Heart, Lung and Circulation (2023) ■, ■–■
1443-9506/23/$36.00
https://doi.org/10.1016/j.hlc.2023.06.854

POSITION STATEMENT

# A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement

**Christian Verdicchio, PhD [a,b,1,*], Nicole Freene, PhD [c,d,1], Matthew Hollings, PhD [a,1], Andrew Maiorana, PhD [e,f], Tom Briffa, PhD [g], Robyn Gallagher, PhD [a], Jeroen M. Hendriks, PhD [b,h], Bridget Abell, PhD [i], Alex Brown, PhD [j], David Colquhoun, MBBS, PhD [k,l], Erin Howden, PhD [m,n], Dominique Hansen, PhD [o], Stacey Reading, PhD [p], Julie Redfern, PhD [a]**

[a]Faculty of Medicine and Health, University of Sydney, Sydney, NSW, Australia
[b]Centre for Heart Rhythm Disorders, University of Adelaide, SAHMRI and Royal Adelaide Hospital, Adelaide, SA, Australia
[c]Physiotherapy, Faculty of Health, University of Canberra, Canberra, ACT, Australia
[d]Health Research Institute, University of Canberra, Canberra, ACT, Australia
[e]Allied Health Department, Fiona Stanley Hospital, Perth, WA, Australia
[f]Curtin School of Allied Health, Curtin University, Perth, WA, Australia
[g]School of Population and Global Health, University of Western Australia, Perth, WA, Australia
[h]Caring Futures Institute, College of Nursing and Health Sciences, Flinders University, Adelaide, SA, Australia
[i]Australian Centre for Health Services Innovation and Centre for Healthcare Transformation, School of Public Health and Social Work, Queensland University of Technology, Brisbane, Qld, Australia
[j]Telethon Kids Institute, Australian National University, Canberra, ACT, Australia
[k]Faculty of Medicine, University of Queensland, Brisbane, Qld, Australia
[l]Faculty of Medicine, Wesley Medical Centre, Brisbane, Qld, Australia
[m]Baker Heart and Diabetes Institute, Melbourne, Vic, Australia
[n]Baker Department of Cardiometabolic Health, University of Melbourne, Melbourne, Vic, Australia
[o]UHasselt, REVAL/BIOMED (Rehabilitation Research Centre), Hasselt University, Hasselt, Belgium
[p]Department of Exercise Sciences, University of Auckland, Auckland, New Zealand

*Received 19 June 2023; accepted 27 June 2023; online published-ahead-of-print xxx*

Patients with cardiovascular disease benefit from cardiac rehabilitation, which includes structured exercise and physical activity as core components. This position statement provides pragmatic, evidence-based guidance for the assessment and prescription of exercise and physical activity for cardiac rehabilitation clinicians, recognising the latest international guidelines, scientific evidence and the increasing use of technology and virtual delivery methods. The patient-centred assessment and prescription of aerobic exercise, resistance exercise and physical activity have been addressed, including progression and safety considerations.

**Keywords** Cardiac rehabilitation • Secondary prevention • Coronary disease • Cardiovascular disease • Exercise assessment • Exercise prescription • Physical activity • Position statement

*Corresponding author at: Dr Christian Verdicchio, Faculty of Medicine and Health, University of Sydney, Sydney, NSW, Australia; Centre for Heart Rhythm Disorders, University of Adelaide and Royal Adelaide Hospital, Adelaide, SA, Australia; Email: christian.verdicchio@sydney.edu.au; Twitter: @c_verdicchio
[1]Co-first authors



Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

# Introduction

Cardiovascular disease (CVD) is the leading cause of death and disease burden globally [1]. Improvements in diagnosis, treatment and long-term management have improved survivorship and reduced hospitalisations following a cardiac event, however they have also greatly increased the number of patients requiring ongoing and lifelong CVD risk management [2,3]. To reduce the risk of future events, international guidelines recommend all eligible patients have access to, and participate in, secondary prevention programs, including cardiac rehabilitation [4,5]. Cardiac rehabilitation is a comprehensive, multidisciplinary intervention consisting of patient assessment and individualised risk profile management, dietary advice, exercise prescription and physical activity counselling and psychosocial support [6]. The National Heart Foundation of Australia, the Australian Cardiovascular Health and Rehabilitation Association (ACRA) and the National Heart Foundation of New Zealand all promote cardiac rehabilitation and have online resources that can provide referrers with a list of local services available for their patients. Exercise-based cardiac rehabilitation has demonstrated effectiveness for reducing hospitalisations and myocardial infarction rates, whilst improving risk profile, exercise capacity and quality of life in patients with coronary disease [7,8]. Exercise programming also benefits patients with other cardiovascular conditions such as heart failure (both reduced and preserved ejection fraction) [9,10], atrial fibrillation [11], peripheral vascular disease [12], congenital heart disease [13], valve disease [14], pulmonary hypertention [15] and, more recently, with cardio-oncology patients [16].

A graduated program of structured exercise and physical activity is a core component of comprehensive cardiac rehabilitation [17]. Recent studies have described new exercise training techniques, which have improved our understanding of the physiological adaptations from exercise training across diverse patient groups. Furthermore, recent data have also provided a greater understanding of technology and virtual delivery methods for the prescription of exercise and physical activity within cardiac rehabilitation programs. A patient-centred approach is important, and communication with patients should be non-judgemental and respectful. Shared decision making, where patients and their carers are actively involved in the care process, results in personalised interventions that are more likely to improve engagement, treatment adherence, and clinical outcomes [18]. Concomitantly, health professionals should consider evidence, guidelines and behaviour change theories, techniques, and tools when collaborating with patients, identifying their individual exercise and physical activity needs, values and preferences. Realistic short- and medium-term goal setting may be considered, and follow-up should be discussed and supported by the entire multidisciplinary team as they are central to the patient's rehabilitation journey [18].

The objective of this position statement is to provide pragmatic, evidence-based guidance for the assessment and prescription of exercise and physical activity by all clinicians working within cardiac rehabilitation (e.g., exercise physiologists, nurses, physiotherapists) in the Australian and New Zealand context. Specifically, the aim is to summarise the assessment and prescription recommendations for aerobic exercise, resistance exercise and physical activity for all patients referred for secondary prevention of their recent cardiac event or a new diagnosis. To do this, a multidisciplinary writing group was convened comprising of experts from relevant disciplines, with regional, gender and cultural representation to ensure diversity. A consensus process was then followed to draft, review, and refine the document. The position paper was then submitted to the Cardiac Society of Australia and New Zealand, ACRA, Exercise and Sports Science Australia, and the Australian Physiotherapy Association for endorsement.

# Aerobic Exercise

Aerobic exercise is defined as any activity that uses large muscle groups that can be maintained continuously and is rhythmic in nature [19]. Common forms of aerobic exercise include walking, jogging, cycling, rowing and swimming. The benefits of aerobic exercise training within cardiac rehabilitation are well established [7,8]. Cardiometabolic benefits include (but are not limited to) improved insulin sensitivity and glycaemic control, reduction in inflammatory markers, reduced visceral fat, improved vascular function and blood pressure control, improved lipid metabolism, improved skeletal muscle structure and function and modest improvements in left ventricular function [10,20,21].

## Assessment

The ACRA cardiac rehabilitation core components state that all patients should receive "an individualised initial assessment that includes physical, psychological and social parameters" [17]. This assessment enables the development and implementation of an individualised exercise program based on the aerobic exercise or functional capacity of the patient.

An aerobic exercise assessment should be conducted to assess the patient's aerobic exercise capacity. Prior to performing any exercise assessment, it is imperative that clinicians consider all relevant contraindications (Table 1). The gold-standard assessment for aerobic exercise capacity is a cardiopulmonary exercise test (CPET) conducted on either a treadmill or cycle ergometer with gas analysis. However, this test is limited to predominantly tertiary centres in Australia and New Zealand due to the cost and specialised equipment and staff required to conduct it. Several methods for assessing aerobic exercise capacity and functional exercise capacity, and the pros and cons of each are summarised in Table 2.

## Prescribing and Progressing Aerobic Exercise

Figure 1 summarises the recommended clinician workflow in relation to assessment, prescription and progression of

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

**Table 1 Absolute and relative contraindications to exercise and physical activity.***

| Absolute Contraindications | Relative Contraindications[#] |
|---|---|
| Progressive worsening of exercise tolerance or dyspnoea at rest or on exertion over previous 3–5 days (uncompensated heart failure) | 2 kg increase in body mass over previous 1–3 days^ |
| Unstable angina | Concurrent continuous or intermittent dobutamine therapy |
| Blood glucose <4.0 mmol/L or >15.0 mmol/L with symptoms of weakness/tiredness, or with ketosis | Decrease in systolic blood pressure with exercise |
| Acute systemic illness or fever | NYHA functional class IV |
| Recent embolism (<4 weeks) | Complex ventricular arrhythmia at rest or appearing with exertion |
| Thrombophlebitis | Supine resting heart rate ≥100 bpm |
| Active pericarditis or myocarditis* | |
| Severe symptomatic aortic stenosis | Moderate aortic stenosis |
| Regurgitant valvular heart disease requiring surgery | Blood pressure >180/110 mmHg (evaluated on a case-by-case basis) |
| Previously undiagnosed atrial fibrillation | Sternal Instability Scale grade 1–2 (minimally to partially separated sternum) |
| Sternal Instability Scale grade 3 (completely separated) | |
| Resting heart rate >120 bpm | |
| Orthostatic blood pressure drop of >20 mmHg with symptoms | |
| Third-degree atrioventricular block without pacemaker | |

*Adapted from HeartOnline [52]; American College of Sports Medicine Guidelines for Exercise Testing and Prescription [22]; El-Ansary et al. [34].
*During recovery, limit to light to moderate intensity exercise until left ventricular dysfunction has resolved.
#Relative contradictions are a guide only and should be combined with clinical judgement at every session. If in doubt, medical advice should be sought before commencing an exercise or physical activity assessment or session.
^Rapid weight gain may be a red flag for heart failure.
Abbreviation: NYHA, New York Heart Association.

aerobic exercise training. Informed by a comprehensive clinical history and exercise assessment, the fundamental principles of exercise prescription should be applied: Frequency, Intensity, Time, Type, Volume and Progression (FITT-VP) [22]. Frequency (F) considers how often the patient completes the exercise. Intensity (I) is the level of effort the patient should be exercising at based on assessment of their exercise capacity. Absolute intensity refers to the energy required to perform an activity (e.g., caloric expenditure, absolute oxygen uptake, metabolic equivalent of task). Whereas relative intensity refers to the energy cost of the activity relative to the individual's maximal capacity (e.g., % maximum oxygen consumption or heart rate reserve, perceived exertion). For individualised exercise prescription, a relative measure of intensity is recommended, especially for deconditioned individuals [22]. Time (T) is the duration of each exercise session. Type (T) is the mode of exercise to be completed. Volume (V) is the total amount of exercise training, a product of frequency, intensity and time. Progression is the commencement, advancement and progression of intensity or volume over time [15]. It is important to highlight that rest or recovery within and between sessions should also be promoted for patients to maximise their overall health status and adaptations to exercise. Table 3 provides FITT-VP recommendations for an individually tailored aerobic exercise prescription at a moderate-high intensity. Table 4 provides a summary of the definitions of light, moderate, high, and very-high intensities when assessing or prescribing exercise or physical activity.

## Moderate-Intensity Continuous Training Versus High-Intensity Interval Training

In Australia and New Zealand, exercise prescription guidelines for cardiac rehabilitation have historically been more conservative compared to those in Europe and America, focussing on low-to-moderate intensity exercise, with less technical assessment of aerobic capacity [23]. Moderate-intensity continuous training (MICT) is beneficial and safe for all patients with coronary disease and is strongly recommended [6,24]. More recently, high-intensity interval

**Table 2 Types of aerobic exercise, muscle strength and physical activity assessments.**

| Type of assessment | Description | Pros | Cons |
|---|---|---|---|
| Aerobic Capacity | | | |
| **Cardiopulmonary Exercise Test (CPET)** | Incremental treadmill (Modified Bruce, Naughton, Balke protocols [52]), or leg/arm ergometer test (Ramp protocol) with concomitant expired air analysis. | Gold standard<br>Valid and reliable<br>Tailored exercise prescription<br>Investigates the physiology of exercise intolerance [53]<br>Assesses ventilatory responses to exercise<br>Assesses ventilatory thresholds (VT1 and VT2)<br>Heart rate response to peak exercise<br>Blood pressure response<br>Peak $VO_2$ prognostic marker | Requires supervision by an allied health professional with extensive experience and training in the ability to interpret an electrocardiogram [54]<br>Medical Practitioner on site [55]<br>Generally limited to tertiary medical centres, often with specialist cardiac services<br>Expensive equipment required |
| **Graded Exercise Test** | Treadmill or leg/arm ergometer test following a standardised protocol (e.g., Balke, Naughton or Bruce Protocols [56]). Test may be ceased once the patient reaches 85% of their age predicted $HR_{max}$ (65% for those with beta-blockade therapy who are well rate controlled during exercise), or if clinically indicated; e.g., chest pains, dyspnoea, light-headedness, or fatigue [22,55,56] | Assessment of haemodynamic response to exercise<br>Tailored exercise prescription<br>Easy to implement<br>Lower cost than CPET<br>Peak METs prognostic | Requires qualified supervision<br>Inability to walk on slowest treadmill speed |
| **Functional Exercise Capacity/Field Tests** | Incremental Shuttle Walk Test:<br>Incremental walking test between the two cones 10 m apart timed to an audio signal (beep). Patient walks as long as possible or can no longer keep up with the beeps [57].<br>Six-Minute Walk Test (6MWT):<br>Low-resource test that involves walking as far as possible in 6 minutes, along a 20–30m flat track. Calculate average speed (km/hr) to guide exercise prescription = (6MWT distance x10)/1000. | Valid and reliable<br>Externally paced<br>Low-cost requiring minimal equipment<br>Assessment of physiological indices<br>Tailored exercise prescription<br>Well established [17]<br>Prognostic<br>Easy to comprehend and perform<br>Suitable for the less agile<br>Assessment of physiological indices<br>Tailored exercise prescription<br>Minimal resources<br>Blood pressure and heart rate monitoring | External audible timed signal<br>More complex than 6MWT<br>Unsuited for those unable to walk at least 1.8 km/hr<br>Submaximal test as patient unlikely able to reach higher intensities<br>Limited tool to prescribe exercise intensity targets<br>Sensitivity |

HLC3932_proof ■ 24 July 2023 ■ 5/14

**Table 2.** (continued).

| Type of assessment | Description | Pros | Cons |
|---|---|---|---|
| **Muscle Strength** | | | |
| **1RM assessments** | Defined as the maximum weight that can be lifted for one-repetition, through the full available range of motion and with an acceptable level of technical proficiency<br>Completed for any major muscle group and requires either machine weights or free weights<br>Test terminated when patient is unable to perform one acceptable repetition on two consecutive attempts | Good–excellent test-retest reliability regardless of age, sex, experience level or muscle group [58]<br>Safe and tolerable for cardiac rehabilitation patients [59,60]<br>May limit the haemodynamic excursions seen in higher repetition assessments [61]<br>Results can directly inform exercise prescription | Requires machine or free weights with adequate available loading, which can be costly<br>Requires supervision of appropriately trained and experienced clinicians<br>Risk of musculoskeletal complications |
| **Estimated 1RM assessments** | Uses validated prediction equations [62] to estimate 1RM based on a multiple repetition test<br>Multiple repetition test = the highest weight that can be lifted for a specified number of repetitions to failure (e.g., a 3–6-repetition maximum test)<br>Higher reliability with lower repetition tests ($\leq$6 reps)<br>Same equipment, range of motion, technical proficiency and termination criteria as standard 1RM test | Lower loads may suit equipment limitations or patient/clinician hesitancy<br>Safe and tolerable for cardiac rehabilitation patients [59,60]<br>Results can directly inform exercise prescription | Some error associated when population-level estimation equations used to predict individual outcomes<br>Requires machine or free weights with adequate available loading, which can be costly<br>Requires supervision of appropriately trained and experienced clinicians |
| **Low-resource assessments** | The general principle of these assessments is for patients to either: (1) complete a specified number of repetitions in the fastest possible time (e.g., 5 sit-to-stands for fastest time), or (2) complete the highest number of repetitions in a specified period of time (e.g., maximum number of sit-to-stands in 30 seconds) | Easily implemented across most CR settings<br>Minimal equipment requirements<br>Repeatable, objective measurement of muscular strength or endurance | Outcome not transferrable to resistance exercise equipment for prescription |

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

HLC3932_proof ■ 24 July 2023 ■ 6/14

**Table 2.** **(continued).**

| Type of assessment | Description | Pros | Cons |
|---|---|---|---|
| **Physical Activity** | | | |
| **Pedometers** | Research vs consumer pedometers<br>Range in functionality and accuracy and are often found in smartphones or smartphone apps | Less prone to recall error and bias [63]<br>Output (steps) is simple to understand<br>Consumer pedometers have reasonable accuracy for steps [64] | Unable to determine context of activity<br>Insensitive to non-ambulatory and water activities (e.g., cycling, swimming) [63]<br>Output does not capture intensity |
| **Accelerometers** | Research vs consumer accelerometers<br>Capture acceleration of movement in one or more planes, as well as steps | Provides a measure of intensity, allowing an overall measure of activity volume (i.e., MVPA minutes/week) | Accelerometer intensity thresholds may not be appropriate for cardiac populations |
| **Inclinometers** | Research vs consumer inclinometers<br>Measure postural transitions, recording time in sitting/lying, standing and stepping | Considered the most accurate measure of sedentary behaviour | |
| **Physical activity and Sedentary Behaviour questionnaires** | Long-format International Physical Activity Questionnaire [65] (group level measure)<br>Active Australia Survey [66] (group level measure)<br>Physical Activity Vital Sign [67] (clinically feasible, individual level measure)<br>Past-day Adults' Sedentary Time questionnaire [68] (group level measure) | More practical due to their low cost and ease of use in the clinical setting<br>Past-day Adults' Sedentary Time questionnaire has been validated in the cardiac rehabilitation setting | More likely to under or over-estimate physical activity and sedentary time due to recall bias<br>Tend to show low correlations with objective measures<br>No physical activity questionnaires have been validated in the cardiac rehabilitation setting |
| **Activity diaries** | At an individual level, activity diaries can also be used | | Labour intensive for participants [69] |

Abbreviations: METs, metabolic equivalents; VT1, ventilatory threshold 1; VT2, ventilatory threshold 2; $VO_2$, volume of oxygen consumption; 1RM, 1 repetition-maximum; MVPA, moderate-to-vigorous physical activity.

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

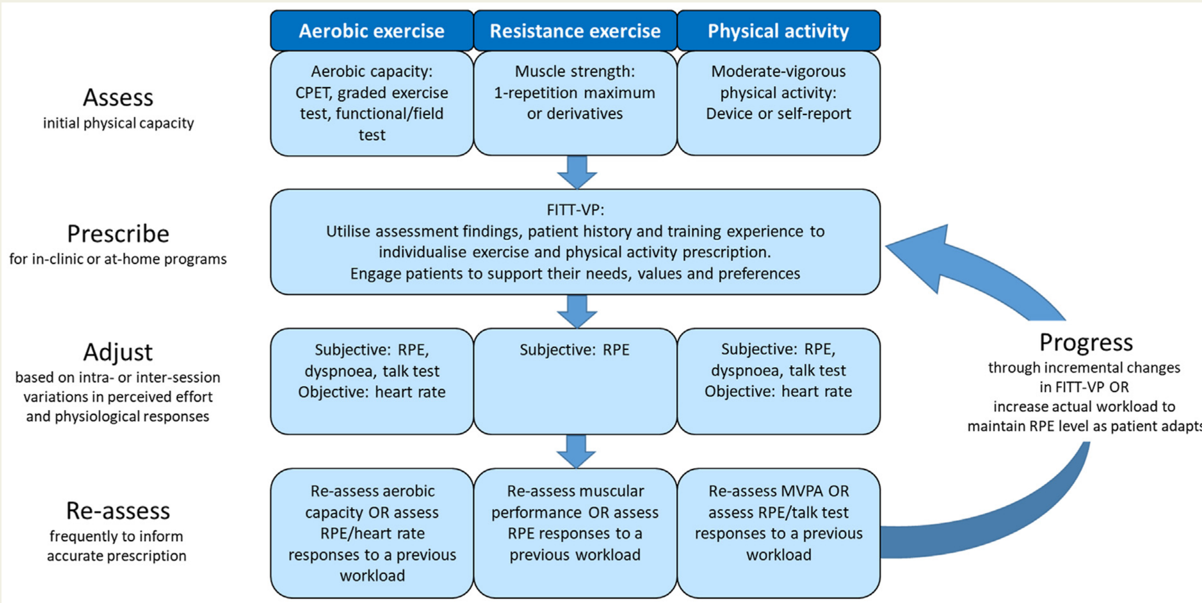


**Figure 1** A practical guide for the assessment, prescription and progression of aerobic exercise, resistance exercise and physical activity.
Abbreviations: CPET, cardiopulmonary exercise test; FITT-VP, frequency intensity time type volume progression; RPE, rate of perceived exertion; MVPA, moderate-to-vigorous physical activity.

training (HIIT) has also been recommended and deemed safe by international authorities for various patients with stable cardiac disease and may provide superior outcomes compared to MICT [25–27].

If appropriate, moderate- and high-intensity training can be prescribed interchangeably as patients progress, while considering patients' preferences and ability, and can be a good combination to improve a patient's aerobic exercise capacity [28]. MICT is recommended for those patients with low aerobic exercise capacity and, where appropriate, patients could be progressed to high intensity sessions as their aerobic exercise capacity improves. Select patients with stable coronary disease, and a good level of aerobic exercise capacity, may progress to high-intensity exercise after a brief period of moderate-intensity exercise training. The most commonly used HIIT model is a warm-up, followed by 4x4-min intervals at 75%–90% peak heart rate ($HR_{peak}$) with an active recovery phase of 3-min between bouts at approximately 60% $HR_{peak}$, followed by a cool-down [28]. However, a flexible approach, tailored to individual requirements is judicious in practice, such as shorter intervals and/or a lower intensity for patients who have a reduced aerobic capacity and who may be unable to complete a full 4-min workload [28].

## Resistance Exercise

Resistance exercise requires the contraction of one or more muscle groups against an external resistance (e.g., weights) with the intention to enhance muscular adaptions such as strength, mass and endurance [22]. Participation in structured resistance exercise sessions, known as resistance training, also improves functional performance and prognosis for patients with heart failure [29] or coronary artery disease [30].

Resistance training is an important aspect of an exercise program for the diverse and ageing cardiac rehabilitation population, offering unique benefits that are not provided by aerobic exercise training. Specifically, resistance training can prevent or reverse the loss of muscle mass (sarcopenia) that occurs after coronary artery bypass grafting and with older age, and can also benefit comorbid metabolic, vascular, cognitive, frailty and mental health conditions [31]. Moreover, the addition of resistance training to aerobic exercise programs enhances both muscular strength and aerobic capacity adaptations in patients with coronary disease [32]. Despite historical concerns regarding safety, resistance exercise is well tolerated by patients with cardiovascular conditions, with very few adverse cardiovascular events reported [32] and acute haemodynamic changes comparable to aerobic exercise [33].

### Assessment

The objective assessment of muscle strength in cardiac rehabilitation is important to determine and quantify baseline muscle strength, guide individual prescription, and evaluate changes in muscular strength. It is critical that clinicians consider all relevant contraindications before conducting any resistance exercise testing (Table 1), including

**Table 3** **FITT-VP Recommendations for prescribing aerobic exercise, resistance exercise and physical activity in cardiac disease patients.**

| | Aerobic Exercise | Resistance Exercise | Physical Activity |
|---|---|---|---|
| *All recommendations should primarily be based on patient need and preference and individual risk assessment* | | | |
| **Frequency** | 3 or more days per week [6]. For patients completing HIIT, at least two of these sessions per week are recommended to be high intensity. | 2–3 sessions per week. Recommend 48 hours between sessions, where possible, to maximise muscular recovery | MVPA should be completed on most days per week, which includes exercise as a subset. |
| **Intensity** | Moderate-to-high intensity (Table 4; e.g., 55%–90% HRmax, RPE 12–16) based on assessment of aerobic capacity (Table 2) | Moderate-to-high intensity (Table 4; e.g., 50%–80% 1RM or 5–7 RPE based on assessment of muscular performance.<br>Initial prescriptions recommended at moderate intensity for patients not experienced in resistance training | MVPA is recommended to meet the physical activity guidelines. Patients can use the Borg RPE. Modified RPE or the Talk Test to monitor how hard they are working (Table 4) |
| **Time** | Session duration >30 min of total aerobic exercise. For patients who are severely deconditioned or have symptoms at low workloads, it is recommended to start with bouts of light-moderate continuous exercise of 5–10 min in duration with breaks as required, to allow full recovery and repeat 2–3 times, progressing towards 30 min of continuous activity. Once moderate intensity activities are tolerated, patients should be encouraged to exercise at higher intensities | Session duration: >20 min<br>Duration of muscle contraction >4 second per repetition (>1 s concentric phase, >3 s eccentric phase)<br>Rest between sets: 60 s [70] | 150–300 min moderate intensity, or 75–150 min vigorous intensity, or a combination of both, per week is the aim. This does not need to be accumulated in 10-minute bouts.<br>Additionally, break up long periods of sedentary time, replacing with any intensity of physical activity, including light intensity. |
| **Type** | A variety of aerobic modes of exercise are recommended that use large muscle groups such as walking, jogging, cycling, swimming, rowing, stair climbing.<br>Arm-ergometry can also be used if there are underlying musculoskeletal issues affecting lower limb use. | Whole body, single- or multi-joint exercises, performed bilaterally where possible. May include a range of modalities including bodyweight, free-weights, machine weights and elastic resistance bands.<br>Altering the type of resistance training performed can be a useful way to manipulate intensity through changes in body position and loading, particularly in low-resource settings | A variety of MVPA is recommended including domestic, occupational, transportation and leisure activities.<br>Explore opportunities to increase physical activity within the individual's existing daily routines, encouraging activities that the individual enjoys.<br>Be aware of local physical activity referral opportunities (e.g., Heart Foundation walking groups, Parkrun), if appropriate. |
| **Volume** | A minimum of 150 minutes of moderate-high intensity aerobic exercise, with an ideal target of >210 min per week for increased cardiometabolic benefit [71] | Total session volume per major muscle group = 15–36 repetitions, arranged as 1–3 sets of 8–15 repetitions.<br>Initial prescriptions can consider lower volumes to allow patient familiarisation prior to progressing towards higher volumes | ≥150 min MVPA per week; ≥7,500 steps/day [72] |

ARTICLE IN PRESS HLC3932_proof ■ 24 July 2023 ■ 9/14



**Table 3. (continued).**

| | Aerobic Exercise | Resistance Exercise | Physical Activity |
|---|---|---|---|
| **Progression** | Start slowly and progress gradually, increasing duration to meet 30 min before increasing intensity. Increases in intensity and duration of 5%–10% every 1–2 weeks are typically well-tolerated within cardiac patients. | Clinicians should progress at least one of the following to optimise resistance training adaptations: volume (reps, sets), intensity, type, frequency. Volume and intensity should be progressed before other training variables. E.g., Progress repetitions before sets or intensity, up to a maximum of 15. Once 15 reps can be completed with ease, then intensity should be progressed to 4–6 on RPE scale at a new target of 8–10 reps. Intensity should then be progressed towards the highest tolerable intensity and sets progressed towards 3 per major muscle group. | Start slowly and progress gradually, increasing duration before intensity. If appropriate, individuals may start with as little as 2–5 minutes of activity, 3–4 times a day. Progress towards 30 min of moderate intensity physical activity or 7,500 steps on most days, noting any activity is better than none |

Abbreviations: HIIT, high-intensity interval training; MICT, moderate-intensity continuous training; $HR_{max}$, Maximal heart rate; MVPA, moderate-to-vigorous physical activity; RPE, rate of perceived exertion; reps, repetitions.

the sternal stability of post-sternotomy patients prior to commencing upper body resistance training [34].

Muscle strength should be assessed or estimated relative to the 1-repetition maximum (1RM) outcome measure. Several alternative methods for the assessment of muscle strength are summarised in Table 2, where individual service-level factors like equipment availability and clinician experience may limit the accessibility of 1RM assessment. It is important to note these alternative methods are limited in their ability to inform exercise prescription.

## Prescribing and Progressing Resistance Exercise

Figure 1 summarises the recommended clinician workflow in relation to assessment, prescription and progression of aerobic exercise training. Prescription of resistance training during cardiac rehabilitation should be informed by the results of a comprehensive assessment and align with the dual principles of resistance training programming: individualisation and progression [26]. Individualisation refers to tailoring the resistance exercise prescription specific to a patient's physical capacity, experience, preference and cardiac history. Progression is the application of the progressive overload principle and it refers to the increases in intensity or volume over time that is essential for promoting muscle adaptions to exercise. Prescription recommendations for resistance training are summarised in Table 3 and exercise intensities in Table 4.

An objective measurement of muscular strength (e.g., 1RM) for each of the available equipment types or movements facilitates accurate initial exercise intensity prescription [26]. In the absence of objective data for all movements, the most relevant subjective measurement to inform prescription and progression of resistance exercise is the rating of perceived exertion (RPE) (Table 4). Scales include the Borg and Omnibus Resistance Exercise Scale (OMNI-RES) for rating perceived exertion that allow patients to rate their own perceived level of exertion from 1–10 (10 is maximal) using a number or pictorial tool that have been validated against other subjective scales for use specifically in resistance exercise [35].

Many patients will have had limited exposure to resistance exercise prior to cardiac rehabilitation enrolment. Thus, it is important for patients to develop good technical proficiency during the initial training sessions, to set the technical foundation and allow for the safe progression of resistance exercise load and volume throughout the program [26]. Clinicians are encouraged to initially provide a demonstration and then communicate with and coach the patient throughout the exercise delivery to facilitate skill acquisition and body awareness. Thus, clinicians should embed clear, concise instructions for each exercise and simple, consistent feedback at the conclusion of each set. Patients should also be advised that: (1) breath-holding (Valsalva manoeuvre) should be avoided during resistance exercise to limit blood pressure excursions; (2) muscle tension during resistance exercise is a normal sensation; and (3) muscle soreness is

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

**Table 4** Aerobic exercise, physical activity and resistance training intensities.

| | | Light Intensity | Moderate Intensity | High/Vigorous Intensity | Very High Intensity |
|---|---|---|---|---|---|
| Aerobic exercise/physical activity | $VO_{2max}$ [26] (%) | <40 | 40–69 | 70–85 | >85 |
| | $HR_{max}$ (%) | <55 | 55–74 | 75–90 | >90 |
| | HRR (%) | <40 | 40–69 | 70–85 | >85 |
| | 6MWT average speed* [73] (%) | | 80 | 100 | |
| | Borg RPE | 10–11 | 12–13 | 14–16 | 17–19 |
| | Modified RPE | 2–3 | 4–6 | 7–8 | 9 |
| | Talk test [74] | Able to sing | Able to talk in full sentences/ unable to sing | Unable to talk comfortably | |
| Resistance training | 1RM (%) | <50 | 50–69 | 70–84 | ≥85 |
| | OMNI-RPE [35] | <5 | 5 | 6–7 | ≥8 |

*These intensities may be an underestimate in fitter individuals in whom the test is submaximal.
Abbreviations: $VO_{2max}$, maximal oxygen capacity; $HR_{max}$, Maximal heart rate, HRR, heart rate reserve; 6MWT, 6-minute walk test; RPE, rate of perceived exertion; 1RM, 1 repetition maximum.

common in the first few days after resistance exercise but is reduced with subsequent exposures [26]. The recommendation for preliminary sessions is to commence at lower ranges of the recommended intensity so that patients can primarily focus on technique without being hampered by muscular fatigue [26].

# Physical Activity

Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure such as walking for transport, dancing, housework, or gardening; with exercise as a subset [36]. Sedentary behaviour is any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining, or lying posture [37]. In people with coronary disease, physical inactivity and sedentary behaviour are risk factors for cardiovascular and all-causes of death [38,39]. Active people with coronary disease have a 50% lower risk of mortality, compared to inactive counterparts [38]. Additionally, sufficient physical activity reduces the impact of coronary disease, slows its progress and improves modifiable risk factors for recurrent CVD and other chronic disease [40]. Consequently, individuals undertaking cardiac rehabilitation and secondary prevention interventions are encouraged to meet the public health physical activity guidelines to improve health outcomes [17].

The World Health Organization physical activity guidelines for adults with chronic disease recommend that individuals should complete 150–300 minutes of moderate intensity aerobic physical activity; or 75–150 minutes of vigorous intensity aerobic physical activity or a combination of both per week [41]. Muscle strengthening should be completed on at least two days per week and varied functional balance and strength activities should be completed three days per week. In addition, long periods of sedentary time should be avoided, replacing sedentary time with any intensity of physical activity, including light intensity, and, for those who find it difficult to meet guidelines, any activity is better than none [41,42].

## Assessing Physical Activity

Physical activity and sedentary behaviour can be assessed subjectively (e.g., questionnaire) or objectively (e.g., pedometer, accelerometer) to determine whether an individual is inactive (i.e., not meeting the physical activity guidelines). The most common metrics used to measure physical activity are minutes of moderate-to-vigorous physical activity (MVPA) and step counts. Table 2 outlines methods for assessing physical activity and sedentary behaviour in clinical practice.

## Prescribing and Progressing Physical Activity

Figure 1 summarises the recommended clinician workflow in relation to assessment, prescription and progression of physical activity. Following a comprehensive assessment of an individual's physical activity levels and their safety to increase these levels (Table 1), physical activity can be prescribed according to the FITT-VP principle. An individual's goals, motivation and confidence to increase physical activity in everyday life should be reviewed as part of a comprehensive assessment, with each patient receiving an individually tailored physical activity program based on these findings. Recommendations for physical activity prescription and counselling at a moderate-vigorous intensity (Table 4) are outlined in Table 3.

Clinicians (e.g., nurses, allied health professionals, medical doctors) are well placed to provide general physical activity advice on the types and amount of activity appropriate for the individual's goals, needs, abilities, preferences, functional limitations, medication regimes and treatment. For more specific physical activity advice, exercise specialists such as physiotherapists and exercise physiologists should be consulted. A medical review is generally unnecessary prior to beginning light-to-moderate intensity physical activity within cardiac rehabilitation and the community, unless there are known contraindications (Table 1) [41]. For vigorous or high intensity physical activity (e.g., jogging, tennis singles), a full clinical assessment and medical review is recommended [15].

# Safety and Monitoring

Regardless of diagnosis, whether there has been an acute cardiac event or procedure, comorbidities or age, all individuals should be encouraged to increase their exercise and physical activity levels safely, starting slowly at an appropriate level and progressing gradually [6,41]. It is recommended that when conducting centre-based exercise sessions there are basic safety standards and procedures in place, such as a defibrillator, resuscitative and first-aid equipment on-site. Prior to each supervised exercise session, it is recommended to assess the patient's contraindications to exercise, measuring pre-exercise heart rate and blood pressure, to ensure that they are within an acceptable range at rest (Table 1). However, as patients progress and their cardiac disease is stable with no symptoms, these pre-exercise measurements are not necessary and may be counterproductive to the patient's feelings around exercise and physical activity in an unsupervised state. Clinical risk may increase over time due to disease progression or clinical deterioration. When in doubt, seek medical advice or support before commencing the exercise session. During exercise it is recommended to monitor the patient's heart rate and RPE (or Borg Scale for Dyspnoea in patients with heart failure) to ensure they are reaching their target intensity during their aerobic bout of exercise and responding to exercise appropriately (Figure 1). ECG monitoring during exercise is not essential for patients within the supervised setting; however, in certain circumstances (e.g., atrial fibrillation, history of significant ventricular arrhythmias), it is beneficial to use for patients showing signs or symptoms necessitating further investigation. For most asymptomatic patients, continuous ECG monitoring can be counterproductive by exacerbating feelings of anxiety around exercise that delays development of patient self-efficacy. A warm-up and cool-down should be included in all exercise sessions and physical activity for 5–10 minutes, gradually increasing and lowering the heart rate and blood pressure to limit rapid haemodynamic changes.

For resistance exercise in people with underlying musculoskeletal conditions, correct technique and modifying intensity or volume are important for reducing the risk of aggravating these conditions [32]. Special consideration should also be given to recent median sternotomies; however, evidence supports early initiation of upper body movements within safe limits of pain [43,44]. "Keep your move in the tube" is a paradigm shift that promotes upper limb activity and exercise using short lever arms by performing activities close to the body. This encourages clinicians to engage patients in early active recovery by educating on what they *can safely do*, in contrast to prescribing overly restrictive precautions not supported by current evidence [43,44]. More recently, early post-sternotomy resistance exercise inclusive of individualised upper limb exercise has been reported as safe and resulted in significant improvement in muscular strength and cognitive recovery [45].

Within the community, patients should be advised to wear comfortable clothing and footwear, have adequate fluid intake and avoid activity after heavy meals, if they are suffering from an illness, and in extreme temperatures. During unsupervised exercise and physical activity, individuals should monitor their intensity (e.g., talk test, RPE; Table 4) and symptoms (i.e., chest pain, dizziness, nausea, feeling unwell, excessive sweatiness). If patients experience any warning signs of a cardiac event, then they should be encouraged to call an ambulance immediately. To improve adherence to the exercise and physical recommendations, interventions using mHealth (e.g., text messages, smartphone apps) and wearable activity trackers should be considered [46].

# Wearable Activity Trackers

There is emerging evidence that the use of free-living wearable activity trackers (e.g., smartwatches, wristbands, chest strap, clothing and shoe-embedded sensors, smartphone pedometers and accelerometers) leads to increased physical activity levels and aerobic capacity in cardiac rehabilitation participants [47]. The increasing self-initiated use of wearable activity trackers by patients provides an opportunity for clinicians to promote physical activity using these devices. The use of wearable activity trackers can be successfully incorporated within clinical settings after reviewing some device and individual factors [48]. Clinicians should consider device availability, usability (e.g., battery life, metrics available (step count, MVPA, heart rate)), clarity of the interface and management of the devices (e.g., downloading and

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

interpreting the data). Reliability and validity of the device is important, as well as data security and management. At an individual level, clinicians should determine whether patients are motivated to use a wearable activity tracker and have matching levels of digital literacy. Clinicians can maximise the effectiveness of wearable activity trackers, over the short and long term, through encouraging, educating, monitoring, and providing effective feedback loops to promote individual engagement and autonomy beyond the structured, supervised cardiac rehabilitation setting.

## Using Telehealth to Assess and Prescribe Exercise and Physical Activity

Over the past decade telehealth has emerged as an alternative and effective model for delivering cardiac rehabilitation, with its utilisation increasing markedly during the COVID-19 pandemic due to widespread restrictions to face-to-face delivery [49]. Ideally, it is recommended that exercise and physical activity assessments are done in-person to ensure a safe and standardised assessment. However, for a variety of reasons, including patient preference, this may not be possible, in which case telehealth exercise assessments are recommended to allow individually tailored exercise and physical activity prescription.

Before assessing exercise and physical activity using telehealth, safety needs to be considered, including verifying the patient's location in case you need to call an ambulance or checking whether they have an action plan and medications nearby if required. Some patients may not be suitable for a telehealth assessment and will need an in-person review, including those with cognitive impairments and low digital literacy. Before commencing the assessment, clinicians should determine what monitoring equipment is available (e.g., blood pressure or heart rate monitors) and conduct a virtual tour to check if the space is safe for exercising. Also, a standard subjective history should be taken, followed by a virtual exercise test. Selection of a suitable exercise test is dependent on the space and equipment available, ensuring that the test can be repeated at the end of the program using the same methods. To assess functional exercise capacity, the 6-minute walk test (6MWT) [50], 1-minute sit-to-stand test [51] and Timed Up and Go [50] could be used. To assess muscle strength, the 5x sit-to-stand evaluates functional quadriceps strength [50]. Consumer pedometers, accelerometers, or questionnaires can be used to assess physical activity (Table 2). Prescription of aerobic exercise, resistance exercise and physical activity should follow the FITT-VP principle (Table 3). Effective virtual assessment, prescription and progression of exercise and physical activity may be challenging; however, the assessment and prescription of exercise and physical activity via telehealth is preferrable to generic untailored programs, providing new opportunities to ensure programs can remain individually tailored when in-person assessment is not possible.

## Summary of Recommendations

- A comprehensive individual assessment of aerobic exercise capacity, muscle strength and physical activity allows limiting factors to be identified, guiding the safe prescription of aerobic and resistance exercise and physical activity that is personalised to the patient's abilities, needs, preferences and goals.
- Aerobic exercise capacity, muscle strength and physical activity assessments should be conducted at enrolment and at discharge to allow for a more detailed analysis of a patient's response to exercise and physical activity, which can guide the target intensities during their program, and allow for measurement of program effectiveness.
- Cardiac rehabilitation should incorporate a range of exercise and physical activity options, with the aim to achieve moderate-to-vigorous intensity exercise and physical activity to receive the optimal health benefits and prevent recurrent CVD events.
- MICT is well established as being safe and effective for cardiac patients, with increasing evidence that HIIT is well-tolerated for selected cardiac patients and can offer improvements to aerobic exercise capacity exceeding those resulting from MICT in some patient cohorts.
- Making use of available resources, including wearable activity trackers and telehealth, will potentially allow increased support for exercise and physical activity resulting in increased health benefits, including improvement of quality of life, supporting and empowering patients to self-monitor and manage their symptoms, and increasing their confidence to be active over the longer term.

## Conclusion

Patients with cardiovascular disease benefit from cardiac rehabilitation, which includes structured exercise and physical activity as core components. This position statement provides up-to-date evidence-based guidance for the assessment and prescription of exercise and physical activity for cardiac rehabilitation clinicians within the Australian and New Zealand context. With ongoing research in this area, it is important for clinicians to be aware of current guidelines and recommendations from other global cardiac bodies.

## Disclosures

Nil disclosures

## Acknowledgements

We would like to acknowledge the Cardiac Society of Australia and New Zealand (CSANZ) Quality and Safety Committee, CSANZ Clinical and Preventative Cardiology Council, CSANZ Allied Health, Science and Technology Council, Australian Cardiovascular Health and

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

Rehabilitation Association, Exercise and Sports Science Australia, and the Australian Physiotherapy Association. The authors thank Professor Doa El-Ansary for reviewing the resistance exercise section.

# Funding

J.R. is funded by a NHMRC Investigator Grant (GNT1143538). M.H. is funded by the NHMRC SOLVE-CHD Synergy Grant (GNT1182301).

# References

[1] World Health Organization. Cardiovascular Disaese Factsheet 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds). [accessed 18.4.23].

[2] Redfern J, Gallagher R, O'Neil A, Grace SL, Bauman A, Jennings G, et al. Historical context of cardiac rehabilitation: learning from the past to move to the future. Front Cardiovasc Med. 2022;9:842567.

[3] Redfern J, Figtree G, Chow C, Jennings G, Briffa T, Gallagher R, et al. Cardiac rehabilitation and secondary prevention roundtable: Australian implementation and research priorities. Heart Lung Circ. 2020;29(3):319–23.

[4] Visseren FLJ, Mach F, Smulders YM, Carballo D, Koskinas KC, Back M, et al. 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies with the special contribution of the European Association of Preventive Cardiology (EAPC). Rev Esp Cardiol (Engl Ed). 2022;75(5):429.

[5] Chew DP, Scott IA, Cullen L, French JK, Briffa TG, Tideman PA, et al. National Heart Foundation of Australia & Cardiac Society of Australia and New Zealand: Australian Clinical Guidelines for the Management of Acute Coronary Syndromes 2016. Heart Lung Circ. 2016;25(9):895–951.

[6] Ambrosetti M, Abreu A, Corra U, Davos CH, Hansen D, Frederix I, et al. Secondary prevention through comprehensive cardiovascular rehabilitation: From knowledge to implementation. 2020 update. A position paper from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. Eur J Prev Cardiol. 2020.

[7] Rauch B, Davos CH, Doherty P, Saure D, Metzendorf MI, Salzwedel A, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: a systematic review and meta-analysis of randomized and non-randomized studies—The Cardiac Rehabilitation Outcome Study (CROS). Eur J Prev Cardiol. 2016;23(18):1914–39.

[8] Salzwedel A, Jensen K, Rauch B, Doherty P, Metzendorf MI, Hackbusch M, et al. Effectiveness of comprehensive cardiac rehabilitation in coronary artery disease patients treated according to contemporary evidence based medicine: Update of the Cardiac Rehabilitation Outcome Study (CROS-II). Eur J Prev Cardiol. 2020;27(16):1756–74.

[9] Haykowsky MJ, Timmons MP, Kruger C, McNeely M, Taylor DA, Clark AM. Meta-analysis of aerobic interval training on exercise capacity and systolic function in patients with heart failure and reduced ejection fractions. Am J Cardiol. 2013;111(10):1466–9.

[10] Edelmann F, Gelbrich G, Dungen HD, Frohling S, Wachter R, Stahrenberg R, et al. Exercise training improves exercise capacity and diastolic function in patients with heart failure with preserved ejection fraction: results of the Ex-DHF (Exercise training in Diastolic Heart Failure) pilot study. J Am Coll Cardiol. 2011;58(17):1780–91.

[11] Elliott AD, Verdicchio CV, Mahajan R, Middeldorp ME, Gallagher C, Mishima RS, et al. An exercise and physical activity program in patients with atrial fibrillation: the ACTIVE-AF randomized controlled trial. JACC Clin Electrophysiol. 2023.

[12] Fakhry F, Spronk S, van der Laan L, Wever JJ, Teijink JA, Hoffmann WH, et al. Endovascular revascularization and supervised exercise for peripheral artery disease and intermittent claudication: a randomized clinical trial. JAMA. 2015;314(18):1936–44.

[13] Tran DL, Maiorana A, Davis GM, Celermajer DS, d'Udekem Y, Cordina R. Exercise testing and training in adults with congenital heart disease: a surgical perspective. Ann Thorac Surg. 2021;112(4):1045–54.

[14] Butchart EG, Gohlke-Barwolf C, Antunes MJ, Tornos P, De Caterina R, Cormier B, et al. Recommendations for the management of patients after heart valve surgery. Eur Heart J. 2005;26(22):2463–71.

[15] Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, et al. 2020 ESC guidelines on sports cardiology and exercise in patients with cardiovascular disease: the task force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). Eur Heart J. 2021;42(1):17–96.

[16] Howden EJ, Bigaran A, Beaudry R, Fraser S, Selig S, Foulkes S, et al. Exercise as a diagnostic and therapeutic tool for the prevention of cardiovascular dysfunction in breast cancer patients. Eur J Prev Cardiol. 2019;26(3):305–15.

[17] Woodruffe S, Neubeck L, Clark RA, Gray K, Ferry C, Finan J, et al. Australian Cardiovascular Health and Rehabilitation Association (ACRA) core components of cardiovascular disease secondary prevention and cardiac rehabilitation 2014. Heart Lung Circ. 2015;24(5):430–41.

[18] Redfern J, Maiorana A, Neubeck L, Clark AM, Briffa T. Achieving coordinated secondary prevention of coronary heart disease for all in need (SPAN). Int J Cardiol. 2011;146(1):1–3.

[19] Wahid A, Manek N, Nichols M, Kelly P, Foster C, Webster P, et al. Quantifying the association between physical activity and cardiovascular disease and diabetes: a systematic review and meta-analysis. J Am Heart Assoc. 2016;5(9).

[20] Dimeo F, Pagonas N, Seibert F, Arndt R, Zidek W, Westhoff TH. Aerobic exercise reduces blood pressure in resistant hypertension. Hypertension. 2012;60(3):653–8.

[21] Haykowsky MJ, Liang Y, Pechter D, Jones LW, McAlister FA, Clark AM. A meta-analysis of the effect of exercise training on left ventricular remodeling in heart failure patients: the benefit depends on the type of training performed. J Am Coll Cardiol. 2007;49(24):2329–36.

[22] American College of Sports Medicine. In: Liguori G, editor. ACSM's Guidelines for Exercise Testing and Prescription. Eleventh Edition. 1Philadelphia: Wolters Kluwer; 2021.

[23] Price KJ, Gordon BA, Bird SR, Benson AC. A review of guidelines for cardiac rehabilitation exercise programmes: is there an international consensus? Eur J Prev Cardiol. 2016;23(16):1715–33.

[24] Elliott AD, Rajopadhyaya K, Bentley DJ, Beltrame JF, Aromataris EC. Interval training versus continuous exercise in patients with coronary artery disease: a meta-analysis. Heart Lung Circ. 2015;24(2):149–57.

[25] Wewege MA, Ahn D, Yu J, Liou K, Keech A. High-intensity interval training for patients with cardiovascular disease—is it safe? A systematic review. J Am Heart Assoc. 2018;7(21):e009305.

[26] Hansen D, Abreu A, Ambrosetti M, Cornelissen V, Gevaert A, Kemps H, et al. Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. Eur J Prev Cardiol. 2022;29(1):230–45.

[27] Group JCSJW. Guidelines for rehabilitation in patients with cardiovascular disease (JCS 2012). Circ J. 2014;78(8):2022–93.

[28] Taylor JL, Bonikowske AR, Olson TP. Optimizing outcomes in cardiac rehabilitation: the importance of exercise intensity. Front Cardiovasc Med. 2021;8:734278.

[29] Nakamura T, Kamiya K, Hamazaki N, Matsuzawa R, Nozaki K, Ichikawa T, et al. Quadriceps strength and mortality in older patients with heart failure. Can J Cardiol. 2021;37(3):476–83.

[30] Sato R, Akiyama E, Konishi M, Matsuzawa Y, Suzuki H, Kawashima C, et al. Decreased appendicular skeletal muscle mass is associated with poor outcomes after ST-segment elevation myocardial infarction. J Atheroscler Thromb. 2020:52282.

[31] Williams MA, Haskell WL, Ades PA, Amsterdam EA, Bittner V, Franklin BA, et al. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2007;116(5):572–84.

[32] Hollings M, Mavros Y, Freeston J, Fiatarone Singh M. The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: a systematic review and meta-analysis of randomised controlled trials. Eur J Prevent Cardiol. 2017;24(12):1242–59.

[33] Karlsdottir AE, Foster C, Porcari JP, Palmer-McLean K, White-Kube R, Backes RC. Hemodynamic responses during aerobic and resistance exercise. J Cardiopulm Rehabil. 2002;22(3):170–7.

[34] El-Ansary D, Waddington G, Denehy L, Adams R. Physical examination of the sternum following cardiac surgery: validity and reliability of a Sternal Instability Scale (SIS). Heart Lung Circ. 2015;24:S415.

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854

[35] Lagally KM, Robertson RJ. Construct validity of the OMNI resistance exercise scale. J Strength Cond Res. 2006;20(2):252.
[36] Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126–31.
[37] Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN)—Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;14(1):75.
[38] Gonzalez-Jaramillo N, Wilhelm M, Arango-Rivas Ana M, Gonzalez-Jaramillo V, Mesa-Vieira C, Minder B, et al. Systematic review of physical activity trajectories and mortality in patients with coronary artery disease. J Am Coll Cardiol. 2022;79(17):1690–700.
[39] van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. Arch Intern Med. 2012;172(6):494–500.
[40] Alves AJ, Viana JL, Cavalcante SL, Oliveira NL, Duarte JA, Mota J, et al. Physical activity in primary and secondary prevention of cardiovascular disease: overview updated. World J Cardiol. 2016;8(10):575–83.
[41] Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451.
[42] Dibben GO, Dalal HM, Taylor RS, Doherty P, Tang LH, Hillsdon M. Cardiac rehabilitation and physical activity: systematic review and meta-analysis. Heart. 2018;104(17):1394–402.
[43] Adams J, Lotshaw A, Exum E, Campbell M, Spranger CB, Beveridge J, et al. An alternative approach to prescribing sternal precautions after median sternotomy, "Keep Your Move in the Tube". Proc (Bayl Univ Med Cent). 2016;29(1):97–100.
[44] El-Ansary D, LaPier TK, Adams J, Gach R, Triano S, Katijjahbe MA, et al. An evidence-based perspective on movement and activity following median sternotomy. Phys Ther. 2019;99(12):1587–601.
[45] Pengelly J, Royse C, Williams G, Bryant A, Clarke-Errey S, Royse A, et al. Effects of 12-week supervised early resistance training (SEcReT) versus aerobic-based rehabilitation on cognitive recovery following cardiac surgery via median sternotomy: a pilot randomised controlled trial. Heart Lung Circ. 2022;31(3):395–406.
[46] Patterson K, Davey R, Keegan R, Freene N. Smartphone applications for physical activity and sedentary behaviour change in people with cardiovascular disease: a systematic review and meta-analysis. PloS One. 2021;16(10):e0258460.
[47] Ashur C, Cascino TM, Lewis C, Townsend W, Sen A, Pekmezi D, et al. Do wearable activity trackers increase physical activity among cardiac rehabilitation participants? A systematic review and meta-analysis. J Cardiopulm Rehabil Prev. 2021;41(4):249–56.
[48] Bayoumy K, Gaber M, Elshafeey A, Mhaimeed O, Dineen EH, Marvel FA, et al. Smart wearable devices in cardiovascular care: where we are and how to move forward. Nat Rev Cardiol. 2021;18(8):581–99.
[49] Pecci C, Ajmal M. Cardiac rehab in the COVID-19 pandemic. Am J Med. 2021;134(5):559–60.
[50] Hwang R, Fan T, Bowe R, Louis M, Bertram M, Morris NR, et al. Home-based and remote functional exercise testing in cardiac conditions, during the COVID-19 pandemic and beyond: a systematic review. Physiotherapy. 2022;115:27–35.
[51] Bohannon RW, Crouch R. 1-Minute sit-to-stand test: systematic review of procedures, performance, and clinimetric properties. J Cardiopulm Rehabil Prev. 2019;39(1):2–8.
[52] Mezzani A, Hamm LF, Jones AM, McBride PE, Moholdt T, Stone JA, et al. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation, and the Canadian Association of Cardiac Rehabilitation. J Cardiopulm Rehabil Prev. 2012;32(6):327–50.
[53] D'Ascenzi F, Cavigli L, Pagliaro A, Focardi M, Valente S, Cameli M, et al. Clinician approach to cardiopulmonary exercise testing for exercise prescription in patients at risk of and with cardiovascular disease. Br J Sports Med. 2022:bjsports-2021-105261.
[54] Myers J, Forman DE, Balady GJ, Franklin BA, Nelson-Worel J, Martin BJ, et al. Supervision of exercise testing by nonphysicians: a scientific statement from the American Heart Association. Circulation. 2014;130(12):1014–27.
[55] Fletcher GF, Ades PA, Kligfield P, Arena R, Balady GJ, Bittner VA, et al. Exercise standards for testing and training: a scientific statement from the American Heart Association. Circulation. 2013;128(8):873–934.
[56] Pollock ML, Bohannon RL, Cooper KH, Ayres JJ, Ward A, White SR, et al. A comparative analysis of four protocols for maximal treadmill stress testing. Am Heart J. 1976;92(1):39–46.
[57] Alotaibi JF, Doherty P. Evaluation of determinants of walking fitness in patients attending cardiac rehabilitation. BMJ Open Sport Exerc Med. 2016;2(1):e000203.
[58] Grgic J, Lazinica B, Schoenfeld BJ, Pedisic Z. Test–retest reliability of the one-repetition maximum (1RM) strength assessment: a systematic review. Sports Med Open. 2020;6(1):31.
[59] Barnard KL, Adams KJ, Swank AM, Mann E, Denny DM. Injuries and muscle soreness during the one repetition maximum assessment in a cardiac rehabilitation population. J Cardiopulm Rehabil. 1999;19(1):52–8.
[60] Werber-Zion G, Goldhammer E, Shaar A, Pollock ML. Left ventricular function during strength testing and resistance exercise in patients with left ventricular dysfunction. J Cardiopulm Rehabil. 2004;24(2):100–9.
[61] Gjovaag TF, Mirtaheri P, Simon K, Berdal G, Tuchel I, Westlie T, et al. Hemodynamic responses to resistance exercise in patients with coronary artery disease. Med Sci Sports Exerc. 2016;48(4):581–8.
[62] Wood TM, Maddalozzo GF, Harter RA. Accuracy of seven equations for predicting 1-RM performance of apparently healthy, sedentary older adults. Meas Phys Educ Exerc Sci. 2002;6(2):67–94.
[63] Copeland JL, Ashe MC, Biddle SJ, Brown WJ, Buman MP, Chastin S, et al. Sedentary time in older adults: a critical review of measurement, associations with health, and interventions. Br J Sports Med. 2017;51(21):1539.
[64] Fuller D, Colwell E, Low J, Orychock K, Tobin MA, Simango B, et al. Reliability and validity of commercially available wearable devices for measuring steps, energy expenditure, and heart rate: systematic review. JMIR Mhealth Uhealth. 2020;8(9):e18694.
[65] Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
[66] Australian Institute of Health and Welfare. The Active Australia survey: a guide and manual for implementation, analysis and reporting. Canberra: Australian Institute of Health and Welfare; 2003.
[67] Lobelo F, Rohm Young D, Sallis R, Garber MD, Billinger SA, Duperly J, et al. routine assessment and promotion of physical activity in healthcare settings: a scientific statement from the American Heart Association. Circulation. 2018;137(18):e495–522.
[68] Freene N, McManus M, Mair T, Tan R, Clark B, Davey R. Validity of the past-day adults' sedentary time questionnaire in a cardiac rehabilitation population. J Cardiopulm Rehabil. 2020;40(5):325–9.
[69] Sternfeld B, Goldman-Rosas L. A systematic approach to selecting an appropriate measure of self-reported physical activity or sedentary behavior. J Phys Act Health. 2012;9(Suppl 1):S19–28.
[70] Borde R, Hortobagyi T, Granacher U. Dose-response relationships of resistance training in healthy old adults: a systematic review and meta-analysis. Sports Med. 2015;45(12):1693–720.
[71] Wadden TA, West DS, Delahanty L, Jakicic J, Rejeski J, Williamson D, et al. The Look AHEAD study: a description of the lifestyle intervention and the evidence supporting it. Obesity (Silver Spring). 2006;14(5):737–52.
[72] Ayabe M, Brubaker PH, Dobrosielski D, Miller HS, Kiyonaga A, Shindo M, et al. Target step count for the secondary prevention of cardiovascular disease. Circ J. 2008;72(2):299–303.
[73] Online H. Heart Education Assessment Rehabilitation Toolkit 2022. Available from: https://www.heartonline.org.au/. [accessed 18.4.23].
[74] Sørensen L, Larsen KSR, Petersen AK. Validity of the talk test as a method to estimate ventilatory threshold and guide exercise intensity in cardiac patients. J Cardiopulm Rehabil. 2020;40(5):330–4.

Please cite this article in press as: Verdicchio C, et al. A Clinical Guide for Assessment and Prescription of Exercise and Physical Activity in Cardiac Rehabilitation. A CSANZ Position Statement. Heart, Lung and Circulation (2023), https://doi.org/10.1016/j.hlc.2023.06.854