preferred, and training intensity can be determined with relation to the start of claudication, achieving maximal march distance, or achieving vasodilation. Most of the existing programs utilize the model of interval walking until near maximal pain, with a modulation of speed and/or grade to induce the onset of claudication within 3–5 min and moderate to moderately severe claudication within 8–10 min. Once pain is experienced, patients are encouraged to rest and repeat the bout of exercise when their symptoms resolve. A walking exercise duration of 30–60 min and a program duration of at least 12 weeks are recommended [7,77]. Popular protocols utilize a walking speed of 4.6 km/hour, with inclination adjusted so as not to provoke pain within 3 min and a total program duration of 6 months or walking at 4 km/hour without inclination and with further speed adjustment if the patient can complete a 10 min walk without experiencing pain. Programs with walking despite pain increase claudication distance; however, patients' training adherence remains suboptimal due to pain [78]. Moreover, the potential harmful effects of this training principle include provoking inflammatory damage in the endothelium. The alternative approach of pain-free walking can elicit similar benefits, according to data derived from a small study [79] where the authors utilized a pain-free "2/3 claudication distance" formula. One cycle comprised 3 to 5 walks, with 1–3 min rests between them, 3 times a day, 5 days a week, for at least 12 weeks. With training progression and increasing claudication distance, regular re-testing can be performed on a weekly basis [80].

Although walking is the most efficacious mode of training, cycle ergometer exercise is utilized in selected patients—e.g., those with obesity or gait problems [72].

Resistance training starting with an intensity of 30%–50% of 1-RM, including 2–3 sets, and with regular progression every 2–4 weeks for a total time period of 6 months is recommended [7].

6.10. COVID-19

6.10.1. Introduction

Coronavirus disease 19, known as COVID-19, is a contagious, highly transmissible disease caused by severe acute respiratory syndrome coronavirus 2 [81]. The rapid spread of COVID-19 caused a pandemic, leading to more than 6 million deaths (March 2022), affecting global health care systems and economies, and causing governments to impose multiple restrictions. COVID-19 induces a state of systemic inflammation with enhanced oxidation; evoked systemic inflammatory status, termed a cytokine storm, can result in multi-organ failure [82,83].

The clinical picture of COVID-19 fluctuated from asymptomatic or mild respiratory symptoms to severe life-threatening pneumonia and respiratory and cardiac failure [84]. Typical COVID-19 manifestations observed in computed tomography images of the chest included ground-glass opacities and air bronchogram signs [85]. The most vulnerable group of patients were immunocompromised and older adults with underlying diseases [86]. COVID-19 affects the cardiovascular system by attachment to cells utilizing membrane protein angiotensin-converting enzyme 2, with subsequent internalization and interaction between proteins and viral ribonucleic acid [83]. As angiotensin-converting enzyme 2 is widely expressed in many human tissues—e.g., in the lungs and heart—viral penetration causes diffuse, multiorgan damage [87]. Numerous studies have found a strong link between preexisting cardiovascular disease and poor outcomes in patients with COVID-19.

6.10.2. Cardiac Manifestations of the COVID-19

It has been documented that COVID-19 is responsible for the induction of myocardial injury, arrhythmia, acute coronary syndrome, and venous thromboembolism. Cardiac injury, including elevated troponin level, and ECG or echocardiographic abnormalities have been reported in many studies, with COVID-19 cardiac involvement being documented in 7–28% of hospitalized COVID-19 patients [88]. Cardiac complications are multifactorial and may be result of myocardial damage, hypoxia, the dysfunction of the angiotensin-converting enzyme 2 receptor, or systemic inflammatory status [89]. Heart failure and myocarditis have been reported, respectively, in 10–52% and 8–12% of patients hospitalized for COVID-19 [90]. A specific COVID-19-related cardiac condition is Takotsubo stress cardiomyopathy, with the presence of mid-left ventricular segments hypokinesis [91]. Arrhythmias occurred in the acute phase of COVID-19, and the most common arrhythmia was atrial fibrillation; however, the occurrence of sustained ventricular tachycardia has been reported in 5–6% of hospitalized patients [92]. Moreover, patients with COVID-19 remained at higher risk of thromboembolic complications due to coagulopathy [93].

6.10.3. Impact of the COVID-19 on Cardiac Rehabilitation Services

The recent COVID-19 pandemic created many barriers to the implementation of center-based cardiac rehabilitation programs. Consequently, cardiac rehabilitation programs have been affected for extended periods, leading to poor patient outcomes [94].

Some cardiac rehabilitation centers remained partially operational, whereas, in other centers, staff developed remote exercise training. Over half of centers were forced to halt operations completely, with staff being redeployed. A study by Pires objectively compared physical activity and sedentary time during the COVID-19 pandemic with those in the previous two years in cardiac patients attending center-based cardiac rehabilitation and after the suspension of programs due to COVID-19, with patients continuing onto a home-based digital program. The conclusions drawn were that most patients showed significant decreases in their average daily time of moderate to vigorous training when compared with the period before COVID-19. Nevertheless, after training resumption, these patients regained cardiovascular fitness and were able to meet the recommendations for moderate to vigorous training [95]. On the other hand, COVID-19 emphasized the importance of home-based and remotely controlled cardiac rehabilitation programs. Cardiac telerehabilitation utilizing advanced technology for both monitoring and communicating with the cardiac population became an innovative alternative, helping to overcome some of the barriers preventing participation in programs, considering that remote technology delivers sufficient training information—i.e., in terms of intensity; time; distance—and allows patients' heart rate, blood pressure, and electrocardiograms to be recorded, enabling an optimal, individualized, and safe exercise prescription [96].

6.10.4. Exercise following the COVID-19

Due to the short time since the outbreak of COVID-19, there is still a lack of evidence about the effect of rehabilitation based on exercise training in COVID-19 survivors. It has been documented that appropriately prescribed physical exercise reduces inflammatory status; thus, in-hospital physiotherapy interventions should modulate the inflammatory status initiated by the virus and intervene in endothelial dysfunction [97,98]. The following conclusions can be drawn from the accumulation of clinical experience of COVID-19 in Chinese studies [99]:

Acute phase

Physiotherapy interventions should be based on the patient's condition. Early respiratory rehabilitation in severely and critically ill patients should be postponed if the patient's condition remains unstable or progressively deteriorates. Bed and bedside activities for severely and critically ill patients include positioning, early mobilization, and respiratory physiotherapy (airway clearance techniques). Exercise regimens for mildly and moderately ill patients include light exercises <3.0 METs, performed twice a day, with duration based on the patient's physical status and lasting between 15 and 45 min. The oxygen saturation, heart rate, blood pressure, and rating of perceived exertion should be constantly monitored during physiotherapy interventions. Oxygen saturation should remain above 92–93%; heart rate should not increase above more than 20 beats per minute from the baseline; systolic blood pressure should be between $\geq$90 mmHg and $\leq$180 mmHg, and the rating of perceived exertion should not exceed a score of 11–12 during exercise.

Contraindications for physiotherapy entail [100]:

- Oxygen saturation < 93%;
- Heart rate < 40 beats per minute or >120 beats per minute;
- Systolic blood pressure < 90 mmHg and >180 mmHg;
- Body temperature > 37.2 °C;
- Fatigue increasing during exercise and persisting after rest;
- Presence of severe cough, dizziness, blurred vision, palpitations, or sweating.

Post-acute phase:

A statement by Davies et al. delivers valuable recommendations for rehabilitation after the acute phase of COVID-19. A period of rest is recommended post infection, depending on the severity of disease and the left ventricular function, in order to minimize the risk of post infection cardiac failure. Patients with symptoms such as severe sore throat, muscle pain, shortness of breath, general fatigue, chest pain, cough, and fever should avoid exercises > 3 METs for 2–3 weeks after the cessation of these symptoms [101]. Post-discharge hospital-based cardiac rehabilitation consists of progressive aerobic exercises so that patients can gradually recover their level of activity before the onset of disease. Prior to exercise training, an initial assessment should be performed, including the six-minute walking test, strength assessment, and the identification of existing deficits in the basic activities of daily living. Interval training with an initial intensity of 2–3 MET, 3 to 5 times a week, is recommended. In addition, resistance training at moderate intensity should be implemented. Generally accepted exercise training exclusion criteria are a heart rate of >100 beats/min, blood pressure of <90/60 or >140/90 mmHg, and oxygen saturation of < 95% [102]. An influential account of the beneficial effects of exercise training for COVID-19 patients comes from Hermann et al. In their study, patients (mean age 66 years, average duration of stay 19.3 days before referral) participated in a 2–4-week inpatient cardiac rehabilitation program, with protocols adapted to the severity of the disease. The program typically included 25–30 therapy sessions, performed 5–6 days per week. It entailed individualized aerobic and strength training, with intensity derived from an initial six-minute walk test [103]. The aerobic program consisted of supervised walking or stationary cycling, with a pulse oximeter used for monitoring during the exercise. In addition, strength training and respiratory physiotherapy were performed. After completing exercise sessions, significant improvements in the six-minute walk test of 130 m were observed. Further studies are required to optimize exercise parameters and establish a consensus regarding the use of cardiopulmonary programs for this emerging group of patients.

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