Cardiac Rehabilitation & Exercise Training in Congenital Heart Disease

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Cardiac rehabilitation

- Agency of Health Care Policy and Research (AHCPR, 1995): Comprehensive long-term services involving medical evaluation, prescribed exercise, cardiac risk factor modification, education, counseling and behavioral interventions – not just exercise training
- AHA scientific statements (2005): Coordinated, multifaceted interventions designed to optimize a cardiac patient's physical, psychological, and social functioning, in addition to stabilizing, slowing, or even reversing the progression of the underlying atherosclerotic processes, thereby reducing morbidity and mortality

Brief history

- 1950's: absolute bed rest for 6-8 weeks in post-MI patients (mortality of 30-40%)
- 1960's: attempt for early ambulation – ECG monitoring
- 1970's: clinical trials for cardiac rehabilitation program
- After 1980's: expansion of application of cardiac rehabilitation program

AHA/ACCF Guideline

AHA/ACCF Secondary Prevention and Risk Reduction Therapy for Patients With Coronary and Other Atherosclerotic Vascular Disease: 2011 Update

A Guideline From the American Heart Association and American College of Cardiology Foundation

Endorsed by the World Heart Federation and the Preventive Cardiovascular Nurses Association

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Cardiac rehabilitation

Class I

1. All eligible patients with ACS or whose status is immediately post coronary artery bypass surgery or post-PCI should be referred to a comprehensive outpatient cardiovascular rehabilitation program either prior to hospital discharge or during the first follow-up office visit.[55,154,161,163] ***(Level of Evidence: A)***
2. All eligible outpatients with the diagnosis of ACS, coronary artery bypass surgery or PCI ***(Level of Evidence: A)***,[55,154,158,161] chronic angina ***(Level of Evidence: B)***,[161,163] and/or peripheral artery disease ***(Level of Evidence: A)***[153,164] within the past year should be referred to a comprehensive outpatient cardiovascular rehabilitation program.
3. A home-based cardiac rehabilitation program can be substituted for a supervised, center-based program for low-risk patients.[153,159,160] ***(Level of Evidence: A)***

Class IIa

1. A comprehensive exercise-based outpatient cardiac rehabilitation program can be safe and beneficial for clinically stable outpatients with a history of heart failure.[159,159a–159c] ***(Level of Evidence: B)***

For congenital heart disease?

- Less evidence than coronary artery disease or heart failure
- Many patients with CHD are becoming grown-up.
- Long-term management with consideration of quality of life is becoming more important.
- Exercise training
  - Is it really beneficial?
  - How?

Measures of physical work

- Work = Force x Distance
  - F = ma
- Ventilatory oxygen consumption(VO_2)
  - The most common biologic measure of physical work
  - Universal relationship between oxygen consumption and energy expenditure: 5 kcal / 1 L oxygen
  - Unit
    - Liters per minute
    - METs: 1 METs ≈ 3.5 mL/kg/min (resting metabolic rate)
  - Maximal(Peak) oxygen consumption (VO_2max)

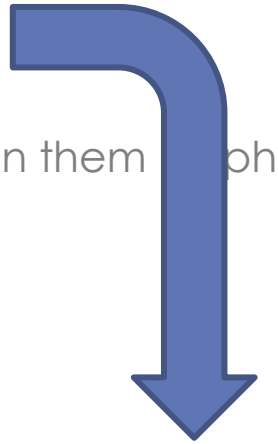
$$\dot{V}O_2 = CO \times \Delta a\text{-}vO_2$$

CO: cardiac output

$\Delta a\text{-}vO_2$: arterio-venous oxygen difference

Functional disability in CHD due to:

- The disease itself
- Deconditioning
  - Sedentary lifestyles
  - Restrictions imposed on them physicians, parents, teachers and children themselves



Should respond to exercise training!

Habitual level of physical activity in normal children and in patients 13 girls and 26 boys after surgical repair of tetralogy of Fallot

	Normal children	Patients	
Girls	4.26 (3.9-4.8)	2.19 (1-4)	$p < 0.001$
Boys	4.37 (3.3-6.9)	3.74 (1.5-6.5)	$p < 0.05$

The habitual level of physical activity is expressed as a score based on a questionnaire.
* Statistical analysis was performed after logarithmic transformation of the values to normalize the distribution of data. Therefore the geometric mean and the range are reported

Reybrouk, et al. *Am Heart J* 1986:112:998-1003

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CURRENT OPINION

Physical activity in adolescents and adults with congenital heart defects; individualized exercise prescription†

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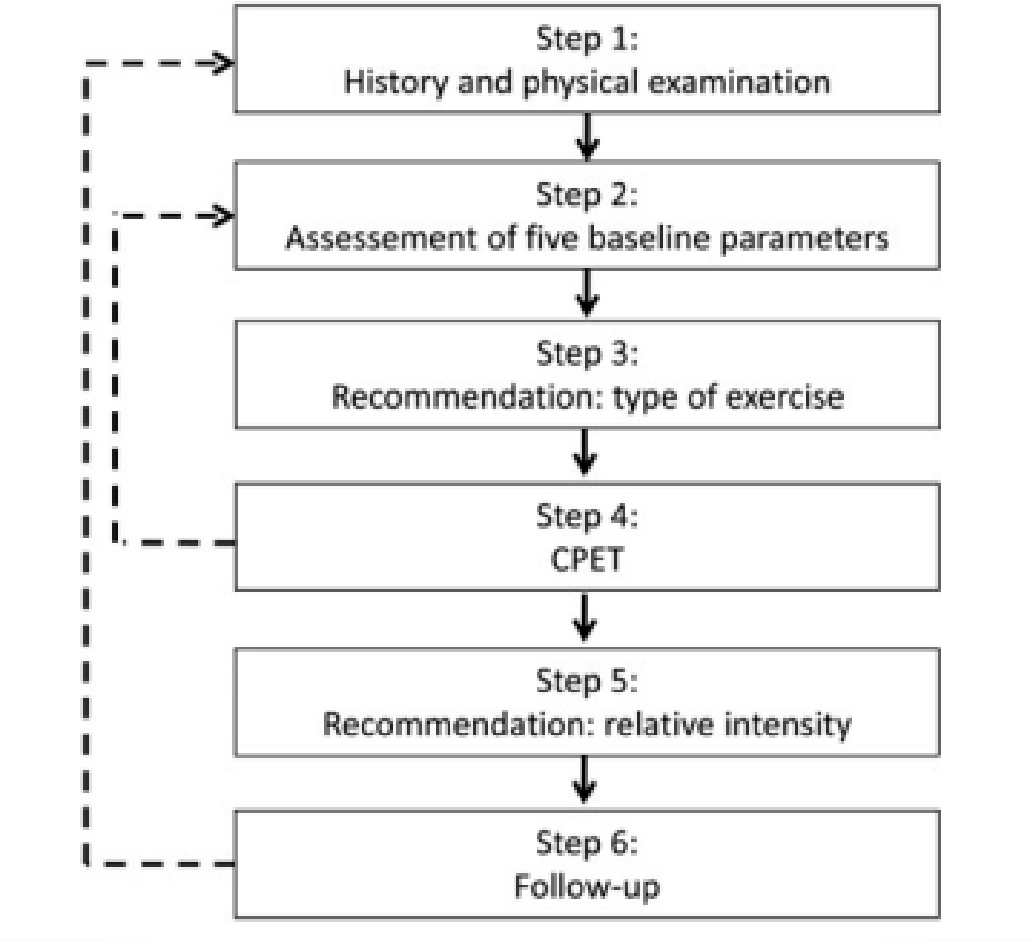
Six steps evaluating adolescent and adult patients with CHD



Evaluation

- Ventricular assessment (systolic function, presence of hypertrophy and evidence of pressure or fluid overload)
- Pulmonary artery pressure
- Size of the aorta
- Presence of arrhythmias
- Oxygen saturation

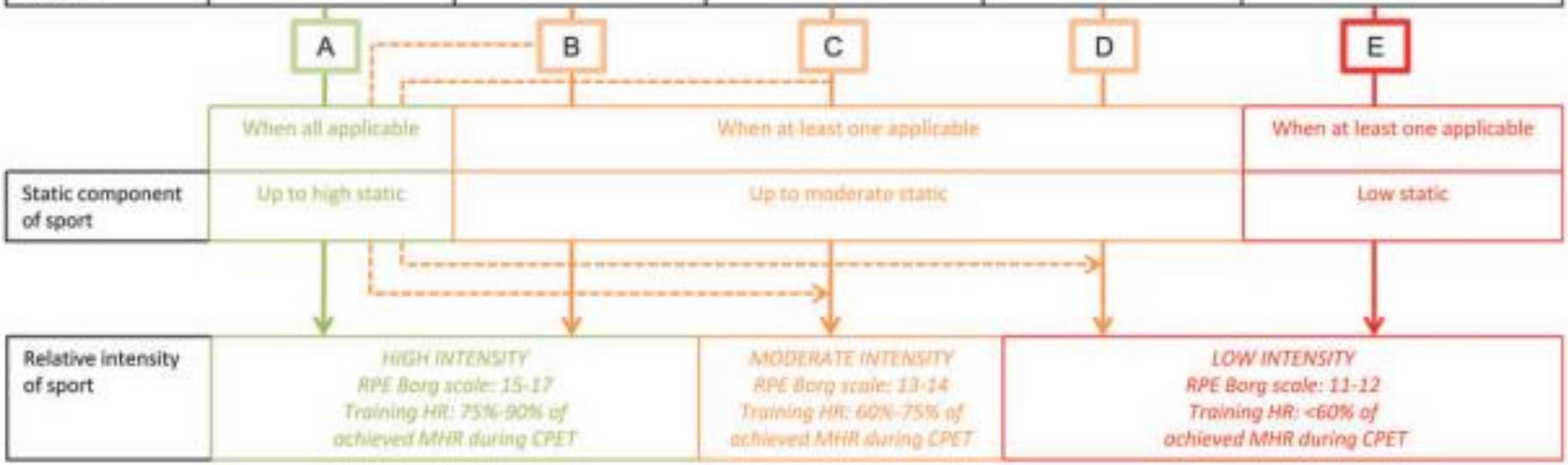
Cardioplumonary exercise test (CPET)

- Peak VO_2, maximal HR, Borg scale
- O_2 saturation
- Detection of arrhythmia or conduction disorder
- Blood pressure response to exercise

Alternatives of CPET

- Questionnaire
- Six-minute walk test
  - Pros: Easy to perform and mimics activities of daily living
  - Cons: only submaximal esp. in patients with mild to moderate disability
- Exercise test with ECG monitoring

1. Ventricles	No systolic dysfunction No hypertrophy No pressure load No volume load	No systolic dysfunction No hypertrophy Mild pressure load Mild volume load	Mild systolic dysfunction Mild hypertrophy Single ventricle physiology Systemic right ventricle	Moderate systolic dysfunction Moderate hypertrophy Moderate pressure load	Severe systolic dysfunction Severe hypertrophy Severe pressure load Moderate/severe volume load
2. Pulmonary artery pressure	Low pulmonary artery pressure	Low pulmonary artery pressure	Mildly elevated pulmonary artery pressure		Moderately/severely elevated pulmonary artery pressure
3. Aorta	No/mild dilatation	Moderate dilatation	Severe dilatation	Dilatation approaching indication for repair	
4. Arrhythmia	No arrhythmia	No arrhythmia	Mild arrhythmic burden Non-malignant arrhythmia		Significant arrhythmic burden Malignant arrhythmia
5. Saturation at rest/during exercise	No central cyanosis	No central cyanosis	No central cyanosis	Central cyanosis	



Solid lines indicate recommendation ; if option for sports with high static component, reduce intensity (dotted lines)

Classification of sports

	A. Low dynamic	B. Moderate dynamic	C. High dynamic
I. Low static	Bowling	Fencing	Badminton
	Cricket	Table tennis	Race walking
	Golf	Tennis (doubles)	Running (marathon)
	Riflery	Volleyball	Cross-country skiing (classic)
		Baseball[a]/softball[a]	Squash[a]
II. Moderate static	Auto racing[a,b]	Field events (jumping)	Basketball[a]
	Diving[b]	Figure skating[a]	Biathlon
	Equestrian[a,b]	Lacrosse[a]	Ice hockey[a]
	Motorcycling[a,b]	Running (sprint)	Field hockey[a]
	Gymnastics[a]		Rugby[a]
	Karate/Judo[a]		Soccer[a]
	Sailing		Cross-country skiing (skating)
	Archering		Running (mid/long)
			Swimming
			Tennis (single)
			Team handball[a]
III. High static	Bobsledding[a,b]	Body building[a]	Boxing[a]
	Field events (throwing)	Downhill skiing[a,b]	Canoeing, Kayaking
	Luge[a,b]	Wrestling[a]	Cycling[a,b]
	Rock climbing[a,b]	Snow boarding[a,b]	Decathlon
	Waterskiing[a,b]		Rowing
	Weight lifting[a]		Speed skating
	Windsurfing[a,b]		Triathlon[a,b]

Adapted and modified after Mitchell et al.[5]

[a]Danger of bodily collision.

[b]Increased risk if syncope occurs.

Rate of perceive exertion and % of maximal heart rate

RPE (Borg scale, ranging 6–20)	Subjective description of exercise intensity	Feels like	% of MHR
<10	Very light	Nothing	<35
10–11	Light	Something	35–54
12–13	Moderate	Perspiring	55–69
14–16	Hard	Sweating working	70–89
17–19	Very hard	Hard working	≥90
20	Maximal	Can't breathe anymore	100

RPE, rate of perceived exertion; MHR, maximal heart rate achieved during cardiopulmonary exercise testing.

Frequency & duration

- Minimum of 3-4.5 hr of physical activities per week
- Minimum minutes per session : 30 min
- Team sports or competitive sports
  - Difficult to restrict the intensity
  - Peers with similar level of fitness

CR studies in CHD

Study	n	Diagnosis	Program Duration, wk	Sessions per Week	Time per Session, min	Type	Control	Impact on Peak $\dot{V}o_2$ (mL/kg per Minute), %	Comment
Goldberg[73]	26	16 TOF, 10 VSD	6	3	<45	Home-based	No	Unchanged	Other parameters improved
Ruttenberg[74]	12	3 TOF, 3 TGA, 1 AVC, 5 AS	9	3	45	Facility-based	No	Unchanged	Large (50%) dropout rate; other parameters improved
Bradley[77]	9	5 TGA, 9 TOF	12	2	60	Facility-based	No	↑ 20	Internally inconsistent data; RER not measured; improvements may be effort related
Balfour[78]	6	1 Fontan, 5 other	12	3	60	Facility-based	No	↑ 20	Large (>50%) dropout rate
Fredriksen[75]	55	12 TGA, 8 ASD/VSD, 11 LVOTO, 3 RVOTO, 10 TOF, 4 Fontan, 7 other	20	2	NA	Facility-based and home-based	Yes	Unchanged	Large program variability; other parameters improved
Minamisawa[76]	11	Fontan	8–12	2–3	30	Home-based	No	↑ 7	
Opocher[79]	10	Fontan	32	2	30–45	Facility-based and home-based	No	↑ 11	
Rhodes[80,81]	16	12 Fontan, 4 other	12	2	60	Facility-based	Yes	↑ 16	Rehabilitation patients' improvement was sustained 7 mo after the program and was significantly superior to that of control subjects

TOF indicates tetralogy of Fallot; VSD, ventricular septal defect; TGA, transposition of the great arteries; AVC, atrioventricular canal; AS, aortic stenosis; LVOTO, left ventricular outflow tract obstruction; and RVOTO, right ventricular outflow tract obstruction.

Safety

- None of the more than three dozen randomized controlled trials of cardiac rehabilitation exercise training in patients with coronary artery disease, involving over 4,500 patients, described an increase in morbidity or mortality in rehabilitation compared with control patient groups.
- A survey of 142 cardiac rehabilitation programs in the United States, 1980 to 1984
  - Nonfatal myocardial infarction: 1 per 294,000 patient-hours
  - Cardiac mortality rate: 1 per 784,000 patient-hours
  - A total of 21 episodes of cardiac arrest occurred, with successful resuscitation of 17 patients.

Reason for underutilization

- Geographical maldistribution
- Failure of physicians to refer
  - Esp. for elderly, women and ethnic minority
- Reimbursement
- Poor patient motivation
- Lack of public (even physicians!) awareness of its benefits
- Patients are pushed to return to hectic life very soon, leaving no time for cardiac rehab.

Home-based program

- Components
  - Regular clinic follow-up
  - Planned communication
  - Management by rehabilitation nurses and other specially trained personnel
  - Periodic trans-telephonic ECG monitoring
  - Smartphones & wearable devices!!!
- Comparable (to conventional supervised program) improvements in functional capacity, without reported complications

Conclusion

- Though solid evidence is still not available, exercise-based cardiac rehabilitation program is likely to be beneficial in patients with congenital heart disease.
- Multi-disciplinary effort is need to have consensus on optimal program and its implementation.