Progression of Exercise Training in Early Outpatient Cardiac Rehabilitation

AN OFFICIAL STATEMENT FROM THE AMERICAN ASSOCIATION OF CARDIOVASCULAR AND PULMONARY REHABILITATION

Ray W. Squires, PhD; Leonard A. Kaminsky, PhD; John P. Porcari, PhD; Jeanne E. Ruff, MS; Patrick D. Savage, MS; Mark A. Williams, PhD

Aerobic and resistance exercise training is a cornerstone of early outpatient cardiac rehabilitation (CR) and provides impressive benefits for patients. The components of the exercise prescription for patients with cardiovascular diseases are provided in guideline documents from several professional organizations and include frequency (how many sessions per week); intensity (how hard to exercise); time (duration of the exercise training session); type (modalities of exercise training); volume (the total amount or dose of exercise); and progression (the rate of increasing the dose of exercise). The least discussed, least appreciated, and most challenging component of the exercise prescription for CR health care professionals is the rate of progression of the dose of exercise. One reason for this observation is the heterogeneity of patients who participate in CR. All components of the exercise prescription should be developed specifically for each individual patient. This statement provides an overview of the principles of exercise prescription for patients in CR with special emphasis on the rate of progression. General recommendations for progression are given and patient case examples are provided to illustrate the principles of progression in exercise training.

Key Words: cardiac rehabilitation • exercise prescription • progression of exercise training

Exercise training is a prominent and critical component of early outpatient cardiac rehabilitation (CR), providing impressive patient benefits for cardiorespiratory and metabolic indices, quality of life, and cardiovascular disease management as shown in Table 1.[1-7] It is estimated that exercise training alone reduces total and cardiovascular mortality by 27% and 31%, respectively, for patients with cardiovascular diseases.[4] Improving cardiorespiratory fitness (CRF) is a crucially important element in the secondary prevention of cardiovascular disease adverse outcomes.[6,8,9,10] For example, in a cohort of 5641 patients who participated in CR in Canada, for each 1-MET increase in estimated CRF during CR, total mortality was reduced by 25% over 1 y.[11] Similarly, previous studies have reported a decrease in cardiac or total mortality ranging from 8% to 34% for each 1-MET improvement in CRF.[12,13]

Medically directed exercise training in CR is prescribed using established guidelines, is based on recommendations for apparently healthy adults, and generally results in an improvement in CRF and skeletal muscle fitness.[5,14] The primary components of the exercise prescription (Ex Rx) are frequency, intensity, time, type, volume, and progression and are given by the acronym FITT-VP. The specific ranges for most of the exercise prescriptive factors for aerobic and resistance exercise training for patients with cardiovascular diseases are well established.[3-5,14] However, an often understated and the least well-defined component of Ex Rx is the rate of progression of the exercise volume over the course of CR. This is the most difficult component of Ex Rx for CR health care professionals to master in clinical practice. An appropriate progression in exercise program volume is essential to optimize the gains in CRF and skeletal muscle strength while minimizing potential adverse complications.

The purpose of this position statement is to provide concise, clinically relevant recommendations for progression of exercise training in CR. The recommendations are appropriate for essentially all patients who do not have contraindications to exercise training who participate in CR, including the elderly and patients with severe forms of cardiovascular diseases. The primary focus will be aerobic exercise training, the dominant form of training in early outpatient CR. A secondary focus will be general resistance training. Topics addressed in this statement are (1) an overview of the general principles of Ex Rx for patients with cardiovascular diseases including exercise volume, also referred to as the dose of exercise that correctly identifies the importance of exercise as a medical treatment, overload, training effect, and components of the exercise prescription; (2) a review of the literature regarding the rate of progression of the exercise dose in CR, including the combined extensive clinical experience of the authors; and (3) patient case examples of the progression of aerobic and resistance exercise.

Author Affiliations: *Department of Cardiovascular Medicine, Mayo Clinic, Rochester, Minnesota (Dr Squires); Fisher Institute of Health and Well-Being, Clinical Exercise Physiology Laboratory, Ball State University, Muncie, Indiana (Dr Kaminsky); Department of Exercise and Sport Science, University of Wisconsin-LaCrosse, LaCrosse, Wisconsin (Dr Porcari); Guerrieri Heart & Vascular Institute, Peninsula Regional Medical Center, Salisbury, Maryland (Ms Ruff); Cardiac Rehabilitation, University of Vermont Medical Center, Burlington, Vermont (Mr Savage); and Department of Medicine, Creighton University School of Medicine, Omaha, Nebraska (Dr Williams).*

This article was endorsed by the AACVPR Document Oversight Committee and the AACVPR Board of Directors approved the endorsement in August 2017.

The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.jcrpjournal.com).

Correspondence: *Ray W. Squires, PhD, Department of Cardiovascular Medicine, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (squires.ray@mayo.edu).*

DOI: 10.1097/HCR.0000000000000337

EXERCISE DOSE, THE CONCEPT OF OVERLOAD, AND THE TRAINING EFFECT

The exercise dose is commonly defined as the total amount of energy expended during exercise training over a period of

Table 1

Selected Benefits of Aerobic and Resistance Exercise Training for Patients With Cardiovascular Diseases[a]

Aerobic exercise	
Increased cardiorespiratory fitness	Improved cardiovascular risk factors
	Hypertension
	Insulin resistance/glucose intolerance
	Elevated triglycerides
	Low HDL-C
	Elevated LDL-C
	Excessive body fat stores
Reduced mortality	Reduced myocardial ischemia
Improved glycemic control in type 2 diabetes	Decreased risk of thrombosis
Decreased endothelial dysfunction	Improved symptoms
	Angina pectoris
	Dyspnea with exertion
	Leg claudication
Reduced progression of atherosclerosis	
Resistance exercise	
Increased skeletal muscle strength and endurance	Improved quality of life
Improved functional capacity	Less disability/improved independence
Improved body composition	Improved glucose metabolism
Increased basal metabolic rate	

Abbreviations: HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

[a]Adapted from Hambrecht et al,[1] Pàramo et al,[2] Jolliffe et al,[4] American College of Sports Medicine,[5] Boden et al, [6], and Hambrecht et al.[7]

1 wk.[4] For aerobic exercise training, it is the combination of frequency (sessions per wk), intensity (how hard), type (modality), and time (total duration). In terms of kilocalories (kcal) expended per wk in aerobic exercise training as a means of quantification of the dose of exercise, guidelines recommend at least 1000 kcal/wk for the general population.[5] However, for CR participants with the goal of substantially improving CRF and halting the progression of coronary atherosclerosis, 1500 kcal/wk appears to be required.[7] Another method of quantification of the exercise dose is to calculate metabolic equivalents per min (MET-min) of exercise. For example, if a patient performs 10 min of exercise at an intensity of 3 METs, the volume equals 30 MET-min. Although the precise exercise volume to produce health benefits is difficult to determine, it appears that 500 to 1000 MET-min of exercise per wk produces substantial health benefits such as lower rates of coronary heart disease and premature mortality.[5] Table 2 provides an example calculation of MET-min and kilocalories for a typical patient, using methods described by the American College of Sports Medicine[5] and Kaminsky et al.[15] An automated spreadsheet calculator for kcal per session and MET-min per session is available online (http://links.lww.com/JCRP/A22). For resistance exercise training, the dose is given by the frequency, resistance amount, number of repetitions per set, and the number of sets for each exercise.

Overload is defined as an exercise dose which is above and beyond the accustomed amount of exercise for a given individual.[16-18] For aerobic exercise training, overload may be accomplished by increasing any 1 of the components of the exercise dose: frequency, intensity, time, or type (eg, moving patients from non–weight-bearing to weight-bearing modes of exercise or to combination upper and lower extremity exercise devices resulting in greater energy expenditure). For resistance exercise training, either increasing the frequency of sessions, the amount of resistance, the number of repetitions per set, the number of sets per exercise or decreasing the rest period between sets provides overload.[5,17] Overload results in physiologic and anatomic adaptations to exercise training, within the capacity of the individual patient, which result in improvement in CRF for aerobic exercise training and increased skeletal muscle strength and endurance for resistance exercise training.[7,17] These physiological improvements in the components of fitness are defined as the training effect. The degree of adaptation to exercise training with progressive overload varies between persons due to multiple factors as shown in Table 3.[16,18]

It is not possible to specifically predict the magnitude of the training effect for a given patient. The ranges of improvement for CRF and skeletal muscle strength in patients with cardiovascular diseases who participate in exercise training for a period of 12 wk or longer in clinical trials conducted under near-ideal circumstances are usually given as 5% to 40% and 24% to 90%, respectively.[17,19,20] Gains in CRF assessed by exercise testing are usually greater for estimated than for directly measured peak $\dot{V}O_2$.[21,22] Not all patients in CR will exhibit improvement in CRF measured by cardiopulmonary exercise testing, but almost all patients will demonstrate improved aerobic submaximal exercise endurance for a given exercise heart rate or rating of perceived exertion.[21]

Example of a patient with improved submaximal exercise endurance without an improvement in CRF

A 62-y-old man with severe chronic heart failure treated with a left ventricular assist device completed CR. The primary mode of aerobic exercise was treadmill and track walking. His 6-min walk distance increased substantially from 221 m (42% of normal) to 537 m (104% of normal), but directly measured peak $\dot{V}O_2$ did not significantly improve (11.1-11.4 mL/kg/min, 40% of normal).

There is some overlap in the benefits of aerobic and resistance exercise. For example, resistance exercise training without concurrent aerobic exercise training may induce small improvements in CRF in some individuals.[17,23] In addition, resistance exercise training may result in improvement in glucose metabolism, blood lipids, and aerobic exercise endurance.[17] Conversely, aerobic exercise training may improve skeletal muscle strength, bone mineral density, and basal metabolic rate.[17] However, in the end, aerobic exercise training is superior to resistance exercise training

Table 2

An Example of Calculation of Exercise Volume in MET-min and kcal for a Typical Patient[a]

A patient weighing 85 kg exercises on a motorized treadmill at 2.5 mph, 3% grade (3.9 METs, estimated from speed and grade using reference number 5) for 30 min on 5 d/wk

- MET-min = 3.9 METs x 30 min per session = 117 MET-min per session x 5 sessions per wk = 585 MET-min/wk
- Kcal calculation, where 1 MET is approximately equal to 1 kcal/kg body weight/hr:

  Kcal = 3.9 METs x 85 kg x 0.5 hr = 166 kcal per session x 5 sessions = 829 kcal/wk

Abbreviation: METs, metabolic equivalents.

[a]Adapted from Kaminsky et al.[15]

Table 3

Factors Affecting the Amount of Adaptation to Exercise Training[a]

- Genetic potential: the variability in the magnitude of the training effect for patients who perform the same volume or dose of exercise.
- Health status: Comorbid conditions, cancer treatment effects, frailty, and cardiopulmonary symptoms such as limiting angina or dyspnea and profound fatigue may affect the exercise training results.
- Age: Older patients generally adapt more slowly to exercise training than younger patients.
- Sex: Women generally experience smaller absolute gains in fitness, although relative gains are the same as for men.
- Baseline fitness: In general, the lower the baseline level of fitness, the greater the relative gains in fitness from exercise training.

[a]From Astrand et al[16] and Garber et al.[18]

for improving CRF and cardiovascular risk factors while resistance exercise training results in greater gains in skeletal muscle strength and muscle mass. Thus, for patients to experience an optimal training effect in terms of improving CRF and skeletal muscle strength, a gradual increase in the exercise dose for both aerobic and resistance exercise training is required during CR.

SPECIAL CONSIDERATIONS FOR EXERCISE PRESCRIPTION FOR PATIENTS IN CR

The components of FITT for both aerobic and strength training developed for patients participating in CR have been provided by the American College of Sports Medicine (ACSM) and are presented in Table 4.[5] Symptom-limited graded exercise testing before beginning CR is the optimal method for determining the most precise Ex Rx for an individual patient. However, graded exercise testing at the start of CR rarely occurs in clinical practice for a variety of reasons. A 6-min walk test may be performed as a surrogate measure of exercise capacity.[3] In addition, performance of the 1-repetition maximum test for each resistance exercise is the gold standard for prescription of resistance exercise intensity, but many programs do not routinely perform this test because of time constraints or other reasons. Ratings of perceived exertion (RPE) are a useful and practical method for prescribing exercise intensity for both aerobic and resistance exercises, particularly for patients without formal graded exercise or strength testing.[24]

Aerobic exercise training intensity is the most important variable in improving CRF during CR for most patients. Moderate-intensity continuous aerobic training (MCT) is defined as 60% to 85% of peak heart rate and/or RPE of 12 to 14 on the 6 to 20 scale.[5] In contrast, high-intensity aerobic interval training (HIIT) involves alternating 10 sec to 5 min of more intense training (85%-95% of peak heart rate, RPE 15-17) interspersed with 1 to 3 min of MCT during an exercise session.[5,14,25,26] Periodic assessment of exercise intensity using heart rate and/or RPE should occur during each supervised exercise session. A recent meta-analysis of trials comparing HIIT and MCT in patients with coronary artery disease reported a greater improvement in mean CRF (+1.8 mL/kg/min in peak $\dot{V}O_2$) with HIIT.[27] Various progression models for using HIIT in the CR setting based on patient fitness are provided by Ribeiro et al.[28] Using MCT and HIIT during alternate exercise sessions is a common approach recommended by the authors of this statement. Although using HIIT in CR has become more accepted in recent years and is contained within the ACSM guidelines,[5] there remains a concern regarding the safety of prescribing exercise at a higher intensity than has been traditionally recommended. However, investigators in Norway evaluated the safety of exercise training using the records of 4826 patients who participated in CR and performed a combination of MCT and HIIT.[26] They reported 1 fatal event in 129 456 patient-hours of MCT and 2 nonfatal adverse events in 46 364 patient-hours of HIIT and concluded that both forms of training were associated with low risk of adverse events. For programs limited to 12 to 18 supervised sessions by local reimbursement policies, adequate progression of the exercise dose, including HIIT, may be shifted to "maintenance" or community-based, longer duration programs after completion of early CR.

The need to individualize the exercise prescription for optimizing risk reduction or patient-specific factors is an important consideration. For example, a critical aspect in prescribing exercise for obese patients in CR is to gradually increase the exercise dose to facilitate fat mass loss. Ades et al[29] reported greater fat mass loss (5.9 kg vs 2.8 kg, $P < .01$) for patients who exercised 45 to 60 min at 50% to 60% of capacity, 5 to 7 d/wk (energy expenditure of 3000-3500 kcal/wk) than for patients who exercised in the usual manner for CR: 25 to 40 min at 65% to 70% of capacity 3 d/wk (800 kcal/wk or less). To achieve weekly exercise energy expenditures of 3000+ kcal, a steady progression in the dose of exercise over several weeks is required. In addition, patients with extremely low baseline fitness, including the frail elderly, benefit from an initial intermittent approach to

Table 4

American College of Sports Medicine General Recommendations for Exercise Prescription (FITT) for Patients With Cardiovascular Diseases in Outpatient Cardiac Rehabilitation Programs[a]

	Aerobic Exercise	Resistance Exercise
Frequency	Minimally 3 d/wk, preferably ≥5 d/wk	2-3 nonconsecutive d/wk
Intensity	40%-80% of exercise capacity using HRR, $\dot{V}O_2$ R or $\dot{V}O_2$ peak, or an RPE of 12-16 on the 6-20 scale	Perform 10-15 repetitions of each exercise, RPE 11-13 or 40%-60% of 1-RM
Time	20-60 min per session	1-3 sets; 8-10 exercises for the major muscle groups
Type	Arm ergometer, upper and lower extremity ergometer, upright and recumbent cycles, recumbent stepper, rower, stair climber, treadmill, walking track	Select equipment that is safe and comfortable for patient use

Abbreviations: FITT, frequency, intensity, time and type; HRR, heart rate reserve; RPE, rating of perceived exertion; $\dot{V}O_2$ peak, peak exercise oxygen uptake; $\dot{V}O_2$ R, oxygen uptake reserve (see American College of Sports Medicine[5] for an explanation of $\dot{V}O_2$ R); 1-RM, 1 repetition maximum.
[a]Adapted from American College of Sports Medicine.[5]

Table 5

Example of Exercise Progression Using an Intermittent Approach for Patients With Aerobic Capacities of ≤4 Metabolic Equivalents[a]

Week	% AC[b]	Exercise Bout, min	Rest Bout, min	Repetitions	Time at % AC, min
1-2	40-50	3-7	3-5	3-4	10-20
3-4	50-60	7-15	2-5	2-3	15-30
5	60-70	12-20	2	2	25-40

Abbreviation: AC, aerobic capacity.

[a]Adapted from American College of Sports Medicine.[5(p215)]

[b]40%-50% AC = 35%-45% of heart rate reserve (HRR) or ratings of perceived exertion (RPE) of 9-11; 50%-60% AC = 45%-55% of HRR or RPE 12-13; 60%-70% AC = 55%-65% of HRR or RPE of 13-14.

aerobic exercise training (alternating short periods of tolerable MCT with rest periods) as shown in Table 5.

PROGRESSION OF THE DOSE OF EXERCISE TRAINING IN CR

The ACSM position statement defines progression of exercise dose for aerobic training as: "…gradual progression of exercise volume by adjusting duration, frequency and/or intensity is reasonable until the desired goal (maintenance) is attained."; resistance training as: "…gradual progression of greater resistance and/or more repetitions per set, and/or increased frequency is recommended."[18(p1336)]

In addition, there are a limited number of more specific recommendations regarding the topic made by preeminent exercise physiologists, such as Astrand[16] and Pollock,[30] as well as by the ACSM guidelines document.[5] A summary of these recommendations, as well as considerations made by the authors of this article, is provided in Table 6. However, there are no clinical trials comparing methods or rates of progression of the dose of exercise training for patients in CR to precisely guide CR health care professionals. Also, there are multiple potential factors that may affect progression of the dose of exercise, as indicated in Table 7. The effects of these considerations are not trivial. Failure to adequately progress the dose of exercise may limit the benefits of exercise training for the patient. Unfortunately, in this scenario, the patients may perceive futility in attending CR, surmising that they can perform more effective exercise training on their own versus attending the program. Alternatively, programs that fail to progress the dose of exercise may give patients the impression that they are fragile and that higher doses of exercise should be avoided. Conversely, progression at too rapid a rate may result in adverse effects, such as orthopedic injury, delayed muscle soreness, or cardiovascular symptoms (angina pectoris, dyspnea, extreme fatigue with failure to recover from an exercise session, lightheadedness).[16,31] However, there is no evidence that an overly cautious approach to progression of the exercise dose in CR is prudent.

Table 6

Specific Recommendations for Progression of the Dose of Exercise in Early Outpatient Cardiac Rehabilitation[a]

1. Individualize progression for each patient.
2. Review each patient's progression each session.
3. There should be evidence of progression each week.
4. Include all the FITT components in progression, however,
5. In general, increase only 1 component of FITT at a time for either aerobic or resistance training.
6. Increase the duration of aerobic exercise by 1-5 min per session until the goal duration has been achieved.
7. Increases in intensity and duration of 5%-10% are generally well tolerated.
8. While a gradual approach to increasing exercise intensity is recommended, avoid undue restriction in progressing intensity.
9. In general, it is recommended to increase the duration of aerobic exercise to the desired goal first and then increase intensity and/or frequency.
10. Counsel patients to avoid straining and to maintain proper technique with weight training.

Abbreviation: FITT, frequency, intensity, time, and type.

[a]From American College of Sports Medicine,[5] Astrand et al,[16] Pollock et al,[30] and from the collective clinical experience of the authors.

PATIENT CASE EXAMPLES OF THE PROGRESSION OF AEROBIC AND RESISTANCE EXERCISE TRAINING

Patient case example 1: Using RPE and HIIT to progress the dose of aerobic exercise with exercise volume estimated by kilocalories per session and MET-min per session.

Clinical information: Summarized in Box 1.

Progression of exercise prescription: Summarized in Box 2.

This case illustrates progression of exercise time and intensity in an obese cardiac patient using RPE and HIIT with a substantial improvement in directly measured CRF. Despite the high volume of training, there was no change in body weight. Included in the case are estimates of energy expenditure in kilocalories and MET-min to illustrate the increase in exercise dose over time. The case also illustrates the discrepancy between estimated peak METs based on treadmill test time and/or peak workload versus directly measured peak METs with cardiopulmonary exercise testing.

Patient case example 2: Progression of resistance exercise training with RPE using hand weights and weight machines

Clinical information: Summarized in Box 3.

Progression of exercise prescription: Summarized in Box 4.

This case illustrates beginning resistance exercise training relatively soon after cardiothoracic surgery in a patient with normal sternal healing, following the 6-wk upper extremity lifting restriction requested by the surgeon and gradually progressing the dose of exercise using RPE and patient tolerance for 5 exercises, including both upper and lower extremities.

Patient case example 3: Progression of aerobic exercise in a very deconditioned patient using RPE and adding weight-bearing exercise as fitness improved.

Clinical information: Summarized in Box 5.

Progression of exercise prescription: Summarized in Box 6.

Table 7

Potential Factors That May Affect the Rate of Progression of the Dose of Exercise

1. Patient-specific factors (resulting in the imperative to individualize all aspects of the exercise prescription, including the rate of progression)
   - *Current fitness*: In general, extremely deconditioned patients require a slower progression of the exercise dose than do higher fit patients.
   - *Previous experience with exercise training*: Patients without previous experience with exercise training usually progress more slowly than do patients with such experience.
   - *Health status including comorbidities*: Patients with a greater burden of cardiovascular disease and other comorbid conditions may progress at a slower pace than patients with a lower disease burden.
   - *Age*: Older patients, in general, achieve an adequate training effect but may require a slower rate of progression due to a greater burden of disease and a longer time requirement for improvement in fitness.
   - *Sex*: Women in CR tend to be older and have a greater burden of disease than men and may require a more gradual approach to progression
   - *CV risk status*: Patients at higher risk for adverse events during exercise training, such as patients with chronic heart failure or extensive myocardial ischemia, should progress more cautiously than lower-risk status patients.
   - *Patient expectations/preferences*: Individual patients have unique expectations and preferences in terms of exercise training; CR health care professionals should counsel patients regarding the goal dose of exercise but must be sensitive to the needs and desires of their patients in setting goals for the dose of exercise.
2. CR health care professional factors
   - *Clinical training/experience*: Professionals with more extensive training in exercise physiology for patients with cardiovascular diseases and greater clinical experience in working with a wide variety of patients in the CR setting are more confident in their ability to progress the dose of exercise more rapidly than professionals with less training and experience.
3. Medical system factors
   - *Program policies and procedures*: There is variability across programs in policies regarding Ex Rx and the latitude afforded CR health care professionals in adjusting the Ex Rx, including the rate of progression and estimation of exercise volume.
   - *Baseline-graded exercise test present or absent*: In general, most CR health care professionals are more confident in progressing the dose of exercise more rapidly in patients who have undergone exercise testing than for patients without testing.
   - *Medical director preferences*: Depending on the experience, training, and preferences of the medical director, exercise training may progress at a faster or slower rate.
   - *Referring provider preferences*: A referring provider may specifically request limitations on the exercise prescription for a given patient, including the goal dose of exercise which may impact progression.

Abbreviations: CR, cardiac rehabilitation; CV, cardiovascular; Ex Rx, exercise prescription.

Box 1

Patient Case Example 1: Using RPE and HIIT to Progress the Dose of Aerobic Exercise With Exercise Volume Estimated by Kilocalories per Session and MET-min per Session

Patient: 70-y-old woman with acute coronary syndrome; underwent stenting of the left anterior descending, obtuse marginal branch, and right posterior descending coronary arteries; a residual 70% lesion in the distal circumflex vessel remained unstented.

Coronary risk factors: Obesity (172 lb, BMI = 34.0 kg/m^2), treated hypertension, hyperlipidemia, and obstructive sleep apnea.

Cardiac medications: Dual antiplatelet therapy, β-blocker, calcium channel blocker, angiotensin receptor blocker, long-acting nitrate, statin.

Early outpatient CR program: Began 11 d after hospital dismissal; the exercise plan called for up to 36 supervised sessions over 12-16 wk plus independent exercise (primarily walking).

- *Initial cardiopulmonary exercise test results:* $\dot{V}O_2$ peak = 13.5 mL/kg/min (3.9 METs); estimated peak METs = 4.9; peak heart rate = 116 beats/min.
- *Initial Ex Rx*: *Frequency*: 5-6 d/wk (3 supervised sessions/wk + 2-3 independent session/wk); *Intensity*: RPE 12-14; *Time*: 10 min plus warm-up and cooldown with a goal of 30-45 min; *Type*: treadmill, independent walking; *Progression*: increase 1-5+ min per session, as tolerated.

Abbreviations: BMI, body mass index; CR, cardiac rehabilitation; METs, metabolic equivalents.

Box 2

Patient Case Example 1: Summary of Progression of the Dose of Aerobic Exercise (Type = Treadmill: Speed/Grade), Heart Rate Corresponds to the Target RPE

Session, n	Time, min	Type	Peak RPE	Heart Rate, beats/min	Peak METs	Kcal	MET-min
1	10	1.7 mph	12	88	2.3	31	23
2	15	2.0 mph	12	96	2.5	52	38
3	25	2.2 mph/0.5%	13	97	2.8	97	71
4	30	2.3 mph/0.5%	13	92	2.9	120	88
Started HIIT next session; updated Ex Rx: *Intensity*: RPE 12-17, after warm-up and 5 min at RPE 12-14; start higher-intensity intervals at 30-60 sec at RPE 15-17 alternating with 60-120 sec of more moderate-intensity exercise at RPE 12-13; aim for 3-5 higher intensity intervals during 2-3 supervised sessions/wk; *Time*: gradual increase to 45 min.							
5	30	2.3 mph/2%	16	106	3.4	126	92
15	45	2.0 mph/4.5%	17	104	3.8	206	149
35	45	2.0 mph/6.0%	17	98	4.2	216	157

Repeat cardiopulmonary exercise test: body weight unchanged at 171 lb; $\dot{V}O_2$ peak = 16.6 mL/kg/min (4.7 METs); an increase of 23% in $\dot{V}O_2$ peak; estimated peak METs = 6.0; peak heart rate 121 beats/min.

Abbreviations: METs, metabolic equivalents; RPE, ratings of perceived exertion.

Box 3

Patient Case Example 2: Progression of Resistance Exercise Training With Ratings of Perceived Exertion Using Hand Weights and Weight Machines

Patient: 71-y-old man, 144 lb, BMI = 24.0 kg/m^2.

History of cardiovascular diseases: Angina pectoris treated with a drug-eluting stent in the left anterior descending coronary artery 13 y ago; poor CRF: 5 METs estimated 11 y ago; peripheral artery disease, bilateral lower extremity claudication, left worse than right with open surgical revascularization of the left common and superficial femoral arteries 6 y ago. Residual mild, right lower extremity claudication remains present.

Current cardiovascular event: Accelerating exertional angina over than past 6 mo; coronary angiogram demonstrated critical left main disease (90+% stenosis), 70% proximal circumflex, 100% proximal right coronary artery; coronary artery bypass graft surgery with a standard sternotomy was performed with left internal mammary artery to the left anterior descending, saphenous vein graft to the obtuse marginal branch, saphenous vein graft to the right posterior descending coronary artery, and closure of an atrial septal defect. Hospital recovery was complicated by cardiogenic shock treated with an intra-aortic balloon pump and inotropic medications.

Coronary risk factors: Treated hyperlipidemia and hypertension, remote history of cigarette smoking, historically physically inactive.

Cardiac medications: Dual antiplatelet therapy, β-blocker, loop diuretic, statin.

Early outpatient CR program: started 12 d after hospital dismissal, 18 d after surgery; the exercise plan was for 36 supervised sessions over 12-18 wk.

- *Ex Rx for resistance training (no formal measurements of muscle strength were performed)*: *Frequency*: 2-3 supervised sessions per week; *Intensity*: RPE 12-14; avoid cardiac symptoms and straining with lifting; *there was a surgeon-directed 10 lb upper extremity lifting restriction for the first 6 wk after surgery*; *Type*: hand weights (biceps curl) and weight machines (upright row, leg press, chest press, triceps extension), all exercises performed bilaterally; *Volume*: 1 set of 8-15 slow repetitions; *Progression*: when the patient can perform 15 repetitions of a specific exercise using proper lifting form through the full range of motion with an RPE ≤14, at the next session the resistance will be increased slightly and the number of repetitions decreased to 8. Over the next several sessions, the number of repetitions will gradually increase to 15 and the process will continue.
- There were no sternal healing complications and resistance training using the biceps curl and leg press began during the fourth exercise session, 24 d after surgery. The additional upper extremity exercises began 2 wk later, 6 wk after surgery.

Abbreviations: BMI, body mass index; CR, cardiac rehabilitation; CRF, cardiorespiratory fitness; Ex Rx, exercise prescription; METs, metabolic equivalents; RPE, ratings of perceived exertion.

Box 4

Patient Case Example 2: Summary of the Progression of the Dose of Resistance Exercise (Pounds of Resistance [lb], Number of Repetitions [reps] in Each Column)

Session, n	Biceps Curl	Upright Row	Leg Press	Chest Press	Triceps Extension
4	3 lb/15 reps	…	20 lb/15 reps	…	…
9	4 lb/15 reps	10 lb/15 reps	40 lb/15 reps	10 lb/15 reps	10 lb/15 reps
14	5 lb/15 reps	25 lb/15 reps	40 lb/15 reps	20 lb/15 reps	20 lb/10 reps
19	8 lb/10 reps	45 lb/5 reps	60 lb/10 reps	35 lb/10 reps	27 lb/10 reps
24	10 lb/10 reps	55 lb/12 reps	80 lb/8 reps	40 lb/14 reps	30 lb/15 reps
29	10 lb/15 reps	65 lb/10 reps	80 lb/15 reps	40 lb/15 reps	30 lb/15 reps

Patient case example 3 illustrates a gradual rate of progression in exercise time and intensity in a patient with multiple comorbid conditions and extreme deconditioning using RPE as an indicator of intensity. The patient transitioned from non–weight-bearing exercise only to 30 min of a combination of weight-bearing and non–weight-bearing modes of exercise. She returned to ambulation without the aid of a walker.

Two additional patient case examples are shown in the Supplemental Digital Content 1 Appendix, available at: http://links.lww.com/JCRP/A74.

SUMMARY AND CONCLUSIONS

Exercise training in the setting of CR provides multiple benefits including improved CRF, a crucially important marker of prognosis. Guidelines for the prescription of aerobic and resistance exercise training for patients with cardiovascular diseases have been developed and widely disseminated. The most challenging and least well-defined aspect of the exercise prescription for patients in CR is the progression of the dose of exercise. Cardiac rehabilitation health care professionals' confidence and ability to guide progression of

Box 5

Patient Case Example 3: Progression of Aerobic Exercise in a Very Deconditioned Patient Using Ratings of Perceived Exertion (RPE) and Adding Weight-Bearing Exercise as Fitness Improved

Patient: 50-y-old woman (173 lb, 71 in, BMI = 24.7 kg/m^2) with an ascending aortic dissection treated with aortic root replacement with a Dacron graft that included a pericardial aortic valve. She did not have clinically important coronary artery disease. Pertinent medical history included polyglandular autoimmune disorder, primary biliary cirrhosis, and Cushing disease with resultant hypertension. Her recovery from surgery was much more prolonged than average and she required multiple rehospitalizations. She became extremely deconditioned and could not ambulate without the aid of a walker.

Cardiovascular risk factors: Treated hypertension, untreated hyperlipidemia (intolerant to statins), depression, overweight.

Outpatient CR program: Began 8 mo after surgery; the plan for exercise training called for up to 36 supervised sessions over 12-16 wk.

- *Initial Ex Rx*: *Frequency*: 5-6 d/wk (3 supervised sessions + 2-3 independent sessions, as tolerated, consisting of several brief walks using the walker each day); *Intensity*: RPE 11-13; *Time*: 10-15 min with a goal of 30 min + warm-up and cooldown; *Type*: non–weight-bearing modalities initially (arm ergometer, recumbent stepper, cycle ergometer); *Progression*: increase duration by 1-5+ min per session, add treadmill walking when patient is able.

Abbreviations: BMI, body mass index; Ex Rx, exercise prescription.

Box 6

Patient Case Example 3: Summary of the Progression of the Dose of Aerobic Exercise (Type = Arm Ergometer, Recumbent Stepper, Cycle Ergometer), Heart Rate Corresponds to the Target RPE

Session, n	Time, min	Type	Peak RPE	Heart Rate	Peak METs
1	15 min	AE 1 W	13	68 beats/min	1.1
2	20 min	CE 11 W	13	74 beats/min	1.5
3	24 min	RS 15 W	13	70 beats/min	1.6
Starting with session number 8, the patient began using the treadmill (weight-bearing form of exercise). *Updated Ex Rx*: Intensity: RPE 12-14; *Time*: for treadmill (TM), start with 5 min, gradually progress to 15 min, *continue with 15 min with either RS or CE for a total time of 30 min + warm-up and cool-down.*					
8	5 min	TM 0.6 mph	12	72 beats/min	1.5
9	8 min	TM 0.7 mph	13	74 beats/min	1.5
12	12 min	TM 1.0 mph	12	81 beats/min	1.8
20	15 min	TM 2.0 mph	12	78 beats/min	2.5
35	15 min	TM 3.0 mph	14	85 beats/min	3.3

Abbreviations: AE, arm ergometer; CE, cycle ergometer; METs, metabolic equivalents; RPE, ratings of perceived exertion; RS, recumbent stepper; TM, treadmill; W, watts.

the dose of exercise for their patients to the recommended goal of 1500+ kcal/wk are the product of having a working knowledge of the principles of exercise progression and clinical experience in working with a variety of patients. This position statement provides specific recommendations, including patient case examples, for the progression of exercise training in CR to help fulfill that need. An appropriate progression in exercise program volume is essential to optimize the gains in CRF and skeletal muscle strength while minimizing potential adverse complications.

ACKNOWLEDGMENT

The authors appreciate the contribution of Rebecca C. Toth, MS, Cardiovascular/Pulmonary Rehabilitation and Preventive Cardiology, Peninsula Regional Medical Center, Salisbury, Maryland, for preparation of patient case example number 3.

REFERENCES

1. Hambrecht R, Wolf A, Gielen S, et al. Effect of exercise on coronary endothelial function in patients with coronary artery disease. *New Engl J Med*. 2000;342(7):454-460.
2. Pàramo JA, Olavide I, Barba J, et al. Long-term cardiac rehabilitation program favorably influences fibrinolysis and lipid concentrations in acute myocardial infarction. *Haematologia*. 1998;83(6):519-524.
3. American Association of Cardiovascular Pulmonary Rehabilitation. *Guidelines for Cardiac Rehabilitation and Secondary Rehabilitation Programs*. 5th ed. Champaign, IL: Human Kinetics; 2013:58, 71-88.
4. Jolliffe JA, Rees K, Taylor RS, Thompson D, Oldridge N, Ebrahim S. Exercise-based rehabilitation for coronary heart disease. *Cochrane Database Syst Rev*. 2001;(1):CD001800.
5. American College of Sports Medicine. *ACSM's Guidelines for Graded Exercise Testing and Prescription*. 10th ed. Philadelphia, PA: Wolters Kluwer; 2018.
6. Boden WE, Franklin BA, Wenger NK. Physical activity and structured exercise for patients with stable ischemic heart disease. *JAMA*. 2013;309:143-144.
7. Hambrecht R, Niebauer J, Marburger C, et al. Various intensities of leisure time physical activity in patients with coronary artery disease: effects on cardiorespiratory fitness and progression of coronary atherosclerotic lesions. *J Am Coll Cardiol*. 1993;22:468-477.
8. Kavanagh T, Mertens DJ, Hamm LF, et al. Prediction of long-term prognosis in 12,169 men referred for cardiac rehabilitation. *Circulation*. 2002;106:666-671.
9. Kavanagh T, Mertens D, Hamm LF, et al. Peak oxygen intake and cardiac mortality in women referred for cardiac rehabilitation. *J Am Coll Cardiol*. 2003;42:2139-2143.
10. Keteyian SJ, Brawner CA, Savage PD, et al. Peak aerobic capacity predicts prognosis in patients with coronary heart disease. *Am Heart J*. 2008;146:292-300.
11. Martin BJ, Arena R, Haykowski M, et al. Cardiovascular fitness and mortality after contemporary cardiac rehabilitation. *Mayo Clin Proc*. 2013;88:455-463.
12. Dorn J, Naughton J, Imamura D, Trevisan M. Results of a multicenter randomized clinical trial of exercise and long-term survival in myocardial infarction patients: the National Exercise and Heart Disease Project (NEHDP). *Circulation*. 1999;100:1764-1769.
13. Feurstadt P, Chai A, Kligfield P. Submaximal effort tolerance as a predictor of all-cause mortality in patients undergoing cardiac rehabilitation. *Clin Cardiol*. 2007;30:234-238.
14. Mezzani A, Hamm LF, Jones AM, 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 Cardiopulmonary Rehabil Prev*. 2012;32:327-350.
15. Kaminsky LA, Brubaker PH, Guazzi M, et al. Assessing physical activity as a core component in cardiac rehabilitation: a position statement of the American Association of Cardiovascular and Pulmonary Rehabilitation. *J Cardiopulmonary Rehabil Prev*. 2016;36:217-229.
16. Astrand PO, Rodahl K, Dahl H, Stromme SB. *Textbook of Work Physiology: Physiological Bases of Exercise*. 4th ed. Champaign, IL: Human Kinetics; 2003:313-368.
17. Williams MA, Haskell WL, Ades PA, et al. AHA Scientific Statement: Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and the Council on Nutrition, Physical Activity, and Metabolism. *Circulation*. 2007;116:572-584.
18. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43:1334-1359.
19. Redwood DR, Rosing DR, Epstein SE. Circulatory and symptomatic effects of physical training in patients with coronary artery disease and angina pectoris. *N Engl J Med*. 1972;286:959-965.
20. Ehsani AA, Heath GW, Hagberg JM, Sobel BE, Holloszy JO. Effects of 12 months of intense exercise training on ischemic ST-segment depression in patients with coronary artery disease. *Circulation*. 1981;64:1116-1124.
21. Savage PD, Antkowiak M, Ades PA. Failure to improve cardiopulmonary fitness in cardiac rehabilitation. *J Cardiopulmonary Rehabil Prev*. 2009;29:284-291.
22. Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign. A scientific statement from the American Heart Association. *Circulation*. 2016;134(24):e653-e699.

23. Hickson RC, Rosenkoetter MA, Brown MM. Strength training effects on aerobic power and short-term endurance. *Med Sci Sports Exerc*. 1980;12:336-339.
24. Borg GA. Psychological bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377-381.
25. Meyer K, Schwaibold M, Westbrook S, et al. Effects of short-term exercise training and activity restriction on functional capacity in patients with severe chronic congestive heart failure. *Am J Cardiol*. 1996;78(9):1017-1022.
26. Rognmo Ø, Moholt T, Bakken H, et al. Cardiovascular risk of high- versus moderate-intensity aerobic exercise in coronary heart disease patients. *Circulation*. 2012;126:1436-1440.
27. Liou K, Ho S, Fildes J, Ooi SY. High intensity interval versus moderate intensity continuous training in patients with coronary artery disease: a meta-analysis of physiological and clinical parameters. *Heart Lung Circ*. 2016;25:166-174.
28. Ribeiro PAB, Boidin M, Juneau M, Nigam A, Gayda M. High-intensity interval training in patients with coronary heart disease: prescription models and perspectives. *Ann Phys Rehabil Med*. 2017;60:50-57.
29. Ades PA, Savage PD, Toth MJ, et al. High-calorie-expenditure exercise: a new approach to cardiac rehabilitation for overweight coronary patients. *Circulation*. 2009;119:2671-2678.
30. Pollock ML, Pels AE, Foster C, Ward A. Exercise prescription for rehabilitation of the cardiac patient. In: Pollock ML, Schmidt DH, eds. *Heart Disease and Rehabilitation*. 2nd ed. New York, NY: John Wiley & Sons; 1986:477-515.
31. Blackburn GG, Harvey SA, Dafoe WA, Squires RW. Exercise prescription development and supervision. In: Pashkow FJ, Dafoe WA, eds. *Clinical Cardiac Rehabilitation: A Cardiologist's Guide*. 2nd ed. Baltimore, MD: Williams and Wilkins; 1999: 137-160.