Making Cardiopulmonary Exercise Testing Interpretable for Clinicians

Medical Applications Workshop
Web3D Conference

Los Angeles
28 July 2019
William E. Kraus, M.D.
CPX Indications (AHA)

• **Class I indications - (good evidence)**
  – 1. Evaluate exercise capacity and response to therapy in heart failure patients being considered for transplantation.
  – 2. Differentiate cardiac versus pulmonary limitation for dyspnea on exertion.

• **Class IIa - (weight of opinion)**
  – 1. Evaluate exercise capacity when indicated for medical reasons when subjective estimates (exercise test time or work rate) are unreliable.

• **Class IIb - (efficacy less established)**
  – 1. Evaluate response to intervention in which improvement of exercise tolerance is an important end point.
  – 2. Determine exercise training intensity for cardiac rehab.

• **Class III - (not recommended)**
  – 1. Routine use to evaluate exercise capacity.
CPX Testing

AHA Scientific Statement

Clinician’s Guide to Cardiopulmonary Exercise Testing in Adults
A Scientific Statement From the American Heart Association

Gary J. Balady, MD, FAHA, Chair; Ross Arena, PhD, FAHA; Kathy Sietsema, MD; Jonathan Myers, PhD, FAHA; Lola Coke, RN, PhD; Gerald F. Fletcher, MD, FAHA; Daniel Forman, MD; Barry Franklin, PhD, FAHA; Marco Guazzi, MD, PhD; Martha Gulati, MD; Steven J. Keteyian, PhD; Carl J. Lavie, MD; Richard Macko, MD; Donna Mancini, MD; Richard V. Milani, MD, FAHA; on behalf of the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology; Council on Epidemiology and Prevention; Council on Peripheral Vascular Disease; and Interdisciplinary Council on Quality of Care and Outcomes Research

Circulation 122:191-225, 2010
Exercise Testing and Training

AHA Scientific Statement

Exercise Standards for Testing and Training
A Statement for Healthcare Professionals
From the American Heart Association

Gerald F. Fletcher, MD, Chair; Gary J. Balady, MD, Vice Chair; Ezra A. Amsterdam, MD;
Bernard Chaitman, MD; Robert Eckel, MD; Jerome Fleg, MD; Victor F. Froelicher, MD;
Arthur S. Leon, MD; Ileana L. Piña, MD; Roxanne Rodney, MD;
Denise G. Simons-Morton, MD, PhD; Mark A. Williams, PhD; Terry Bazzarre, PhD

Circulation 104:1694-1740, 2001
Setting Up and Running and Exercise Testing Laboratory

AHA Scientific Statement

Recommendations for Clinical Exercise Laboratories
A Scientific Statement From the American Heart Association

Jonathan Myers, PhD, FAHA, Chair; Ross Arena, PhD, FAHA; Barry Franklin, PhD, FAHA; Ileana Pina, MD, FAHA; William E. Kraus, MD, FAHA; Kyle McInnis, PhD; Gary J. Balady, MD, FAHA; on behalf of the American Heart Association Committee on Exercise, Cardiac Rehabilitation, and Prevention of the Council on Clinical Cardiology, the Council on Nutrition, Physical Activity, and Metabolism, and the Council on Cardiovascular Nursing

Circulation 119: 3144-3161, 2009
Coupling of External to Cellular Respiration

Response: ↑ $Q_O_2$  ↑  ↑  SV, HR  ↑  ↑  $V_T$, f

CPX Testing Important Terms

- **VO\(_2\)** = oxygen consumption (measure of CV-R fitness)
  - Absolute (L/min) vs relative (mL/kg/min)
- **RER** = respiratory exchange ratio (measure of effort)
  - Amount of CO\(_2\) per O\(_2\) consumed
  - RER > 1.0 extra CO\(_2\) produced related to lactate production
  - RER > 1.10 considered maximal effort
- **Ve/VCO\(_2\)** slope = vent efficiency/dead space
  - Prognostic in HF: > 34 → worse prognosis
- **Dyspnea index** = peak exercise ventilation/MVV
  - > 50% = onset of dyspnea
  - > 80% = exercise ceases usually within 1 minute
  - Breathing reserve = (1 – Dyspnea Index)
- **O\(_2\) pulse** = VO\(_2\)/HR = SV x AVO\(_2\) diff
  - Surrogate for stroke volume
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**Test Stage - Baseline**

**Test Stage - Exercise**

**Test Stage - Recovery**

[Source: Duke Mobi Physiology Institute]
CPX Test Interpretation

• Step 1: PFTs.
  – FEV$_1$ < 1.0L? → lung limited; Is MVV ~ FEV$_1$ x 35?
• Step 2: Exercise time & protocol used & reason for stopping
  – CP or desaturations during exercise?
• Step 3: RER
  – > 1.10 = maximal test; likely limited by lactate.
  – < 1.10 may or may not be max
• Step 4: VO$_2$ and % predicted
  – VO$_2$ of 14 mL/kg/min may be normal for 70 y woman.
• Step 5: Ve/VCO$_2$
  – ↑ Ve/VCO$_2$ = ↑ dead space → CHF, pulmonary vascular disease
• Step 6: Dyspnea Index (peak VE/MVV)
  – ≥ 80% → lung limited
CPX Test Interpretation --alternative

• Step 1: PFTs
  – FVC, FEV₁, FEV₁/FVC < 80% → lung limited; Is MVV ~ FEV₁ x 35?
• Step 2: RER – adequacy of test
  – > 1.10 = maximal test; likely limited by lactate.
  – < 1.10 may or may not be max
• Step 3: VO₂ and % predicted – total oxidative capacity limited
  – VO₂ of 14 mL/kg/min may be normal for 70 y woman.
• Step 4: O₂-pulse and % predicted – cardiac limited – Panel 2
  – Compare with VO₂ and HR response
Normal Study
CPX Test Interpretation --alternative

• Step 1: PFTs
  – FVC, FEV₁, FEV₁/FVC < 80% → lung limited; Is MVV ~ FEV₁ x 35?

• Step 2: RER – adequacy of test
  – > 1.10 = maximal test; likely limited by lactate.
  – < 1.10 may or may not be max

• Step 3: VO₂ and % predicted – total oxidative capacity limited
  – VO₂ of 14 mL/kg/min may be normal for 70 y woman.

• Step 4: O₂-pulse and % predicted – cardiac limited – Panel 2
  – Compare with VO₂ and HR response

• Step 5: Ve/VCO₂ and VE/MVV – Panel 7
  – ↑ Ve/VCO₂ = ↑ dead space → CHF, pulmonary vascular disease; pulmonary limited
Normal Study
CPX Test Interpretation --alternative

• Step 1: PFTs
  – FVC, FEV₁, FEV1/FVC < 80% → lung limited; Is MVV ~ FEV₁ x 35?

• Step 2: RER – adequacy of test
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• Step 4: O2-pulse and % predicted – cardiac limited – Panel 2
  – Compare with VO₂ and HR response

• Step 5: Ve/VCO₂ and VE/MVV – Panel 7
  – ↑ Ve/VCO₂ = ↑ dead space → CHF, pulmonary vascular disease; pulmonary limited

• Step 6: VO₂ at VT; HR at VT – sk muscle limited – Panels 3, 6, 9
  – Percent of predicted
Normal Study
Normal Study
Nine-panel Plots

Some Examples
What is this?
What is this?
It’s All About Climate!
The Issue of Our Time