Designing Optimal Exercise Programs – Guideline & Science-Based Approaches

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Disclosures

No relevant disclosures to report

Evidence-based publications used to develop presentation

References included throughout presentation

Clinical decisions & patient exercise programming should use sound judgement & reasoning

Each patient should be treated as an individual as guidelines are used as a "guide"

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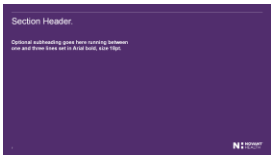
Objectives

Understand current exercise assessment techniques from exercise programming literature, including the role exercise & functional testing play when cardiopulmonary exercise & /or graded exercise testing are not available or feasible.

Describe exercise prescription precision medicine:

- Exercise intensity
- Exercise progression
- Exercise volume

Include resistance training in personalized exercise training programs following recommended guidelines for individuals with CVD & Pulm dx.



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Why is what we do important?

Every 1 MET increase in peak workload, approx. 25% reduction CVD mortality

10% training intensity increase (%VO2peak) helps increase VO2peak by 1.0 ml/kg/min (7% CVD mortality reduction)

Precision medicine targets risk factors subsequently helping all aspects of secondary prevention

Individualizing treatment plans optimizes patient outcomes & improves QOL

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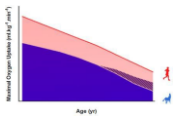
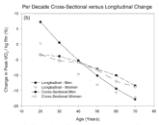
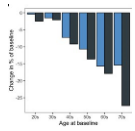
Decline in CRF with Aging

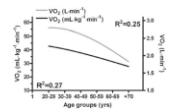


Carrick-Ranson G., et al. (2023) JAP, 135

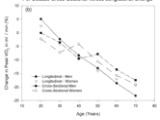




J.M. Letnes et al. (2020) Prog Card Dis: 63



Loe H, et al. PLoS ONE 8(5): e64319.



Fleg J., et al. (2005) Circulation, 112

Table 2. Change in CRF per LMM I and LMM II: Aerobics Center Longitudinal Study, 1974-2000*

Age Group, y	Women		Men	
	LMM I	LMM II	LMM I	LMM II
40-49	−0.45	−0.09	−0.48	−0.08
50-59	−0.77	−0.53	−0.58	−0.33
60-69	−1.08	−0.98	−1.01	−1.19
70-79	−1.40	−1.16	−1.71	−1.58

Abbreviations: CRF, cardiorespiratory fitness; LMM I, linear mixed models due to aging; LMM II, LMM due to aging controlled for lifestyle.
*Data are expressed as metabolic equivalents.

Jackson A.S (2009) Arch Inter Med:169(19)

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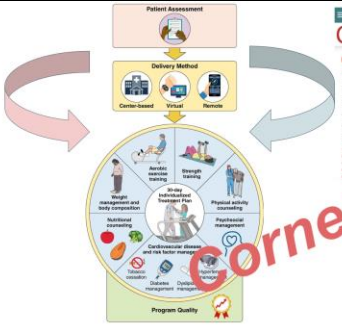
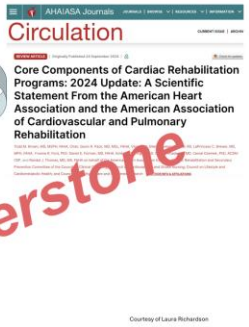



AHA/ASA Journals

Circulation

Core Components of Cardiac Rehabilitation Programs: 2024 Update: A Scientific Statement From the American Heart Association and the American Association of Cardiovascular and Pulmonary Rehabilitation

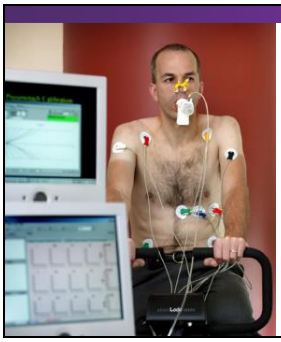
Cornerstone

Courtesy of Laura Richardson

Current Guidelines & Literature supporting CR/PR

- **Multiple exercise testing & prescription choices**
- **Optimal exercise programming maximizes patient outcomes & experience**
- **Precision medicine targets risk factors (ExRx is 1 key piece)**
- **Benefits shown to reduce CVD mortality up to 36%**

Kachur S, Chongthammakun V, Lavie CJ, De Schutter A, Arena R, Milani RV, Franklin BA. Impact of cardiac rehabilitation and exercise training programs in coronary heart disease. Prog Cardiovasc Dis. 2017 Jul-Aug;60(1):103-114. doi: 10.1016/j.pcad.2017.07.002. Epub 2017 Jul 6. PMID: 28689814



Clinical Exercise Test Types

- **Cardiopulmonary Exercise Test (CPET, CPX)– cornerstone of care**
- **Graded Exercise Test (GXT, ETT) – only see heart function**
- **Exercise Echocardiogram Test (EET, Stress Echo)**
- **Exercise Nuclear Stress Test (Exercise Nuc, Nuc Stress)**

Non-exercise tests:
- **Dobutamine Echocardiogram Stress Test (DOBI)**
- **Nuclear Stress Test (Nuc Stress)**
- **Cardiac Magnetic Resonance Imaging (CMRI)**
- **Calcium Computed Tomography (CCTA)**

Submaximal Exercise or Functional Test Types

- **Six Minute Walk Test (6MWT)**
- **YMCA Cycle Ergometer Test (2-3 submax workloads)**
- **Shuttle or Beep Test (not used clinically, rarely in research)**
- **Timed Get Up and Go**
- **1 min Sit to Stand**
- **Short Physical Performance Battery**

Variables measured during Clinical Exercise Tests

	CPET	GXT	EET	Exercise Nuc	6MW or submax	Functional Testing
HR	X	X	X	X	X	X
BP	X	X	X	X	X	X
Workload	X	X	X	X	X	
VO2	X				Predicted	
METS	X	X	X	X	Predicted	
RER	X					
Ve/VCO2 ratio & slope	X					
VTs	X					
Other	O2 Sat	O2 Sat	Echo	Perfusion	O2 Sat, distance	Per test

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CPET Indications – what they evaluate

Exercise tolerance & undiagnosed exercise intolerance

Patients with cardiovascular disease

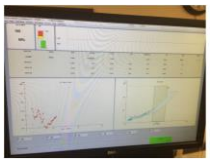
Patients with respiratory diseases/symptoms

Preoperative evaluation

Exercise assessment & Rx for CR/PR

Disability or Impairment

Lung, heart, and heart-lung transplant candidacy



Balady et al. Clinician's Guide to Cardiopulmonary Exercise Testing in Adults: A Scientific Statement. Circulation 2010; 122, 191-225.

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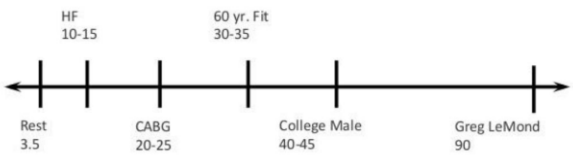
VO2peak Range – what's expected



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Normal CPET values

Variable	Normal Range
FEV1/FVC	70% or greater
Ve/MVV ratio	<80% (Breathing reserve 20% or >)
VO2 @ rest	Approx 3.5 ml/kg/min
VO2peak	80% predicted or greater
Ve/VCO2 slope	<30 if not <25 "healthy normal"
AT or VT1	40% predicted VO2peak or greater
RER or RQ	1.1 or greater = maximal effort
O2 pulse	80% or greater
PetCO2 @ rest	36-44 mmHg

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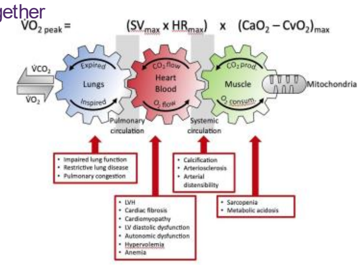
CPET Physiology – coupling & cellular respiration - heart, lung, & muscle together



adapted from Wasserman, 1997

Lim et al (2020) Cardiovascular Functional Changes in Chronic Kidney Disease: Integrative Physiology, Pathophysiology and Applications of Cardiopulmonary Exercise Testing. Front. Physiol., 14 September 2020 Sec. Renal Physiology and Pathophysiology Volume 11

Courtesy of Laura Richardson

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CPET Tools

Fick principle:

VO_2 = CO • AVO_2 difference

VO_2 = SV • HR • AVO_2 difference

VO_2 = EDV • EF • HR • AVO_2 difference

VO_2 = EDV – ESV • HR •Hb * $([O_2]_a - [O_2]_v)$

CPET markers related to performance:

VO2 peak

Ventilatory efficienty (Ve/VCO2 slope)

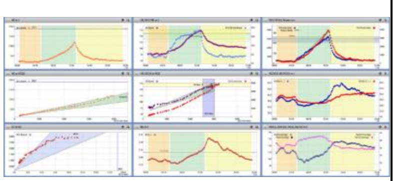
Tidal volume & respiratory rate

Breathing reserve

Chronotropic HR response

Oxygen pulse

Blood pressure



Courtesy of Jeff Christie

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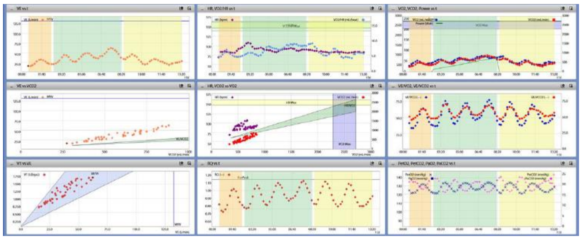
The unexpected can be seen – In whom do you usually see this?



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Courtesy of Jeff Christie

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Ventilatory Thresholds

VT1 (Anaerobic Threshold):

Lactate begin to increase

pH to decrease

Bicarbonate buffers H+ ions, CO_2 produced above aerobic metabolism

VO_2 vs. VCO_2 slope changes - <1 to >1

Ve/VO_2 nadir – lowest then increase

Ve/VCO_2 – decrease or lowest constant

PetCO_2 – highest

PetO_2 - lowest

Typically 50-60% VO_2peak, 60-70% HRpeak

VT2 (Respiratory Compensation Point):

Maximal lactate steady state

Bicarbonates not able to buffer H+ ions, excess CO_2 production

End of isocapnic buffering

VO_2 vs. VCO_2 slope changes exponentially

Ve/VO_2 nadir – "spike" in slope

Ve/VCO_2 – increase from steady state

PetCO_2 – decrease from highest point

PetO_2 – increase from low point

Typically 70-80% VO_2peak, 80-90% HRpeak

Mezzani, A. et al. Aerobic Exercise Intensity Assessment & Prescription in Cardiac Rehabilitation. JCRP 2012 DOI 10.1007/s40279-021-01581-z
Keir, D.A. et al. Identification of Non-Invasive Exercise Thresholds: Methods, Strategies, and an Online App. Sports Medicine, Oct 25, 2021. DOI: 10.1097/HCR.0b013e3182757050.

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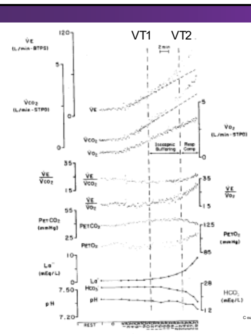

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Original Article

Association of Mitochondrial Function, Substrate Utilization, and Anaerobic Metabolism With Age-Related Perceived Fatigability

Fangyu Liu, MHS, Amal A. Wanigatunga, PhD, MPH, Marta Zampino, MD, Nicolas D. Knuth, PhD, Eleanor M. Simonsick, PhD, Jennifer A. Schrack, PhD, and Luigi Ferrucci, MD, PhD

Adv. Cardiol., vol. 35, pp. 135–145 (Karger, Basel 1986)

Anaerobic Threshold as Detected from Ventilatory and Metabolic Exercise Responses in Patients with Mitochondrial Respiratory Chain Defect

J.M. Bogaard[a], H.R. Scholte[b], H.F.M. Busch[c], H. Stam[a], A. Versprille[a]

[a]Pathophysiological laboratory of the Department of Pulmonary Diseases, and Departments of [b]Biochemistry and [c]Neurology, Erasmus University, Rotterdam, The Netherlands

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Courtesy of Elvis Alvarez Carnero

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Exercise Testing & Prescription

How does aerobic intensity effect CRF in CR & PR patients?

- **CRF is THE strongest predictor of all-cause & CV-related mortality, as well as future fatal & non-fatal coronary events. ↑CRF helps reduce mortality risk**
- **Exercise therapy during CR & PR provides an opportunity to mitigate risk of rehospitalization, reoccurrence & mortality**
- **Exercise-based cardiac rehab effectively ↑CRF; differential effects of prescribed exercise intensity not as well studied**

Mitchell BL, Lock MJ, Davison K, et al. Br J Sports Med 2019;53:1341–1352.

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Exercise Intensity

Majority of studies report prescribing large ranges of exercise intensities based on HR responses to exercise

Large variation in CRF change across studies following CR & PR

Vigorous-intensity exercise may provide greater benefits over moderate or moderate-to vigorous intensities, but additional benefits are unlikely to be clinically significant = lower peak MET increase

Intensity	VO2peak increase potential
Light (35-45% VO2peak)	Little
Moderate (46-55% VO2peak)	4.1 ml/kg/min
Moderate to Vigorous (56-70% VO2peak)	4.9 ml/kg/min
Vigorous (>70% VO2peak)	5.5 ml/kg/min

Mitchell BL, Lock MJ, Davison K, et al. Br J Sports Med 2019;53:1341–1352.

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CPET Objectives & Utility

Objectives:

Establish baseline CRF

Assess response to intervention/training

Standardize submax exercise intensity

Ensure participant safety

Utility:

CPET assesses cardiovascular & respiratory system integration during exercise

Noninvasive, comprehensive assessment of one's exercise capacity

VO2peak used for disease stratification (e.g. VO2peak < 14 ml/kg/min in HF & surgery)

Use test data to tailor exercise training programs & optimize outcomes in athletes through high-risk clinical populations

Clinical evaluation – what's reason for exercise intolerance

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CPET barriers

- **Cost & Resource Intense**
  - Equipment & Maintenance expenses
  - Staffing resources (trained Technician & Physician)
- **Patient Compliance & Tolerance**
  - Physical limitations
  - Patient anxiety
- **Interpretation**
  - Variability
  - Advanced training

Time Constraints

Staffing

Medical supervision

Infrastructure

Protocols & Test standardization

1 size doesn't fit all

Non-invasive vs. Invasive

- **Versatile**
- **Mechanistic**
- **Physiological**
- **Prognositc**

Courtesy of Laura Richardson

Reeves, Gordon R. MD, MPT; Gupta, Shuchita MD; Forman, Daniel E. MD. Evolving Role of Exercise Testing in Contemporary Cardiac Rehabilitation. Journal of Cardiopulmonary Rehabilitation and Prevention 36(5):p 309-319, September/October 2016.

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Precision exercise medicine – how monitor variables?

Duration & Modality

Limited variability between programs

Well done

Intensity & Progression

Much variability

How do you do it in your practice?

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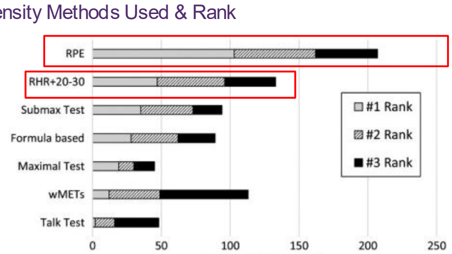
Intensity Methods Used & Rank



Courtesy of Laura Richardson

Pack et al (2022). Exercise Prescription Methods and Attitudes in Cardiac Rehabilitation: A NATIONAL SURVEY. Journal of Cardiopulmonary Rehabilitation and Prevention 42(5):p 359-365, September 2022

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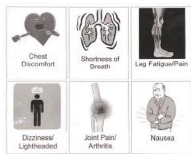
Subjective variables – RPE & Symptoms



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Intensity - Subjective

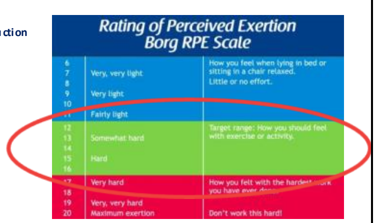
Reliable with consistent & proper instruction

Not optimal

RPE if used correctly

Talk Test

What benefit exercise @ RPE 8 – 10?



Pack et al (2022). Exercise Prescription Methods and Attitudes in Cardiac Rehabilitation: A NATIONAL SURVEY. Journal of Cardiopulmonary Rehabilitation and Prevention 42 (5) p 359-365, September 2022
Nerys Williams, The Borg Rating of Perceived Exertion (RPE) scale, Occupational Medicine, Volume 67, Issue 5, July 2017, Pages 404–405

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HR Calculations – what happens across the life span & fitness levels

Much variability

Low fitness & /or elderly - underestimate

High fitness & /or younger - overestimate

HR max prediction formulas:

= 220 – age (traditional)

= 208 - (0.7 x age) (meta-analysis)

= 206 – (0.88 x age) (women)

= 211 – (0.64 x age) (highly active)

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Intensity - Methods

HR+ Fixed Range

RHR +20 - 30 bpm

Basic, safe starting point

Titrate with exercise progression

Utilize HR Reserve – 40-80% predicted max HR if no CPET/GXT

Talk Test (TT)

VT1 correlates with TT

RPE 11-12 on average

Can they converse easily?

- CO2 & LA steady state

Monitor breathlessness

- 0-10 dyspnea scale

Exercise Progression

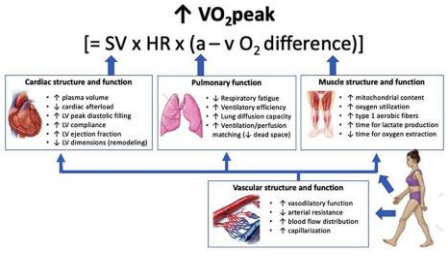
Table 1. Example of a progressive exercise program in cardiac rehabilitation.

Exercise Session	Duration	RPE (6–20)	Heart Rate	Mode	Comment
1	10 min	11–14	Target: 92–102 bpm	Treadmill: begin patient at 1.5–2.5 mph	Record treadmill workload, heart rate achieved, and symptoms
2	15 min	11–14	Target: heart rate may need to be increased to meet RPE goal	Treadmill: increase walking speed or grade if appropriate. Cycle/recumbent: introduce new modality	Record exercise workloads, heart rate achieved, and symptoms.
3	20 min	11–14	Target: heart rate may need to be increased to meet RPE goal	Treadmill: increase walking speed or grade if appropriate. Cycle/recumbent: introduce new modality	Record exercise workloads, heart rate achieved, and symptoms
4	25 min	11–14	Target: heart rate may need to be increased to meet RPE goal	Treadmill: increase walking speed or grade if appropriate. Continue to introduce new exercise modes if appropriate	Record exercise workloads, heart rate achieved, and symptoms

Case study example: female patient, age 65, resting HR = 72 bpm, diagnosed CAD with PCI and coronary stent treatment 14 days ago. Min = minutes, RPE = rating of perceived exertion.

- Monitor symptoms
- 1st Duration
- 2nd Intensity
- RPE >14 as tolerated

Benefits of Aerobic Exercise Program



What do your patients do at home when not in CR/PR?

TABLE 25-1. Estimated Metabolic Costs for Selected Physical Activities* and the Corresponding $\dot{V}o_2$ Values for a 70-kg Adult of Normal Body Habitus

	Activities	Estimated METs	$\dot{V}o_2$ for ~70-kg Adult (mL/min)
Walking, Running, Climbing	Rest, seated	1.0	250
	Walking slowly with children while pushing stroller	2.5	625
	Walking, 3 mph on level ground	3.3	825
	Walking, 3 mph carrying load of <25 lbs	4.0	1000
	Jogging, <5 mph	7.0	1750
	Running, 7 mph	11.5	2875
	Walking up stairs or climbing ladder	8.0	2000
	Running up stairs	15.0	3750
Home and Self-Care	Dressing and undressing	2.0	500
	Grooming: washing, shaving, hairstyling	2.0–2.5	500–625
	Light cleaning, dusting	2.5	625
	Vacuuming	3.5	875
	Sweeping garage or sidewalk	4.0	1000
	Mowing lawn, walking power mower	5.5	1375
Occupational and Recreational	Light work standing: bartending, filing	2.3	575
	Pressing clothes	4.0	1000
	Playing golf, general	4.5	1125
	Machine tool operation	2.5–5.0	625–1250
	Swimming leisurely	6.0	1500
	Playing tennis, general	7.0	1750
	Shoveling, digging dirt	6.0–8.5	1500–2125
	Firefighting: climbing ladder with gear	11.0	2750

*Expressed as multiples of the resting metabolic rate (METs, defined as 3.5 mL/min/kg). METs values were abstracted from The Compendium of Physical Activities, a compilation of data derived from various sources, including questionnaires, laboratory simulations, and field measurements.
mph, miles per hour.

From *Clinical Exercise Testing*, by Karen Sietsema, MD

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Exercise Prescription guidance – precision medicine 2025 AACVPR Guidelines

Target VO2 using MET level & workload from CPET

Karvonen formula with VO2 or Heart Rate Reserve

ACSM Walking, Running, & Cycle Ergometry equations – for steady-state exercise

NuStep & Elliptical – harder to prescribe workloads without good prediction equations

Use the VT2 workload as top end of training range & titrate up as patient is able

Utilize HITT & push past VT2 during high intensity intervals; lower intensity (recovery) should be at VT1 or lower levels – can use rest if need be

Should be doing at least as much work as they do outside rehab – rehab is where they should be stressed

Volume of Aerobic exercise involves frequency, intensity, time, & mode integrated together – target are individualized

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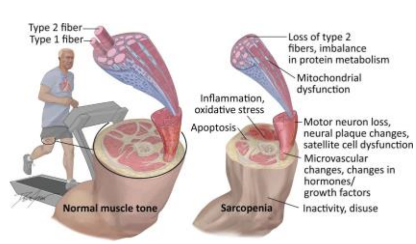
Resistance Training helps maintain/restore muscle



Courtesy of Laura Richardson

Damluji et al (2022) Sarcopenia and Cardiovascular Diseases. Circulation Vol 147, Number 20

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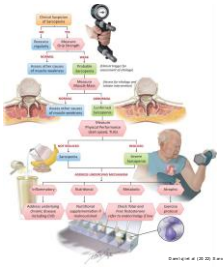
CR/PR – Resistance Training is key component



Sarcopenia

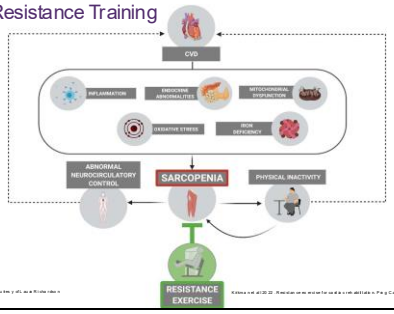
flesh poverty

muscle strength (dynapenia)

mass (quantity)

function (quality)

Resistance Training



lean mass abnormalities

vicious ⇕ cyde

CVD

Table 1.

Current resistance training guidelines for cardiac patients and older individuals.

	Population	Frequency	Intensity	Time	Type
ACSM [4]	Outpatient Cardiac Rehabilitation	2-3 nonconsecutive d • wk^{-1}	- RPE 11-13 on a 6-20 scale - 40%-60% 1RM	- 1-3 sets - 10-15 repetitions - 8-10 exercises	- Focused on major muscle groups - Select equipment that is safe and comfortable for the individual to use
ACSM [28]	Older Adults				
	For Strength & Hypertrophy	2-3 nonconsecutive d • wk^{-1}	- 60-80% 1RM - Slow-moderate lifting velocity	-1-3 sets - 8-12 repetitions -1-3 minutes rest between sets	- Multiple and single joint exercises - Free weights & machines
	For Power	2-3 nonconsecutive d • wk^{-1}	- 30-60% 1RM - High lifting velocity		
	For Muscular Endurance	2-3 nonconsecutive d • wk^{-1}	-Low-moderate intensity	-10-15 repetitions	
AHA [24]	Cardiac Patients	2-3 nonconsecutive d • wk^{-1}		- 1 set - 8-10 repetitions - 8-10 exercises	

ACSM, American College of Sports Medicine; AHA, American Heart Association; RM, repetition maximum; RPE, ratings of perceived exertion.

Circulation

Scientific Statement From the American HeartAssociation

Panel A Resistance Training Prescription Components

RT Intensity	Percent of 1-RM	Number of Reps	Frequency per week	Muscle Adaptation	Population
Low Intensity	<40% 1-RM	15-20 reps	≥ 2 days/week	Endurance	High risk patients
Moderate Intensity	40-60% 1-RM	8-12 reps	≥ 2 days/week	Strength and endurance	General Population
High Intensity	>80% 1-RM	1-6 reps	≥ 2 days/week	Strength	Healthy adults looking to optimize strength

Panel B Contraindications to Resistance Training

Absolute Contraindications

- Unstable coronary heart disease
- Decompensated heart failure
- Uncontrolled atrial and/or ventricular arrhythmias
- Severe pulmonary hypertension (mean pulmonary arterial pressure >55 mm Hg)
- Severe and symptomatic aortic stenosis
- Acute myocarditis, endocarditis, or pericarditis
- Uncontrolled hypertension (>180/110 mm Hg)
- Aortic dissection
- Marfan syndrome
- High intensity RT in patients with active proliferative retinopathy or moderate or worse nonproliferative diabetic retinopathy

Relative Contraindications
(consult a physician before participation)

- Individuals with defibrillators or pacemakers
- Diabetes
- Controlled hypertension
- Musculoskeletal conditions or limitations
- History of stroke
- Low functional capacity (<4 METs)

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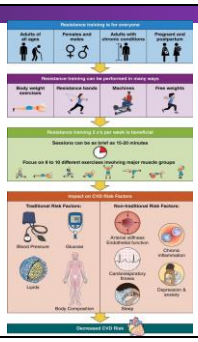
Circulation

AHA Scientific Statement



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Volume of Aerobic Exercise to Optimize Outcomes in Cardiac Rehabilitation

Targeted Weekly Levels for Physical Activity

2025 Official AACVPR Statement

Levels of Physical Activity for substantial health benefits
1000 - 2000 kcal/wk
500 - 1000 MET·min·wk^{-1}

Volume:
(5 kcal/min) (40 min/session) (6 sessions/week)
= 1200 kcal/week

500 kcal/wk 250 MET·min·wk^{-1}	1000 kcal/wk 500 MET·min·wk^{-1}	1500 kcal/wk 750 MET·min·wk^{-1}	2000 kcal/wk 1000 MET·min·wk^{-1}	2500 kcal/wk 1250 MET·min·wk^{-1}	3000 kcal/wk 1500 MET·min·wk^{-1}

Progression of CHD
< 1000 kcal/wk
< 500 MET·min·wk^{-1}

No progression of CHD
> 1500 kcal/wk
> 750 MET·min·wk^{-1}

Regression of CHD
> 2200 kcal/wk
> 1250 MET·min·wk^{-1}

Improve CHD risk factors
> 1000 kcal/wk
> 500 MET·min·wk^{-1}

Weight Loss
> 3000 kcal/wk
> 1500 MET·min·wk^{-1}

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Questions to ask of yourself and your program

1. Are our patients' exercise programs meeting recommended aerobic exercise volume during CR/PR sessions?
2. If not, what can we do differently to ensure they meet recommendations?
3. How can we integrate testing for each patient, if not already being done?
4. If not, can we do a CPET or GXT at the start of the program?
5. Are we using THR ranges outside "resting + 30 bpm" after the first few sessions?
6. Are our patients doing resistance training each rehab session?
7. If not, how do we incorporate resistance training into each rehab session? Use machines or hand weights/dumbbells/body weight?
8. How does the program track patient improvement quantitatively?
9. Do we stress complete lifestyle modification enough? Or do we just focus on one or two areas?

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Exercise Prescription Takeaways

Personalized precision medicine	
Exercise Testing optimizes ExRx	
If no max test results, RPE & Talk Test are good for progression	RPE 11 minimum benefit, 12-15 preferably
Volume specific to patient & program	
Home exercise program complements CR/PR program	Encourage to meet minimum PA recommendations daily

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Physical Activity (PA) Takeaways

"No dose of PA is too small to be healthful" – I-Min Lee, MD, ScD, Harvard Medical School

Walking 3.0 mph on level ground = approx. 3 METs – takes patients out of "high risk" cohort (Franklin, Bet al, Circulation 2020; 141:e705-e736)

Higher fitness (>8 METs peak) associated with lower mortality – 3-4x less likely to die than low fitness (<5 METs peak) across all ages (Phan et al, Am J Cardiol 2022;170:132-137)

Physical fitness is a vital sign, just like resting HR, BP, & Weight (AHA)

Find ways to integrate increased PA into lifestyle

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Thank You. Questions?

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