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Guidelines

Cardiac rehabilitation recommendations of the Group Exercise Rehabilitation Sports – Prevention (GERS-P) of the French Society of Cardiology: 2023 update

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1. Abbreviations

1-RM	one-repetition maximum
ACS	acute coronary syndromes
COPD	chronic obstructive pulmonary disease
CPAP	continuous positive airway pressure
CPET	cardiopulmonary exercise test
ECG	electrocardiogram

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ESC	European Society of Cardiology
FITT	frequency, intensity, time and type
GERS-P	Group Exercise Rehabilitation Sports – Prevention
HAS	Haute Autorité de santé (French National Authority for Health)
HbA1c	glycated haemoglobin
HF	heart failure
HR	heart rate
ICD	implantable cardioverter-defibrillator
INR	international normalized ratio
MDMA	methylenedioxy-methylamphetamine (ecstasy)
MET	metabolic equivalent of task
OSAS	obstructive sleep apnoea syndrome
QoL	quality of life
TAVI	transcatheter aortic valve implantation
VKA	vitamin K antagonist
VT1	first ventilatory threshold
VT2	second ventilatory threshold

2. Background

Cardiac rehabilitation is a therapy in its own right, on the same level as pharmacological, interventional and surgical treatments. Combining exercise training, patient education and optimization of treatments, it is a unique holistic and multidisciplinary patient management approach, which should be proposed for patients with cardiovascular disease. Despite excellent proven benefits in terms of morbidity and mortality, quality of life (QoL) and exercise capacity, it remains insufficiently prescribed and accessible. Nevertheless, numerous publications have validated its safety and efficiency. In addition, it is classed as a rank I A therapy according to European guidelines on cardiovascular disease prevention [1] and for ischaemic cardiac disease [2] or for heart failure [3].

This update of the 2012 French recommendations [4] presents new indications, more modern methods for exercise training and how they should be prescribed, reviews the new regulatory aspects of medical care and rehabilitation, and provides new options in order to propose programmes that are better adapted to patient profiles, more diversified and more readily accessible.

Even though some questions remain unanswered and some subjects still debated, the relevance of cardiac rehabilitation has never been so clearly validated and recognized. The foreseeable changes in terms of risks and cardiovascular disease in the population further reinforce its indispensable nature. In this article, we will also address the perspectives and some improvements to be made to ensure a larger number of patients can benefit from better-adapted programmes, more flexible patient management duration and more varied modalities. Based on these adaptations, it should be possible to achieve the public health objective of reducing cardiovascular risks and optimizing holistic patient management.

3. Indications for cardiac rehabilitation

The assessment of the indications considers the level of proof (class I to III) and the degree of evidence (grade A to C) as determined in the European recommendations [1]. In all cases, this is based on exercise training associated with [5]:

- the cardiovascular risk factors should be verified and updated as necessary;
- educational aspects (nutrition, tobacco, stress, etc.) and psychological care are essential;
- cardiac rehabilitation must also allow treatment optimization [6];
- return to work should remain a priority for patients still active in the workforce.

In specific cases, cardiac rehabilitation should allow:

- management of nursing care (scar care, etc.) as well as specific and accentuated monitoring;
- management of vitamin K antagonists (VKAs), prevention of the risk of endocarditis, management of immunosuppressive treatment, management of an implantable cardioverter-defibrillator (ICD), etc.

3.1. Coronary heart disease (non-surgical)

Cardiac rehabilitation in patients with coronary heart disease reduces cardiac mortality by 26%, rehospitalization by 23% and myocardial infarction by 18% [2] (Table 1).

3.1.1. After acute coronary syndromes (ACS) (class I grade A)

The benefits of physical activity are proven in secondary prevention for all coronary patients after ACS (ST-segment elevation myocardial infarction or non-ST-segment elevation myocardial infarction) [7–10]. The exercise capacity under treatment can be assessed from the third day if there are no complications, and it should be symptom limited. Monitoring is recommended during the first few training sessions [5]. The risk of stent thrombosis during cardiac rehabilitation is very low, estimated at 0.08% [11]. In addition, starting exercise training early reduces ventricular remodelling [12].

Exercise training includes endurance sessions, with continuous and/or interval training. Although still a topic of debate, to date, no difference has been observed between these two endurance methods in terms of prognosis [13]. Resistance training is also recommended [5].

Cardiac rehabilitation in an outpatient setting should be preferred.

3.1.2. Chronic coronary syndrome (class I grade A)

Cardiac rehabilitation is recommended to improve exercise capacity and QoL and counteract risk factors, optimize adherence and compliance, reduce relapses and delay the atherothrombotic process [14–16]. Assessment of exercise capacity, limited by symptoms, can be undertaken without delay after angioplasty and allows the optimization of medical treatment. Training aims to delay the ischaemic and/or angina threshold. Cardiac rehabilitation in an outpatient setting should be preferred.

3.1.3. Coronary dissection (class IIa grade C)

Coronary dissection is not a very frequent disease (4% of ACS). Progressive exercise training (without Valsalva manoeuvre), at the level of first ventilatory threshold (VT1) improves exercise capacity and reduces the risk of relapse [17].

3.2. Heart surgery

Early referral to cardiac rehabilitation is preferable (Table 2). It is essential that a surgical report be included in the patient records transferred to the rehabilitation department. Attentive monitoring of the clinical status allows early detection of any infectious complications (scar infection, unexplained fever or inflammation). Pericardial effusion requires regular reassessment until its resolution as the risk of secondary tamponade remains possible. Nonsteroidal anti-inflammatory or colchicine treatments have not proven their efficacy [18]. Supraventricular arrhythmia is frequent but is not a contraindication for cardiac rehabilitation if the heart rate (HR) is controlled. Any thromboembolic complication (postoperative phlebitis, intraventricular thrombus) requires a temporary break in exercise training. The level and type of exercises must be adapted taking into account sternotomy, the state of surgical

Table 1
Indications of cardiac rehabilitation in coronary disease (non-surgical).

	Objective	Level of proof Class	Degree of evidence Grade
STEMI or NSTEMI	Reduction in mortality and recurrence	I	A
	Early (< 30 days) improved remodelling	IIa	B
	Prefer outpatient treatment	I	A
Chronic coronary syndrome including angioplasty	Reduced progression of the atherothrombotic process	I	A
Coronary dissection	Improvement of exercise capacity	IIa	C

STEMI: ST-segment elevation myocardial infarction; NSTEMI: non-ST-segment elevation myocardial infarction.

Table 2
Indications of cardiac rehabilitation in heart surgery.

	Objective(s)	Level of proof Class	Degree of evidence Grade
CABG	Reduced mortality and recurrent coronary events	I	A
Valve replacement or valvuloplasty	Improved exercise capacity Reduced morbidity and mortality Education on anticoagulants and prevention of endocarditis	I	B
Thoracic aortic surgery	Improve exercise capacity Under blood pressure monitoring during effort	IIa	B
Pre-surgery	Improvement of clinical condition, preparing surgery For patients with multiple comorbidities	IIb	B
TAVI	Correct sedentarity Improve QoL	IIa	B

CABG: coronary artery bypass surgery; TAVI: transcatheter aortic valve implantation; QoL: quality of life.

scars, eventual anaemia and postoperative pain. Combined exercise training (endurance, resistance and respiratory) is recommended.

3.2.1. Coronary artery bypass graft surgery (class I grade A)

Improvement of prognosis, exercise capacity and QoL [19–21] have been demonstrated. Cardiac rehabilitation favourably influences the return to work.

3.2.2. Heart valve surgery (class I grade B)

It is recommended that all patients undergoing heart valve surgery be offered an exercise training programme. Early rehabilitation is effective and risk-free after valvuloplasty or valve replacement [22,23]. The benefits in terms of exercise capacity are similar to those for bypass surgery, with improved exercise tolerance and reduced morbidity and mortality [21,24]. Patient education should target anticoagulant treatment, self-measurement of international normalized ratio (INR) (for relevant patients) and prevention of endocarditis [25].

3.2.3. Thoracic aortic surgery (class IIa grade B)

Cardiac rehabilitation after surgery for aortic dissection provides functional benefits. It is well tolerated at a moderate intensity when systolic blood pressure during training is maintained below 160 mmHg (expert consensus) by avoiding efforts with a strong isometric component [26,27]. By analogy, a similar protocol can be considered after surgery for aortic aneurysm [28].

3.2.4. Pre-surgery period (class IIb grade B)

Patient management in the form of education and/or cardiovascular rehabilitation can be offered to patients with multiple comorbidities (in particular, morbid obesity, respiratory diseases) to reduce the length of hospital stay after surgery or to limit postoperative complications or depression [29,30].

3.2.5. Percutaneous valve repair

A cardiac rehabilitation programme should be proposed after percutaneous valve repair.

After transcatheter aortic valve implantation (class IIa grade B), it can correct the deleterious consequences of sedentarity (time spent sitting) in patients and improve QoL [31,32]. The patients involved are often older, frail and have numerous comorbidities. The same recommendations probably apply after percutaneous mitral and tricuspid valve repair, although we currently lack scientific data [33].

3.3. Heart failure (HF)

Cardiac rehabilitation is part of the therapeutic arsenal for patients with HF [3] (Table 3). It can start as early as possible after an exacerbation or at any time in a patient with chronic HF [34,35].

3.3.1. HF with reduced ejection fraction (class I grade A)

The cardiac rehabilitation programme must include at least: personalized exercise training, a specific patient education programme, drug titration and management of comorbidities (iron deficiency, diabetes, sleep apnoea, depression, cachexia, etc.) [5,36,37].

To assess the physical capacities and limitations of each individual patient, a cardiopulmonary exercise test (CPET) should be performed before starting the exercise training programme. For patients with the most severe disease (New York heart Association functional class IIIb), it is recommended that the programme be started in a hospital setting, before considering outpatient management. It is often necessary to extend the duration of the programme beyond what was initially planned.

A regular reassessment of physical performance is recommended (e.g. 'mid-way' CPET).

Table 3
Indication of cardiac rehabilitation in heart failure and heart transplantation.

Heart failure	Objective(s)	Level of proof Class	Degree of evidence Grade
Reduced EF	Reduction of readmissions Trend for improved prognosis Improved exercise capacity and QoL	I	A
Preserved EF	Reduction of readmissions Improved QoL	IIa	B
Mild alteration of EF	Identical to reduced EF	I	A
Resynchronization	Improved exercise capacity and QoL	I	B
Left ventricular assist device	Improved exercise capacity and QoL Centres with relevant expertise	I	B
Heart transplantation	Improved prognosis, exercise capacity Centres with relevant expertise	I	A

EF: ejection fraction; QoL: quality of life.

Endurance training protocols use continuous and/or interval intensity exercise (interval training is particularly useful for patients with the lowest fitness levels) [5,37]. Active resistance training such as targeted muscle reinforcement [1,38,39] and inspiratory muscle training [5,40,41] are recommended.

Provided the exercises are properly adapted, the intensity is progressively increased and there is regular screening for any sign of decompensation, the risks associated with rehabilitation are very low. The effects on prognosis are favourable, with a 30% reduction in hospital readmission and a beneficial mortality trend [42–44]. The improvement of exercise capacity and the reduction in symptoms contribute to improving QoL. Non-responders (improvement in VO_2 peak < 6–10% despite an appropriate programme) and non-compliant patients have a poorer prognosis [45–47]. Patient education has a major role here, making it possible to reduce readmissions (often linked to dietary or therapeutic compliance errors).

3.3.2. HF with preserved ejection fraction (class IIa grade B)

Some studies have shown the benefits of cardiac rehabilitation programmes in terms of QoL, recovery of autonomy and reduction in readmissions, with improvements in exercise capacity similar to those observed in patients with reduced ejection fraction [48–50].

3.3.3. Heart failure with moderately reduced ejection fraction

Few studies have specifically examined this population [51]. We generally consider that the indications and the results are similar to HF with reduced ejection fraction.

3.3.4. Cardiac resynchronization therapy (class I grade B)

Cardiac rehabilitation potentiates the effects of resynchronization. Indeed, the peripheral improvements as a result of training are complementary, explaining the additional gain in exercise tolerance [52–54]. Therapeutic education should focus on 'living with' the implanted device.

3.3.5. Left ventricular assist device (class I grade B)

Left ventricular assist devices are implanted as a bridge to transplant, another therapeutic decision or as a destination therapy. In all cases, it is a preferential indication for cardiac rehabilitation [55–57] related to physical deconditioning. Patient education must cover device and anticoagulant treatment management. This type of complex rehabilitation requires highly technical specially trained centres working in close collaboration with the surgical team. The advantages are similar to those for rehabilitation following a heart transplant (see Section 3.4) [58].

3.4. Heart transplantation (class I grade A)

Cardiac rehabilitation following heart transplantation presents some specificities linked to the surgery, the patient's immune status and the psychosocial impact (Table 3). The immunosuppressive therapies (immunosuppressants, corticosteroids) have some muscle toxicity that can restrict the spontaneous return to physical activity.

In the first 3 months, cardiac rehabilitation is subject to monitoring for potential complications. Consequently, the exercise training should be gentle at first and then progressive. It should be guided by CPET and the patient's perceived exertion feeling (chronotropic incompetence due to the denervation means that heart rate is not a suitable monitoring parameter) [59,60].

A recent meta-analysis indicated a beneficial effect of training in the short-term, with additional gains with interval training compared to continuous training [61]. Cardiac rehabilitation in this context takes longer [62–64].

Patient education must focus primarily on anti-rejection treatments (immunosuppression), the prevention of complications linked to reduced immunity and to cardiovascular risk factors. Psychological support and help with socio-professional reintegration are particularly important in this context.

3.5. Peripheral artery disease (class I grade A)

Supervised or home-based rehabilitation [5] helps increase the pain threshold, distance, duration and speed of walking as well as improving QoL (Table 4). However, supervised rehabilitation provides greater benefits than home-based training [65]. Indications for rehabilitation in patients with peripheral artery disease are:

- asymptomatic with ankle-brachial systolic pressure index < 0.9;
- intermittent claudication or chronic permanent ischaemia;
- after revascularization.

Prior to rehabilitation, the patient should undergo assessment of walking ability (treadmill test, 6-minute walk test, etc.) and screening of associated diseases (including cardiovascular). For patients with a very limited walking capacity, a stress test can be performed on an arm ergometer [66].

Walking on flat terrain or a treadmill is the basic exercise (Table 5 [5,67–70]). Other types of exercise may be recommended in complement walking or in patients unable to walk, e.g. upper-body exercises, muscle strengthening, analytical exercises of the lower limbs. Walking in warm water is also beneficial [71]. Patient education and treatment of risk factors are essential in this very high-risk population [72,73].

Amputees require specialized management to deal with their prostheses. Following revascularization surgery, scar tissue must

Table 4
Indication of cardiac rehabilitation in peripheral artery disease and other diseases.

	Objective(s)	Level of proof Class	Degree of evidence Grade
Peripheral artery disease	Improved limping, range and speed of walking QoL	I	A
ICD	Improve exercise capacity and reduce risk of arrythmias With or without other rehabilitation indication	I	B
Congenital heart disease	Improve exercise capacity Postoperative or in case of physical deconditioning	IIa	B
Pulmonary hypertension	Improved exercise capacity and QoL	IIa	B
Hypertrophic cardiomyopathy	Improved exercise capacity, improved symptoms and QoL	IIa	B
	Significant obstruction and symptoms	III	C
Atrial fibrillation	Improved symptoms, QoL and reduced relapses	IIb	C
Myocarditis	Improve exercise capacity Outside the acute inflammatory period	IIb	C
High cardiovascular risk	Cardiovascular disease prevention As an outpatient	I	A

ICD: implantable cardioverter-defibrillator; QoL: quality of life.

Table 5
Supervised exercise training programme in patients with peripheral artery disease [5,67–70].

Exercise characteristics	Walking on a treadmill or flat terrain under supervision of an exercise physiologist
Frequency	3–5 times/week
Duration of each exercise session	Approximately 30 minutes
Intensity	Alternating walking phases causing moderate or intermediate claudication pain and recovery phases. A gradual progression to more vigorous exercise intensity in line with the patient's capacity may be proposed
Duration of programme	At least 12 weeks

be accounted for and training on a cycle ergometer should be avoided in case of arterial anastomosis in the Scarpa femoral triangle region. After the initial phase of rehabilitation, patients must engage in a life-long daily walk lasting at least 20 minutes to maintain the benefits.

3.6. Other indications

3.6.1. ICD (class I grade B)

Patients with ICDs often have another indication for cardiac rehabilitation (ischaemic cardiopathy, HF, etc.) but some patients are implanted in primary arrhythmogenic cardiopathies (Table 4). These patients should be referred to cardiac rehabilitation with the objective of gaining assurance during physical activity and benefitting from specific therapeutic education [74,75].

In patients with HF, there is no increase in the risk of ventricular arrhythmia during exercise [76–78], The heart rate zone of programmed therapies must be known to train the patient to 10–20 beats below this threshold.

Gym and/or training movements involving the upper body should be performed carefully in the weeks following implantation to prevent any complications at the level of the surgical site and probes.

The use of electrostimulation must be discussed with the implantation centre.

A wearable cardioverter defibrillator is often recommended in case of severe left ventricular dysfunction while waiting for the decision for definitive implantation. It is compatible with rehabilitation activities and must not be withdrawn during exercise training.

3.6.2. Congenital heart disease (class IIa grade B)

The management of congenital heart disease has improved greatly, and almost 90% of children with congenital heart disease now reach adulthood [79]. Most of these patients have altered functional capacity, even those with less severe heart diseases (surgically repaired aortic coarctations, closed shunt, repaired valvulopathies, etc.) [80]. These patients have often been restricted from physical activities and must be offered exercise training [81–83].

Cardiac rehabilitation is recommended in patients with limited exercise capacity or after surgery, preferably in expert centres, in liaison with the referring congenital cardiology team.

A CPET is recommended [83,84]. Training should consider the risk of arrhythmias and potential oxygen desaturation.

For adolescents, French regulations allow their treatment in adult structures from the age of 16 years (a declaration must be made to the tutelary authorities). Hybrid or alternative programmes (gamified, outpatient, tele-rehabilitation) appear particularly suitable for this population [80].

3.6.3. Primary pulmonary hypertension (class IIa grade B)

Until the start of the 2000s, pulmonary hypertension was a contraindication for exercise training. Since 2015, European guidelines recognize a beneficial effect on exercise capacity, muscle function and QoL, and possibly on right ventricular function, as well as pulmonary haemodynamics [85,86]. The 2018 consensus meeting confirmed the advantages of exercise training in patients with severe pulmonary hypertension [87].

The exercise training relies on a tailored and supervised physical exercise programme in expert centres, and presents no risk of serious adverse events in patients who have been stable for at least 2 months. The training intensity is around 50–60% of the maximum workload achieved during the initial assessment, keeping saturation above 85–90%. Nasal oxygen therapy can be provided as necessary and/or for patient comfort. The heart rate during training should be maintained at around 60–80% of the maximum heart rate reached during the initial assessment.

3.6.4. Hypertrophic cardiomyopathy (class IIa grade B)

Exercise training is no longer always contraindicated except in patients presenting a risk based on the European Society of Cardiology (ESC) hypertrophic cardiomyopathy score [88]. It is recommended that patients be assessed by a CPET. In this population, specific attention should be paid to symptoms, blood pressure adjustment and arrhythmias [89].

3.6.5. Laminopathies and arrhythmogenic right ventricular cardiomyopathy

High-intensity or prolonged physical activity is contraindicated for these forms of heart disease. Cardiac rehabilitation can be offered at low to moderate intensities (below VT1) [88].

3.6.6. Atrial fibrillation (class IIb grade C)

Atrial fibrillation is not a contraindication for stress testing or training. On the contrary, improvements to atrial fibrillation symptoms, QoL and exercise capacity have been shown after cardiac rehabilitation, without adverse events. A few studies have shown a reduction in atrial fibrillation burden, although mortality remained unchanged [90,91].

3.6.7. Myocarditis (class IIb grade C)

Exercise training is not recommended while inflammation persists. A return to regular activity is permitted, under monitoring, after stabilization. However, high intensities are not recommended for 3–6 months, in line with the European [88] and American [92] positions.

3.6.8. High cardiovascular risk (class I grade A)

With a view to primary prevention [1], all patients with a high cardiovascular risk must have access to recommended treatments and behavioural changes including therapeutic education and dietary advice, help with smoking cessation and engaging in regular physical activity. Management in an outpatient cardiac rehabilitation structure makes it possible to assess and initiate a programme to improve lifestyle habits, which should subsequently be pursued in appropriate structures (e.g. diabetes trajectory, obesity management, sports health).

4. Contraindications for exercise training

There are few contraindications to exercise training and they are often temporary. They are generally similar to those for exercise tests (Table 6) [93,94].

Table 6
Contraindications for exercise training.

Absolute contraindications	Relative contraindications (as assessed by the cardiologist)
ACS ≤ 3 days or non-stabilized Decompensated HF Severe, uncontrolled ventricular rhythm disorders Presence of an intracardiac thrombus with a strong risk of embolism (mobile, recent and/or untreated with anticoagulants) Pericardial effusion, moderate to severe and/or with a haemodynamic impact Recent thrombophlebitis with or without pulmonary embolism with moderate to high risk of recurrence according to ESC guidelines [94] Severe AND symptomatic obstacle to left ventricular ejection Any evolutive inflammatory and/or infectious disorder (including initial-phase myocarditis) Evolutive aortic dissection Inability to perform physical exercise Refusal by the patient	Stenosis of the left main coronary artery Ventricular aneurysm Supraventricular tachycardia with poorly controlled ventricular rate High-degree or complete acquired heart block Recent stroke or TIA Severe anaemia (haemoglobin < 9 g/dL), significant electrolyte imbalance, uncontrolled hyperthyroidism, etc. Resting blood pressure > 200/110 mmHg (adapt for patient's age)

ACS: acute coronary syndromes; ESC: European Society of Cardiology; HF: heart failure; TIA: transient ischaemic attack.

5. Assessment and risk stratification

5.1. Initial review [5,95]

The admission to a cardiac rehabilitation programme is validated by the cardiologist in charge of the programme following a request including an exhaustive report. The clinical assessment must include:

- a description of the symptoms and the complete physical examination;
- the search for comorbidities: chronic obstructive pulmonary disease (COPD), anaemia, kidney failure, orthopaedic issues, frailty, etc.;
- the search for, and assessment of, cardiovascular risk factors: smoking and addictions, high blood pressure, diabetes, dyslipidaemia, overweight/obesity, physical inactivity/sedentarity, family history, psychosocial risks and symptoms/non-traditional risk markers (hormonal factors, migraine with aura, erectile dysfunction, pollution, symptoms of breathing respiratory disorder, etc.).

It is also important to assess the patient's motivation and their psychosocial condition, and medication conciliation must be performed. Complementary tests must include at least:

- resting electrocardiogram (ECG);
- recent transthoracic echocardiography;
- biological tests including complete blood count, cholesterol, glucose, glycated haemoglobin (HbA1c), natriuretic peptides, renal and hepatic functions, creatinine kinase, etc.

Except for contraindications (see Table 6), the aim of an exercise test [93] is to stratify the risk of evolution of the patient's condition and to prescribe a personalized exercise-based cardiac rehabilitation programme. The exercise test must:

- comply with the safety protocols and criteria defined for exercise tests [95]. These tests are habitually performed while the patient is taking their medical treatment;
- be limited by the symptoms or sometimes by a maximal HR (patients with implantable defibrillators) or even by maximum systolic blood pressure determined by the operator (i.e. early follow-up for aortic dissection or surgery for aortic aneurysm).

If possible, a CPET should be preferred for all patients. Results can be used to assess prognosis and to determine the ventilatory thresholds to guide the personalization of the subsequent exercise training programme. An intermediate exercise test is indicated in case of new symptoms or significant changes in therapy, or to review prescriptions based on changes in the patient's condition. A final stress test objectively assesses the patient's exercise capacity and is a guide for phase III training. Changes in exercise capacity also have a prognostic value.

A 6-minute walking test can be used to assess the patient's adaptation to sub-maximal efforts; it is highly recommended if a conventional stress test is not performed. This type of test is also relevant in patients with HF.

Table 7
Proposal for the start of a 'standard' exercise training programme (initially based on HR or workload; later, preferably based on a perceived scale). The duration and intensity of exercises must progress and be regularly re-assessed.

Type (criteria)	Frequency	Intensity		Time
		Moderate	Interval training	
Endurance (VT1–VT2[a], max HR, HRR[b], exercise HR[c], Borg)	3–6 times per week	Warm-up; continuous intensity; recovery 40–59% VO_2 peak; VT1 (power, HR); exercise HR[c] according to Karvonen formula Borg 12–14	Warm-up; alternate periods of high- and low-intensity; recovery 1 minute HIP and 2 or 3 minutes LIP, adapted based on tolerance and variations in HR during recovery HIP: 70–90% VO_2 peak power or max HR or VT2 LIP: 30% max HR or ≤ VT1 (power or HR) Borg 14 (LIP); 16–17 (HIP)	20–45 minutes
Resistance (1-RM[d], OMNI-RES[e])	2–3 times per week	30–70% of 1-RM[d] (upper body) 40–80% of 1-RM[d] (lower body) 10–15 reps OMNI-RES[e]: 5–8		≥ 20–30 minutes

1-RM: one-repetition maximum; CPET: cardiopulmonary exercise test; HIP: high-intensity period; HR: heart rate; HRR: heart rate reserve; LIP: low-intensity period; max: maximum; reps: repetitions; VT1: first ventilatory threshold; VT2: second ventilatory threshold.
[a] Values measured during CPET: VT1, VT2 and VO_2 peak.
[b] HRR: max HR − RHR.
[c] Exercise HR = resting HR + (HR reserve × K). K = 0.6 (or 0.8 if the patient is treated with beta-blockers).
[d] Assessment of maximal strength by 1-RM corresponding to the 1-RM for an exercise.
[e] OMNI-RES scale: perceived muscular exertion.

Assessment of the strength of large muscle groups is recommended to guide resistance training [5,96].

Other explorations may also be necessary, including:

- measurement of the ankle brachial index;
- arterial echo-doppler (carotid, abdominal and lower limb arteries);
- Holter-ECG recording;
- ambulatory blood pressure monitoring;
- nocturnal polygraphy in case of evocative symptoms or systematic screening for sleep disorders;
- pulmonary function test;
- magnetic resonance imaging.

5.2. Risk scores

Several risk scores have been proposed in cardiac rehabilitation, although they all have a low predictive value [97]. The most frequently retained risk stratification factors are a low exercise capacity (calculated in metabolic equivalents of task [METs] or VO_2 peak), HR abnormalities and severe arrhythmias, effort-induced ischaemia and altered ejection fraction, followed by blood pressure profile abnormalities during effort and post-surgical complications. The presence of one of these elements can be used to adapt the training intensity, follow-up and monitoring of patients.

6. Exercise training

6.1. Modalities for training [37,96,98–101]

Exercise training must be prescribed on an individual basis after an initial check-up including an assessment of exercise capacity, risk stratification, behavioural characteristics and a discussion of objectives with the patient. The training protocol should be adapted to the context (recent sternotomy, implantation of a pacemaker or cardiac defibrillator) and non-cardiological pathologies or interventions. Ideally, this training should combine endurance, resistance, flexibility and balance.

Endurance training can be undertaken in various ways, including plateau at continuous sub-maximal intensity and interval training, characterized by alternating high-intensity effort and active recovery phases. Several combinations are possible, varying the intensity, the duration of effort and recovery. Muscle strengthening is achieved with dynamic resistance using weights, elastics bands or on weight machines. During these sessions, main muscular groups should be involved and the type of movement to be repeated should be diversified. Respiratory training, individually or as a group, completes the programme. Other physical activities can also be proposed, including gymnastics, training in water, dance, balance and flexibility exercises, yoga, Tai Chi, etc. Electromyostimulation can be used in patients with a very altered physical condition, excluding those with an ICD, and with specific monitoring implemented for patients requiring cardiac stimulation [102].

Fitness equipment includes treadmills, various types of cycle ergometers (sitting, lying, arm, elliptical), rowing machines, walking poles, resistance training on benches or machines, free weights, elastics, etc. Connected devices with a heart rate monitor, pedometer or gamification can be used.

6.2. Organization of training sessions

Telemetric monitoring is recommended during the first few sessions and may be continued depending on the patient's risk profile. Exercise training should be prescribed according to the frequency, intensity, time and type (FITT) principle (Table 7). At least 20 sessions are recommended to see significant improvements in functional capacity. However, the number of sessions should be adapted to the patient's situation: sometimes more sessions are required for the most seriously affected patients (HF, transplant patients) or those who are very unfit; fewer sessions may be required for patients without deconditioning.

6.2.1. Endurance

The programme must take place on 3–6 days/week. Each session includes a warm-up period lasting 5–10 minutes, a 20–45-minute exercise period and a recovery period lasting at least 5 minutes.

Continuous moderate-intensity endurance: this corresponds to aerobic training. The intensity is best determined by the workload and HR at VT1. If VT1 data are not available, the intensity should be set to 40–59% of the VO_2 peak attained. The exercise HR can also be determined using the Karvonen formula (exercise HR = resting HR + [K × HR reserve], where K = 0.6 if no bradycardic agents or 0.8 if bradycardic treatment) and/or 12–14/20 on the Borg scale.

Interval training: this training associates aerobic phases with a low workload and more intense phases leading to the production of lactates. The intensities must account for the ventilatory thresholds (VT1 and VT2). For the intense phases, at 70–80% of peak VO_2, 75–90% of max HR or Borg score 14–16 [1].

The intensity is modulable over the programme depending on cardiac and muscular tolerance, as well as the patient's psychological progress, and must be guided by the Borg scale with the objective of regular increases in intensity.

6.2.2. Resistance

The one-repetition maximum (1-RM) should be assessed (generally derived from the 10-RM technique) or dynamometry performed.

Resistance training should be prescribed at an intensity of 30–70% of the 1-RM for the upper body and 40–80% of the 1-RM for lower-body exercises. During initial prescription, aim for 10–15 repetitions in a single series, increasing over the course of the programme.

Duration of sessions: at least 20–30 minutes (preferably 45–60 minutes) per session.

Two to 3 sessions per week.

Progression guided by the OMNI-RES scale [103], on which patients rate their perceived exertion from 0 (extremely easy) to 10 (extremely hard).

The most recent studies suggest that higher intensities should be preferred over higher number of repetitions (i.e. 70%, 3–10 repetitions, by muscular groups).

6.3. Physical activity after cardiac rehabilitation

Maintaining physical activity and reducing sedentarity are the main public health objectives aiming to prolong and improve the long-term results of cardiac rehabilitation. Physical activity should be individually prescribed and must also avoid sedentary behaviour. Prescribed as progressive, regular exercise in an adapted form to encourage strong and prolonged adherence, it is based on the results of the exercise test performed at the end of the cardiac rehabilitation programme determining the physical capacity and safe level of activity.

Five 30-minute sessions of moderate-intensity endurance activity or 75 minutes per week of more vigorous activity or a combination of the two, associated with 2–3 muscle-strengthening sessions per week are the basis of the minimum recommendations [1]. For the least active patients, this level will be progressively attained and the reduction in sedentary time is also a priority goal. The selected activities must be easy to realistically integrate into the patient's life, making physical activity part of their daily routine. Setting and reassessing objectives, using an activity tracker or a heart rate monitor for self-monitoring can help improve practice in the mid- to long-term.

Patients can be referred to several types of structure for this type of support (the French Cardiology Federation 'Heart and health clubs', 'sport-health'-accredited fitness centres). It is recommended that cardiac rehabilitation centres make their equipment available for phase III, supervised by physiotherapists and/or adapted physical activity coaches, who have been taught to create training programmes. Medical certificates can, if necessary, stipulate some precautions. It is recommended that the building be equipped with an automatic external defibrillator.

A leisure sports activity will be recommended for patients with an appropriate technical level for the particular physical activity and whose clinical status is compatible with its practice [88]. The patient must be capable of self-monitoring and be able to adapt their practice to the environmental conditions (temperature, pollution, altitude and setting).

Sports competitions should not be systematically contraindicated. For example, for low-risk patients, in line with European recommendations [88], the decision should be made with the patient (risk/benefit ratio). This permission is reviewed annually during a complete cardiological check-up.

7. Therapeutic education programme

It is recommended that every cardiac rehabilitation structure propose one or more therapeutic patient education programmes dealing with the disease and the related warning symptoms, nutritional aspects, recommendations around physical activity, assistance and/or counselling on smoking cessation, stress management, treatment management, prophylaxis to prevent infectious endocarditis, etc. (Table 8).

Every therapeutic patient education programme should be structured according to the current legal recommendations and meet the quality criteria defined by the Haute Autorité de santé (HAS; French National Authority for Health). The decree of December 2020 sets out the specifications, the required competencies for each person involved (and the coordinators), the principle of declaration to the relevant regional health authorities and the quadrennial assessment performed by the team [104,105].

Group workshops are facilitated by a multidisciplinary rehabilitation team trained in therapeutic patient education and competent in the relevant sector. Group activities are complemented by individual sessions [106]. Considered and coordinated organization

Table 8
Educational themes (non-exhaustive list).

Theme	Factors
Knowledge of the disease	The heart and how it works Cardiovascular risk factors Diseases (coronary heart disease, HF, arterial disease, etc.) Cardiological tests Warning signs (chest pain, breathlessness, etc.) Self-measurement methods (blood pressure, glycaemia) Pharmacological treatments Interventional and surgical treatments Emergency procedures
Nutrition	Cardioprotective diet Reading labels Detecting hidden salt Information on Nutriscore (advantages, limitations)
Physical activity	Combatting sedentarity What exercises to do and not to do Getting to know the markers of effort intensity Managing endurance training
Miscellaneous	Management of VKA use Prevention of endocarditis Living with a cardiovascular implantable electronic device Living with immunosuppressive therapy
Managing daily activities	Travel, sex, driving, etc.

HF: heart failure; VKA: vitamin K antagonist.

Table 9
Cardioprotective diet (modified from the ESC recommendations and the PNNS [1,110]).

At least 5 portions of fruit and vegetables per day
1 starchy food at every meal (whole cereals recommended)
Eat unsalted nuts (1 handful per day)
2–3 dairy products per day (vary the type: milk, cheese, yoghurt, cream cheese)
Preference for poultry or rabbit and limited consumption of red meat (2 portions/week)
Limit processed meats (deli-meats) (2 portions/week, equivalent to 150 g/week)
Eat fish at least twice per week (including one portion of oily fish)
Eat pulses at least twice per week (source of fibre and protein)
Use virgin olive oil and rapeseed or walnut oil every day
Avoid sweet drinks and foods
Drink coffee, tea, cocoa (rich in polyphenols)
Favour home-made food (limit ultra-processed foods)
Limit alcohol consumption ($\leq$ 10 standard units per week, $\leq$ 2 standard units per day)
Limit salt to < 5 g/day (table salt, ultra-processed foods) especially if high blood pressure or HF
Use herbs and spices abundantly

ESC: European Society of Cardiology; HF: heart failure; PNNS: Programme National Nutrition Santé (French National Health and Nutrition Plan).

is necessary, with regular readjustments during multidisciplinary consultations.

7.1. Nutritional education

The dietary model with the best proven efficacy for the prevention of cardiovascular disease is a Mediterranean-type diet [107–109] (Table 9 [1,110]). The various components include a nutritional survey [111], individual and/or group dietary education and promotion of a Mediterranean diet. Advice should be adapted to the context (hypertension, diabetes, obesity, HF, renal failure, malnutrition).

7.2. Smoking cessation

Smoking is a major cardiovascular risk factor [112] and smoking cessation is one of the most effective secondary prevention strategies [113]. Management of this risk factor must be part of any cardiovascular rehabilitation programme [114]. The institution must provide, if possible, a dedicated consultation with a tobacco specialist, or at least a member of the medical or nursing team who has completed specific training (Inter-University Diploma). The paramedical team plays an important role in this management. The patient must be informed of the crucial importance of quitting smoking and be able to take advantage of proven effective treatments [115].

First-line treatment with nicotine replacement products must be given in the intensive care unit [116], adjusting the dose rapidly to completely cover the withdrawal symptoms. To do so, patches and oral absorption forms (gummies, lozenges) should be combined [117]. The dose will then be progressively reduced over at least 3 months, or more if necessary. Nicotine replacement products are 100% covered by the French social insurance system for patients with a long-term disease. Varenicline (Champix®) can be used if necessary as a second-line treatment, and is also covered by the health system.

Cognitive-behavioural therapies have also been validated. Anti-anxiety and/or antidepressant treatments may be necessary for a period, but anxiety-depression disorders, maintained by smoking, generally improve upon cessation of smoking [118].

Even though the use of e-cigarettes (vaping) cannot be specifically recommended in cardiac patients, it is nevertheless less toxic than regular cigarettes (no carbon monoxide). However, all tobacco consumption must be stopped as double use (vaping-smoking) provides no benefit. In the absence of long-term data, it should be stopped as early as possible [119]. Heated tobacco and nicotine pouches, new lures from the tobacco industry, should certainly not be considered as a step towards cessation and should be discouraged [120].

Prolonged follow-up should be provided, in close cooperation with the cardiologist and the general practitioner, who should be alerted. The patient should leave the rehabilitation centre with a prescription for treatment to help with smoking cessation, a follow-up appointment and a report that mentions the treatment started and the elements to be monitored.

7.3. Treatment for addictions

Beyond tobacco and alcohol, several recent studies have shown that use of illicit drugs including cannabis, cocaine, heroin and opioids, amphetamines and methylenedioxy-methylamphetamine (MDMA or ecstasy) could be a real factor for poor prognosis in patients with established heart disease [121,122]. With the objective of discontinuing use, the process starts with abstaining from consumption, completely and for a sufficiently long time to recover a normal life. Psychological, psychiatric, social and family follow-up are recommended. The care protocol often includes a programme of workshops and therapeutic meetings. It is essential to monitor the patient's addiction trajectory, as any relapse entails an additional risk of cardiovascular and heart rhythm events that must be diagnosed and managed.

7.4. Education on antithrombotic treatments

Given the risks inherent to this treatment, patient education plays a determinant role in the correct use of VKAs, direct oral anticoagulants and antiplatelet therapies [106]. It is recommended that all centres provide education on these antithrombotic treatments in the form of structured sessions, distribution of documentation (monitoring log and up-to-date completed treatment cards). The patient must know the name and dose, indication and planned duration of their treatment, the side-effects, what to do in case they forget or delay taking a dose (travel), what biomonitoring is required, how to detect overdosing (bleeding, anaemia, etc.) and any drug interactions [106]. For patients fitted with a mechanical artificial valve, it is recommended that the centre be accredited for training in self-measurement of INR [123].

7.5. Prophylaxis to prevent infectious endocarditis

European recommendations [124] limit antibiotic-based prophylaxis (Table 10):

- to three patient categories: fitted with any type of replacement valve, with a history of endocarditis and uncorrected or incompletely corrected congenital cyanotic heart disease (residual shunts);

Table 10
Education on prophylaxis to prevent infectious endocarditis.

Provide information on prophylaxis (risks)
Deliver a specific card
Recommend strict dental and skin hygiene
Dental check-ups required twice a year
Disinfection of wounds
No self-medication with antibiotics
Discourage piercing and body art
Consult a doctor in case of persistent fever

- for a single situation presenting a risk: dental interventions affecting the gums or the periapical region or associated with perforation of the oral mucosa.

7.6. Daily life

7.6.1. Driving

The patient's aptitude for driving depends on their risk of loss of consciousness. The decree of 28 March 2022 sets out the list of medical disorders that are incompatible or compatible, with or without adaptations or restrictions, with the obtention, renewal or maintenance of the driver's licence, or that can lead to attribution of a limited-validity driver's licence [125]. Any doctor that expresses reservations to driving must inform the patient of the necessary steps to be undertaken with respect to the local authority's medical aptitude commission. The reasoned opinion of the rehabilitation department must be clearly set out in the patient's records and release notes, with the patient's full knowledge and approval.

Only drivers of heavy vehicles (or light vehicles with passenger transport) are required to undergo a medical aptitude test and to submit to regular examinations. According to the French labour code, aptitude for occupational driving can only be assessed by the occupational physician, based on the opinions of the cardiologist and the accredited doctor on the local authority's commission.

7.6.2. Travel

The advice must consider the severity and stability of the disease and the journey planned. All non-stabilized conditions (i.e. decompensated HF, early or complicated ACS, etc.) are contraindications for non-medical transport. Precautions to be taken in the case of flights or long trips relate to the following [126]:

- ACS less than 2 weeks before travel;
- coronary bypass less than 3 weeks before travel;
- HF;
- uncontrolled ventricular arrhythmias;
- recent thromboembolic disease;
- ventricular assistance;
- recent ICD as secondary prevention.

It is recommended to advise the patient as follows:

- take out travel insurance covering medicalized repatriation and annulation;
- take a summary of their medical history with them, translated into English if possible;
- carry a reference ECG trace;
- bring their last prescription with drugs listed by their international non-proprietary names (or translated into English if necessary);
- pack sufficient stock of treatment to cover the duration of their trip and a few extra days;
- always keep their treatment with them;
- make sure they have sufficient time in airports (boarding, transit, etc.) to minimize stress.

For trips to countries with specific environments, an appropriate physical condition and a minimum of 4 weeks of clinical stabilization are required if physical activity above 2000 m is planned; a stress test must show no symptoms of myocardial ischaemia, no arrhythmia and no haemodynamic instability [127]. However, altitude is not the only parameter to be considered, one should also consider the type of activity, climate conditions, individual 'technical' aptitude, etc. Methods to protect against extreme heat should be presented (hydration, appropriate clothing, etc.) and patients should be advised against intense physical efforts in those conditions. If the trip is planned with the aim of participating in sporting activities, refer to the 2021 European recommendations [88].

7.6.3. Sexual activity

Sexual health is an important aspect of QoL [128] and must therefore be an integral part of patient management by the multidisciplinary team involved in cardiac rehabilitation, and members should be appropriately trained. The team should be proactive, inviting patients to share their questions and experiences, and proposing appropriate solutions; psychological assistance should be available if necessary.

Sexual difficulties may arise in both sexes due to the disease, comorbidities and pharmacological treatments (beta-blockers, diuretics, blood pressure medication, etc.). Dose reduction or a change of therapeutic class can improve sexual function and/or compliance [129]. Phosphodiesterase inhibitors can be prescribed to men with a stable cardiovascular condition presenting a low risk of complications [130].

The risk of occurrence of a cardiovascular event during sexual activity is low, especially if patients are engaged in regular physical activity and have good functional capacity. Cardiac rehabilitation improves sexual health [131]. Patients with an exercise capacity of more than 3 METs who are asymptomatic can engage in sexual activity without notable risks. The American recommendations are more precise, but the elements have a low level of proof [132] (Table 11).

8. Treatment optimization

During cardiovascular rehabilitation is an ideal time to optimize and titrate pharmacological treatments in line with the recommendations for prevention of cardiovascular and other diseases [1]. Indeed, the duration of patient management and the return to normal exercise activity make it possible to tailor the treatment based on tolerance at rest and during effort [6,133]. In association with therapeutic education, this promotes improved adherence and compliance with treatment [134,135].

9. Psychosocial management

As psychosocial factors play a crucial role both before and after the onset of cardiovascular diseases [136], their management during rehabilitation is essential. Numerous psychosocial factors have an impact on the occurrence and prognosis of cardiovascular diseases: anxiety, depression, hostility, anger, D-type personality (combination of negative affect and social inhibition), posttraumatic stress disorder, occupational stress and its possible progression towards burn-out, isolation, lack of social support, low socioeconomic status and traumatic events in childhood [137–142]. In addition, a cardiovascular disease is likely to trigger psychological distress: stress, anxiety, depression and posttraumatic stress disorder [143]. Psychosocial factors have a variable impact depending on gender, and this notion must be considered during rehabilitation [144].

9.1. Psychological management

A psychosocial assessment is essential at the very start of rehabilitation. It can be facilitated using dedicated questionnaires (Hospital Anxiety and Depression, Beck Depression Inventory). The questionnaire developed by the ESC is validated as a simple rapid-screening tool [145]. A psychologist must be available during cardiac rehabilitation and an individual consultation is recommended. In collaboration with the care team, the psychologist

Table 11
Recommendations related to sexual activity [132].

Recommendations	Level of proof Class	Degree of evidence Grade
Therapeutic management related to sexual activity must be offered to both men and women, considering the psychological dimensions and the individual wishes of patients	I	C
Engaging in sexual activity is reasonable in patients classed as at low risk of cardiovascular complications	IIa	B
Patients with a non-stabilized cardiovascular disease or who are symptomatic should not engage in sexual activity until their condition has stabilized and they have been appropriately assessed and treated	III	C
A cardiac rehabilitation programme and regular exercise training reduce the risk of cardiovascular complications during sexual activity	IIa	B
Patients with angina or who are incompletely revascularized must undergo assessment, therapeutic optimization and be stabilized before engaging in sexual activity	III	C
Sexual activity is reasonable in patients with HF who are stable in NYHA Class I or II	IIa	B
Sexual activity is inadvisable in patients with severe symptoms or decompensated heart failure (NYHA Classes III or IV) before therapeutic optimization and improvement to their symptoms	III	C

HF: heart failure; NYHA: New York Heart Association.

should contribute to the therapeutic education programme. In some cases, a second opinion from a psychiatrist may be requested. It is desirable that the psychosocial treatment report be included in the patient's release notes to encourage continued psychological support after cardiac rehabilitation. Management of psychosocial factors relies on four elements:

- therapeutic education;
- engagement with exercise training during rehabilitation (the therapeutic effect is considerable in case of anxiety-depression disorder);
- psychological management by personnel trained in the use of non-drug treatments: relaxation (yoga, sophrology), meditation, in particular mindfulness and cardiac coherence, cognitive behavioural therapy, hypnotherapy or eye movement desensitization and reprocessing, etc. [146,147];
- drug treatments can also be proposed (anti-anxiety or antidepressant treatments) if required after consultation of a psychiatrist [148,149].

9.2. Return to work

Return to work is one of the objectives of cardiac rehabilitation. The occupational activity, in terms of exercise and mental workload, will be assessed as soon as possible. Factors influencing the return to work include [150]:

- the type of heart disease and related functional status: the severity of the heart disease, presence of an implanted device, left ventricular ejection fraction, ventricular arrhythmia, exercise capacity [151,152]. These data will be communicated to the occupational physician via the patient;
- assessment of the workplace: any load-bearing activities and exertional effort, environmental constraints and general working conditions must be defined. During the assessment, the following parameters should be considered: duration of commute, sedentary work, shift work, working under high temperatures, working under cold temperatures and in humid conditions, work at altitude or at height, security positions. The specific case of driving is covered by the decree of 28 March 2022 [125];
- assessment of occupational stress: occupational stress can be assessed using two structured and validated questionnaire models. These are the Karasek model [153], which has been validated for manual labourers; and the Siegrist model, which is better adapted for managers (white collar workers) [154];
- job strain is defined by low decisional latitude and a high psychological pressure. It is an independent factor for the occurrence of a coronary incident and long-term relapse [155], and an indicator in favour of a later return to work.

In some specific cases, an occupational simulation may be proposed at the end of the cardiac rehabilitation. The opinion of the rehabilitation cardiologist on the return to work is important and must be recorded in the patient's release notes: possible date of return to work, any adaptations necessary, therapeutic part-time work, etc. The patient is encouraged to make an appointment as early as possible, and before the end of their sick leave, with the occupational physician for a 'pre-return medical assessment'.

10. Important populations

10.1. Patients with diabetes

Patients with diabetes (mainly type 2 diabetes) account for 20–30% of the overall population in cardiac rehabilitation [156]. They are characterized by a greater frequency of cardiovascular-associated risk factors, polyvascular disease and comorbidities. In addition, their initial exercise capacity is lower [156–158].

Regular exercise is part of the non-pharmacological treatment of diabetes (class I level A) on the same level as dietary advice [159], and it has numerous beneficial effects [160,161]: significant improvement in glycaemic control leading to a 0.7% reduction in HbA1c, on average; reduction in degenerative complications of diabetes; and a reduction in visceral fat. Regular exercise improves the cardiovascular risk profile and insulin sensitivity. It significantly improves the VO_2 peak, but this improvement is correlated with good glycaemic control during rehabilitation [162].

The current recommendations [5,160,161,163,164] suggest three courses of action: combat sedentarity, increase physical activity in daily life and undertake supervised, structured exercise and/or sports activities with a minimum weekly volume of 2.5 hours at moderate to high intensity, combining endurance exercises with muscle strengthening [164,165]. Activities to develop flexibility and balance as well as stress management can be added. Activities undertaken in water are interesting as they reduce the feeling of difficulty linked to the patient's weight and constraints on joints.

The reduction in glycaemia is correlated with the duration of endurance exercise sessions, with effects lasting beyond the end of the session. The effects of endurance on glycaemic control are time-

limited (around 30 hours), which explains the need for regularity in any physical activity [160].

Diabetes complications (retinopathy, kidney disease and neuropathy) are not contraindications for training, although patients with proliferative retinopathy should avoid overly intense activities. In parallel, the patient's glycaemia should be monitored in line with the recommendations [166], with a preference for self-measurement: before exercise, at the end of exercise, and 4–6 hours after exercise, with the aim of identifying hypoglycaemic events rapidly and preventing severe hypoglycaemia among patients treated with insulin or insulin-releasing compounds (sulfamides or glinides).

If the pre-exercise glycaemia is > 2.5 g/L (13.9 mmol/L), urinary acetone should be measured, the hyperglycaemia should be corrected and the exercise training delayed. The rehabilitation team and the patient must know how to recognize symptoms of hypoglycaemia and what to do in case of emergency: stop the effort and consume a combination of simple and complex sugars.

Specific patient education aims to help patients to better understand their disease and the relation between glycaemic regulation anomalies and cardiovascular risk, to engage with their follow-up and monitoring for complications. Through educational modules, patients will become aware of the beneficial effects of physical activity, both in terms of glycaemia and of cardiovascular risks, which should motivate them to continue with their practice in the long-term.

Therapeutic patient education also contributes to optimal compliance by explaining the effects of the various (sometimes complementary) anti-diabetes treatments and familiarizing patients with those that can cause hypoglycaemia (sulfamides, glinides and insulin).

The psychological benefits of cardiac rehabilitation [167] promote active involvement of patients with diabetes in behaviour changes. The duration of cardiac rehabilitation allows optimization of the cardiologist/endocrinologist collaboration in particular for treatment adaptations in line with international recommendations.

An endocrinologist should be consulted if: HbA1c $\geq$ 8%, patients have severe/frequent hypoglycaemic events, newly-diagnosed diabetes to optimize treatment selection, introduction of treatment with glucagon-like peptide-1 analogues or sodium/glucose cotransporter 2 inhibitors in patients with diabetes already treated with sulfamides/glinides and/or insulin (increased risk of hypoglycaemia) [157,163,168].

Cardiac rehabilitation is also a crucial opportunity to screen for diabetes and prediabetes [157]. Indeed, it has been shown that the glucose monitoring performed on patients admitted to rehabilitation after an ACS who have an HbA1c level below 6.5% can identify a significant proportion of previously unidentified patients with glucose metabolism disorders (prediabetes) [168,169]. The patients identified during rehabilitation can then benefit from real, active and multifaceted management.

10.2. Cardio-oncology

This section covers patients with cancer and heart disease, cardiovascular risk factors and those who will be treated with cardiotoxic chemotherapy, in the absence of oncological contraindications. The benefits of exercise in cancer are increasingly understood: slowing of cancer progression, beneficial effects on fatigue and QoL, improved chemotherapy tolerance and reduced cardiotoxicity of chemotherapy [170,171]. Cancers and cardiovascular diseases share numerous risk factors (the cancer itself and its treatments are recognized as cardiovascular risk factors), and cardiac rehabilitation is recommended to compensate for these cardiovascular risk factors, and to reduce mortality in some cancers, particularly breast and colon cancer. The rehabilitation modalities are identical to those for heart disease, although endurance training should be adapted to the oncological situation [172].

10.3. Older people

Older people are defined by the World Health Organization as those aged over 60 years, but in most studies subjects are considered older when aged over 65 years with comorbidities, or over 75 years. Despite the constant growth of this population (25% > 65-year-olds by 2050), prescription and participation in cardiovascular rehabilitation programmes remains low, particularly among women [173]. Nevertheless, beneficial effects in terms of maximum or sub-maximal effort tolerance, QoL, and survival are observed for older adults, with a reduction of 5-year mortality by 21–34% [174]. The objectives are mainly to improve autonomy, the main contributor to QoL in older patients with heart disease.

For the initial assessment, in addition to the standard check-up detailed in Section 5.1, a geriatric assessment – including at least comorbidities and psychosocial aspects, as well as measuring frailty – is necessary to validate the relevance and the modalities of the programme [175]. Patients should be referred to a cardiac rehabilitation institution specializing in cardiovascular diseases when the principal diagnosis is cardiological and they do not present prohibitive comorbidities, for patients capable of recovering or improving their autonomy in their day-to-day lives. For other patients, admission to an elderly care or polyvalent rehabilitation institution should be considered. Beyond the usual management through residential or outpatient services, additional modalities are being assessed to improve access to rehabilitation: home rehabilitation, tele-rehabilitation, hybrid solutions, etc. [176].

The decrease in muscular strength linked to sarcopenia is an independent risk factor for cardiovascular mortality: the combination of resistance training with aerobic exercise is recommended to improve muscular strength and endurance, and to preserve or restore autonomy and thus QoL [95,177,178]. Interval training is free from risks and at least as effective as continuous training [179]. Complementary practices (such as Tai Chi, Qi Gong) also have positive effects and are clearly adapted to this population.

Dietary advice should be adapted to older individuals (accounting for undernutrition and/or deficiencies) and – as for younger populations – lifestyle modifications must be undertaken.

The benefits of quitting smoking and controlling blood pressure are comparable to those obtained in younger populations.

10.4. Women

For women, cardiovascular rehabilitation is characterized as follows:

- women are under-represented in rehabilitation, regardless of age: after heart attack, 30% of men compared to 25% of women are referred to cardiac rehabilitation, although recent progress should be noted [180];
- barriers to cardiac rehabilitation are multiple: lack of interest, lack of information and prescription, fear of an ill-adapted programme, low family support, domestic and family activities considered a priority, lack of transport, etc.

The specific risk factors to be dealt with in patient education programmes for women are the following [181]:

- some traditional risk factors are more frequent (psychosocial stress, excess weight, sedentarity, etc.);

- other risk factors have a greater impact than in men (46% higher risk of fatal coronary heart disease with type 2 diabetes [182] or 25% higher risk of coronary heart disease with smoking [183]);
- in addition, specific risk factors linked to the various stages of women's hormonal or gestational lives must be added: combined contraception, pathological pregnancies, menopause and hormone replacement therapy.

Beneficial effects have been observed with cardiac rehabilitation on morbidity-mortality and on improvements in exercise capacity, even if differences based on sex and gender are noted (+2.2 MET in men vs. +1.7 MET in women) [184,185].

Women have a higher incidence of some cardiovascular diseases, such as coronary dissection, Takotsubo syndrome and myocardial infarction or ischaemia with non-obstructive coronary arteries. However, few studies are available on the effects of cardiac rehabilitation in pathologies more often affecting women, despite the recommendations of HAS [186].

10.5. Patients with comorbidities

10.5.1. COPD

COPD is the disease most frequently associated with cardiovascular diseases [187]. It affects 5–10% of the French population aged over 45 years, among whom 1 million are symptomatic. Of all the respiratory disorders, this chronic respiratory disease is associated with the highest level of proof of efficacy of respiratory rehabilitation in the literature. Respiratory rehabilitation is indicated for all chronic respiratory diseases, whatever the severity, and must be prescribed for any patient who still has symptoms despite optimization of their pharmacological treatment. It is effective in reducing breathlessness and hospital readmissions, while also improving QoL and exercise tolerance [188].

In practice, according to the HAS, any adult over 40 years of age with a smoking habit of more than 10 packets/year who is eligible for cardiovascular rehabilitation should be offered a spirometry test and be referred to a pulmonologist for a check-up to optimize their treatment and assess the need for oxygen therapy during exercise [189].

The specificities of COPD evaluation require tobacco consumption and dietary status to be assessed; the exercise capacity should be evaluated based on a CEPT with monitoring of oxygen saturation [190]. The exercise test and the echocardiography will allow an informed decision on whether rehabilitation should be undertaken in a rehabilitation institution specializing in cardiology or pulmonology, depending on the patient's main limitation.

In patients using respiratory equipment:

- for patients with COPD treated with oxygen long-term or to deal with an acute event, the supply of oxygen during exercise, particularly in subjects displaying hypoxaemia, will allow a higher exercise intensity to be reached, through several mechanisms [191]. In addition, by correcting the hypoxaemia, the risk of inducing functional ischaemia is reduced. As part of limiting this risk, it is recommended that oxygen saturation be maintained above 90% throughout the duration of exercise training. For any patient treated with oxygen, it is recommended that the pulmonologist be contacted to prescribe the appropriate system, educate the patient on the use of the material and ensure long-term follow-up. In France, cardiologists can only prescribe short-term oxygen therapy – lasting 1 month and renewable twice. If the dependence on oxygen therapy limits the capacity for rehabilitation, the patient should be referred to pulmonary rehabilitation;
- for patients with COPD treated with non-invasive ventilation long-term or to deal with an acute event, the pulmonologist should be contacted. In France, cardiologists cannot prescribe initial treatment with non-invasive ventilation upon discharge from hospital. If the reliance on non-invasive ventilation limits the capacity for rehabilitation, the patient should be referred to pulmonary rehabilitation;
- some patients with COPD require long-term treatment with continuous positive airway pressure (CPAP) for central sleep apnoea or obstructive sleep apnoea syndrome (OSAS). A patient treated with CPAP must continue their treatment during the cardiovascular rehabilitation. In partnership with the patient's service providers, rehabilitation is a good time to verify that the patient is complying with their treatment, and that there is no residual apnoea/hypopnoea. If compliance and/or tolerance are sub-optimal, or if the treatment is insufficiently effective, the doctor monitoring the patient for their apnoea should be contacted.

10.5.2. OSAS

Screening is recommended during cardiovascular rehabilitation as:

- OSAS is much more frequent in cardiac patients than in the general population [192] and OSAS is a cardiovascular risk factor;
- screening for OSAS should particularly target patients with evocative symptoms, obesity, resistant hypertension, aortic dissection, severe HF, nocturnal arrhythmia or for whom the index event occurred during the night. It is also justified for professional drivers;
- the usual questionnaires (STOP-Bang, Berlin questionnaire, Epworth scale) are less sensitive in cardiovascular patients than in the general population. Other screening methods can be used (saturation, nasal flow rate, connected devices, etc.). Diagnosis will be based on polygraphy or polysomnography readings, preferably performed at the end of the patient's hospital stay due to the overestimation of OSAS during the acute care phase.

If OSAS is diagnosed, the treatments offered have beneficial effects on clinical symptoms, arrhythmia, hypertension, any pulmonary arterial hypertension, B-type natriuretic peptide levels, and sometimes, left ventricular ejection fraction. It is recommended that these treatments be implemented during cardiac rehabilitation. They include dietary hygiene measures (weight loss, physical activity, smoking cessation, reducing alcohol intake, discontinuation of some medications and sleeping position), exercise training and ventilation by CPAP. The SERVE-HF study [193] showed an unfavourable effect of servo-assisted ventilation on total mortality and mortality among patients with systolic HF and central sleep apnoea. Indications for mandibular advancement devices, palate or tongue surgery or stimulation of the hypoglossal nerve and diaphragm stimulation require a specialist opinion.

10.5.3. Chronic kidney disease

Chronic kidney disease is associated with very high cardiovascular morbidity-mortality [194]. From the first stages of chronic kidney disease, a specific multifactorial myopathy is observed, and its severity increases with disease stage. The consequences of this myopathy are sarcopenia and reduced exercise capacity, frequently associated with frailty syndrome, reduced QoL, high sedentarity and an increased risk of death [195]. For these patients, cardiac rehabilitation programmes are associated with improved exercise capacity and cardiovascular prognosis [196,197], they have been demonstrated to be safe and not to exacerbate renal dysfunction [198]. The principles of cardiac rehabilitation are similar to those for patients without renal disease:

- a CPET is recommended; the risk of musculoskeletal complications requires increased vigilance at advanced stages of CRD [199];
- optimization of the cardiovascular treatment must be associated with reassessment of blood potassium levels and renal function after any treatment adjustment, or in case of dehydration;
- specificities for patients treated by dialysis [200]: the presence of an arteriovenous fistula is not a contraindication for exercise once the fistula has healed. The arteriovenous fistula must be protected from potential trauma and not be compressed. The rehabilitation sessions should be programmed before or the day after a dialysis session;
- specificities for patients treated by peritoneal dialysis [201]: exercise can be undertaken when the peritoneal space is full or empty, depending on their personal preference. Swimming (or balneotherapy) is not contraindicated for peritoneal dialysis patients, on condition that there is no skin damage at the catheter outlet and that the dressing is changed after the session;
- with regard to dietary regime: before dialysis, it is generally low-sodium (6 g salt/day), low-potassium, low-protein (0.8–1.0 g/kg/day), but taking care not to be too strict to avoid causing undernutrition, particularly in older people and/or those with frailty syndrome. When treated by dialysis, protein intake must be increased to 1.3–1.4 g/kg/day and calorie intake to 35–40 kcal/kg/day.

11. Organizational aspects

Cardiac rehabilitation may be proposed in residential or ambulatory settings, preferably ambulatory.

11.1. Legislation

The two decrees from 11 January 2022 relate to the general conditions of implementation and to the technical conditions of rehabilitation services (called 'Soins Médicaux et de Réadaptation') and provide additional information on the specific conditions required for cardiac rehabilitation [202,203]. These decrees are completed by ministerial instructions relative to the authorization to carry out Medical Care and rehabilitation Services (DGOS instructions 28 September 2023). These decrees have been in force since 1 June 2023, institutions have a year to comply with the stipulations after notification of their accreditation by the regional health authority.

The medical care and rehabilitation activity provided in rehabilitation institutions aim to prevent or reduce the consequences of cardiovascular diseases, before or in the aftermath of acute care episodes. This activity includes diagnostic and therapeutic interventions and actions related to prevention, therapeutic education and occupational reinsertion in the context of the patient's personal therapeutic project.

The main points in the reform include the following:

- 'aftercare and rehabilitation' institutions become 'medical care and rehabilitation institutions', with their own medical activity to account for the progression of severity observed in the patient profiles;
- institutions must propose in- and outpatient rehabilitation as required by the patient's profile. Telehealth services and mobile teams are specifically mentioned;
- specialized medical consultations can be proposed within the rehabilitation institution or in direct relation with the institution, upon request from other rehabilitation institutions;
- institutions can act in the framework of a Multiannual Goals and Means Contract (Contrat Pluriannuel d'Objectif et de Moyens) for expertise under the heading 'patient management in early rehabilitation after acute cardiological events';
- it is now obligatory that a psychologist be integrated into the team.

The regulatory aspects of the organization of care in cardiology-specialized rehabilitation institutions include:

- complex, multidisciplinary and intensive rehabilitation lasting at least 3 hours per day should be started as soon as compatible with the patient's functional capacity. The duration is systematically adapted to the patient's state of health;
- implementation of at least two of the following therapies: physiotherapy, occupational therapy, dietetics, psychological support, therapeutic education and adapted physical activity;
- in the context of complete hospitalization or at each hospital consultation, at least two individual or group treatment sequences must be provided.

11.2. In practice: GERS-P recommendations

The main objectives for cardiac rehabilitation are as follows: improve prognosis by reducing morbidity-mortality, improve exercise capacity to sustain effort and QoL for the patient, secondary prevention by correcting cardiovascular risk factors, optimizing pharmacological treatment, socio-professional reinsertion and developing the patient's self-care skills through therapeutic education.

11.2.1. Staff

11.2.1.1. Medical competencies. Due to the potential complexity of the cardiovascular diseases dealt with, the risk of life-threatening events and the specific skills required, the Société française de cardiologie (French Society of Cardiology) recommends that a doctor, who is a recognized specialist in cardiology and vascular diseases or in cardiovascular diseases, takes on the medical responsibility and coordination of rehabilitation institutions specializing in cardiovascular disorders. A minimum of two doctors, including the coordinator, are required.

It is recommended that the coordinating cardiologist have recognized competencies (university diploma/degree) in the field of cardiac rehabilitation. In addition to monitoring and adapting therapies, the cardiologist approves patient admissions and, in collaboration with the multidisciplinary team and the patient, establishes a therapeutic project that is periodically re-assessed.

Depending on needs, the medical team should include other specialists such as the general practitioner, endocrinologist or nutritionist, psychiatrist, tobacco expert, occupational physician, pulmonologist, etc.

11.2.1.2. Multidisciplinary team. In addition to the professionals indicated in the legal general conditions (one nurse and one social worker), the multidisciplinary team must include:

- at least one physiotherapist;
- at least one dietician;
- at least one psychologist.

The paramedical team can also include other skill sets: adapted physical activity coach (coaching, supervised group exercises), nurse's aide, occupational therapist, etc. It is essential that all personnel be regularly trained in emergency procedures and in therapeutic education activities.

11.2.2. The facilities

11.2.2.1. Residential and day-care cardiac rehabilitation. The building must be adapted to the different modalities of care provided and make it possible for the patient's friends and family to accompany them.

The residential rehabilitation must include rooms with one or two beds, equipped with a call system.

For day-care hospitalization, a rest area is required.

In all cases, the rooms available must be designed to allow an emergency response in a timeline compatible with the safety requirements.

11.2.2.2. Rehabilitation areas and equipment must include. An 'emergency room' fitted out to allow emergency procedures and cardiac resuscitation to be performed before patient transfer (one or more beds with an emergency trolley, heart monitors, defibrillator, intubation, and ventilation material, piped gas supply, etc.).

Emergency trolleys must be available in sufficient numbers and geographically placed to cope with any emergency occurring in the unit. An emergency trolley must be present in the exercise test room during tests, and near training rooms. Devices to monitor blood pressure and an ECG must also be available along with:

- first-responder treatments with medication and material for injection and infusion;
- an approved cardioverter defibrillator;
- intubation and ventilation material;
- medical fluids and material for aspiration;
- the use-before dates and working order of the material must be checked regularly.

A technical platform where non-invasive examinations can be performed to assess patient functional evaluation and for monitoring purposes. The obligatory medico-technical equipment includes a standard ECG, a telemetric monitoring system, equipment for exercise tests, an echocardiograph and a vascular Doppler ultrasound. The minimal desirable elements are: a device to analyse ventilatory expired gas during exercise, a Holter ECG recording device, a pulse oximeter, an ambulatory blood pressure monitoring device and heart rate monitors.

Access to a computed tomography scanner and magnetic resonance imaging, and the possibility to request medical biology analyses are also required.

An exercise training platform: the material available must allow the whole reconditioning and education programme to be implemented: gym equipment (weights, barres, benches, mats, etc.), various training machines (cycle ergometer, treadmill, rowing machine, segmentary weight bench, arm ergometer, etc.), monitoring equipment (ECG, heart rate, blood pressure, glycaemia, etc.). All training rooms must be equipped with an emergency call system (telephone or other). Each patient must have at least 4 m^2 of personal space in the gym room. A therapeutic pool and access to outdoor circuits can be added, depending on the possibilities for each centre.

A space for physiotherapy for individual consultations.

A room dedicated to relaxation is desirable.

A room is required to provide information and therapeutic education to patients and their families, educational audiovisual equipment and teaching tools should be available.

11.2.3. Continuity and permanence of care, emergency management

Continuity of care (i.e. during the day, on working days) is ensured by a nurse present on site throughout the period when patients are present. A cardiologist must be able to intervene immediately if necessary. Permanence of care (nights and weekends, bank holidays) is ensured by an on-duty or on-call specialist in cardiovascular medicine, or a doctor with experience in life-threatening emergency interventions and at least one nurse. Emergency medical intervention must be possible at any time.

The possibility to transfer patients at any time and within a reasonable timeframe to an intensive care unit must be organized based on a formalized agreement. All emergency protocols must be set out in writing, validated and distributed. The emergency call procedures must be known to all personnel and tested regularly. In the context of part-time hospitalization, the patient is informed of what to do if abnormal clinical symptoms occur.

11.3. Quality criteria

Despite the scientific documentation available, rehabilitation programmes remain heterogeneous. Beyond the criteria relating to infrastructure and equipment, human resources and organization that are dealt with in specific chapters, criteria to monitor the quality of the programmes could be proposed with a view to standardization of care [204–206].

Among the criteria retained by the ESC, the GERS-P proposes the following self-assessment criteria: % patients effectively admitted out of those referred, waiting time, % sessions completed out of those planned, % lost to follow-up or discontinuing cardiac rehabilitation, % patients evaluated before and after the programme, % treatment optimization, improvement of exercise capacity and muscle strength, reduction of anxiety/depression scores, % verification of cardiovascular risk factors. In addition, internal and/or external audits, participation in scientific activities and in educational training (for health care professionals), development of innovations, collaborations with the various sectors and with other rehabilitation centres should be encouraged.

11.4. Barriers to cardiac rehabilitation

Despite extensive scientific proof of the benefits of cardiac rehabilitation, the number of patients availing of it remains low. The factors negatively influencing participation may be classed as follows [207].

11.4.1. Inherent to the patient

In addition to advanced age or generally altered state and limiting comorbidities, more than 20% of patients refuse rehabilitation when offered, sometimes due to a need to return rapidly to work, or to a lack of motivation, and ignorance of the programmes and benefits.

Women, even young women, are also less frequently included than men according to several studies.

11.4.2. Inherent to the rehabilitation structures

Insufficient in number, waiting time for admission considered too long, poorly distributed geographically, their usefulness is not well covered in medical training, and they are often not very financially attractive.

11.4.3. Inherent to the medical corps

The duration of management of acute events has been reduced and the technical revascularization act takes precedence over the need for long-term management. Reticence persists among the medical corps (who do not see the point). However, patients who have undergone bypass surgery more often access rehabilitation centres after surgery compared to patients treated by angioplasty.

11.5. Alternatives to cardiac rehabilitation in centres

The small number of patients benefiting from cardiovascular rehabilitation in dedicated centres requires alternatives to be found. The barriers to participation are varied (distance from home, socio-professional constraints, long wait for admission, etc.). Several modalities are currently being tested: development of light structures where personalized programmes can be proposed (content, times, etc.), particularly adapted to the active working segment of the population.

The development of home-based rehabilitation (tele-rehabilitation) has been dealt with in publications, and a comparable efficacy to conventional cardiac rehabilitation has been reported in various populations and for various diseases after assessment and piloting by a cardiac rehabilitation centre. Consequently, the modality is included in recommendations [208–210]. There are numerous advantages for patients (rapid enrolment, integration in the family context, reduced commute time, etc.), but the disadvantages must not be overlooked (lower motivation, loneliness, anxiety, etc.). These require specific organization (tele-monitoring with all the necessary precautions, precise initial assessment of the patient's medical state and psychosocial context) to ensure rehabilitation achieves similar levels to those attained in a centre (accounting for risk factors, therapeutic education, exercise training, compliance with treatment, etc.).

12. Medico-economic aspects of cardiac rehabilitation

Despite the wide diversity of programmes, most studies show that cardiac rehabilitation has a favourable cost-benefit ratio compared to no rehabilitation [211]. Economic analyses [212] suggest that the hospitalizations avoided absorb all the direct costs of a cardiac rehabilitation programme. Various studies show that, after smoking cessation, exercise training is the best prevention strategy. Currently ongoing French studies of home-based rehabilitation and tele-rehabilitation open up the possibility of catering for a larger eligible population, leading to better health care coverage in France, and potentially reduced costs.

13. Conclusions, perspectives

Broader indications, more targeted training methods, more varied multidisciplinary teams, the existence of expert centres, and an increasing level of proof for various diseases make rehabilitation an indispensable mode of treatment, to which patients should have easier access in order to improve their prognosis.

A patient assessment is performed by the cardiologist before the start of the rehabilitation programme in order to avoid risks and tailor the programme to the patient's needs, capacities and expectations. Although the proportion of patients with HF benefitting from rehabilitation has increased and must continue to do so, there are still too many – including heart disease patients, patients with congenital cardiopathies, older subjects and women – who do not have access. The indications must be communicated to all those involved in the patient's trajectory to ensure that the patient can be referred to cardiac rehabilitation after diagnosis or at any time during the progression of their chronic disease.

The prescription of training with details on frequency, intensity, duration and type of activity allows greater precision and harmonization of practices, with the objective of leading the patient to make progress and to engage long-term with regular physical activity in phase III. Structured therapeutic education programmes make the patient more autonomous, allowing them to live safely with their disease. Finally, therapeutic optimization, which is facilitated during rehabilitation, often makes it possible to attain recommended treatment objectives. Cardiac rehabilitation is also the ideal context to introduce psychosocial monitoring and to take comorbidities into account, thus improving the patient's lived experience, reducing the consequences of their disease and increasing their chances of returning to professional activity.

The decrees from 2022 set out the modalities for functioning, the skill-sets necessary, as well as the safety and quality criteria applied to rehabilitation institutions.

Finally, the future of cardiac rehabilitation, to benefit the largest possible number of patients, will require the implementation of alternative forms that are simpler, more flexible, more tailored, and provided in centres, at a distance or at home. The objective is to be able to offer each patient the form that suits them, depending on the severity of their disease, their needs, motivation and geographical situation, as well as their personal, familial and professional availability. These adaptations should help to disseminate this safe and effective patient management technique – that is both appreciated by patients and is completely relevant in terms of public health – as widely as possible.

Disclosure of interest

The authors declare that they have no competing interest.

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