Cardiopulmonary Exercise Testing
February 26, 2013

Improving People's Lives
through innovations in personalized health care

Wexner Medical Center
Indications for Exercise Testing

- Functional capacity
- Pulmonary rehab exercise prescription and progression
- Determination of exercise limitations and fitness impairments
- Cardiac vs. pulmonary exercise limitation
- Detect exercise-induced hypoxemia and aid with titrating O2 therapy
- Evaluate specific symptoms or signs that may be aggravated or induced by exercise
- Evaluate prognosis
  - VO2 max correlates with overall mortality
General Requirements

- Personnel:
  - Testing Personnel;
    - Familiar with Exercise testing
    - Basic ECG understanding
    - Knowledge of abnormal response to exercise
    - BLS trained/ACLS encouraged
General Requirements

- Emergency Equipment
  - Written Procedure plan
  - Resuscitation equipment
    - Defibrillator
    - Oxygen Delivery device
    - Airway management
    - Emergency drugs/solutions
    - Appropriate IV equipment
General Requirements

- Laboratory
  - Well ventilated room
  - Temperature and humidity control: 18-22 °C (≤72 °F), ≤60% RH
  - Large enough to accommodate equipment and personnel.
  - Posters/pictures to reduce anxiety
Equipment

- Exhaled gas analysis system
- ECG monitoring system
- Blood pressure sphygmomanometer and stethoscope
- Continuous pulse oximetry
- Perceived exertion and dyspnea scales
- O2, compressed air, high flow blender
  - Elevated FI02 tests
Equipment

**Dyspnea Scale**
1+: slight breathlessness - patient can continue
2+: moderate breathlessness - patient can continue
3+: moderately severe breathlessness - patient must stop exercise soon
4+: severe breathlessness - exercise must stop now!

**ANGINA SCALE**
1: Light, barely noticeable
2: Moderate, bothersome
3: Severe, very uncomfortable
4: Most severe pain ever experienced in the past
Modalities
Exercise Protocol Determination

- Determining protocol should be chosen based on patients individualized perceived functional capacity and personnel judgment
  - ADLs
  - Current physical activity tolerance and regimen
  - Co-morbidities
  - Perceived dyspnea with activity
  - Gait, functional ailments
  - Diagnostic tests: PFTs, ABGs, 6MW
Exercise Testing Protocols

- 2-3 minute increment stages
  - Increase in intensity/work with each stage
  - Speed, grade, or watts (ramp protocol)

- Typical duration ~8-12 minutes

- Common protocols used
  - Modified Naughton (CHF)
  - Modified Bruce
  - Balke
  - 5-10 Watt ramp
Patient Testing

- Explanation of procedure
- Test Prep
- Resting Data
  - ECG, BP, SpO2, gas exchange data
- Test
  - ECG monitoring
  - Gas exchange data
  - BP, SpO2, RPE/RPD scales, patient symptoms
    - During each stage of exercise
- Recovery Data
  - 1 min, 3 min, and 5 min
  - ECG, BP, SpO2, symptom improvement
Gas Exchange

- **VO2 max**: the maximum rate at which a person can consume oxygen.
  - Used to measure exercise capacity
  - Indication of the oxygen transport capacity of the heart, lungs, and circulatory system

- **RER: Respiratory Exchange Ratio** *(VCO2/VO2)*
  - >1.1 indicates a maximal test

- **AT: Anaerobic Threshold**
  - Point at which oxygen can no longer be used efficiently; production of lactic acid
  - VCO2/VO2 >1.00

- **Breathing Reserve**: the difference between MVV and max exercise ventilation
  - Pulmonary reserve
Special Equipment Adaptations
Indications for Terminating Exercise Testing

- **Absolute Indications**
  - Hypertensive response (systolic blood pressure of >250 mm Hg and/or a diastolic blood pressure of >115 mm Hg)
  - Drop in systolic blood pressure >10 mm Hg from baseline blood pressure despite an increase in workload, when accompanied by other evidence of ischemia
  - Moderately severe angina (defined as 3 on standard scale)
  - ST depression/Elevation changes
  - Subject’s desire to stop
  - Sustained ventricular tachycardia
  - SpO2 in COPD patients ≤75-82% with no change in symptoms or a change in symptoms with desaturation.
    - For IPF patients, a SpO2 desaturation ≤75-82%, based on objective signs and symptoms.
Exercise Prescription

- ACSM guidelines
- FITT principle
  - **Frequency**: 3 days/week
  - **Intensity**: 40%/50% - 85% VO2
  - **Time**: >20-60 min
  - **Type**: dynamic activity/large muscle groups
    - Also incorporate resistance training and flexibility

- **Progression is determined by patient tolerance, (RPE/RPD)**
  - Titrate O2 to maintain sats >88%
Exercise Prescription Equations

Treadmill Speed:

% VO2(mL/kg/min) = (0.1xS) + (1.8xSxG) + 3.5 mL/kg/min
- S=speed (m/min)
- G=grade
- 1 mph=26.8 m/min

Watts:

% VO2(mL/kg/min) = \(\frac{1.8xWR}{BM} + 7.0 \text{ mL/kg/min}\)
- WR=work rate in kg/m/min
- BM = body mass in kg
- 1 Watt = WR/6.12
Exercise Prescription Equations

VO2 from Six Minute Walk Test:

\[
\text{Predicted VO}_{2\text{max}} (\text{ml/kg/min}) = [0.02 \times \text{distance (m)}] - [0.191 \times \text{age (yrs)}] - [0.07 \times \text{weight (kg)}] + [0.09 \times \text{height (cm)}] + [0.26 \times \text{RPP (x } 10^{-3})] + 2.45
\]

Where:

- \(m\) = distance in meters
- \(yrs\) = years
- \(kg\) = kilogram
- \(cm\) = centimeter
- \(RPP = \text{rate pressure product (HR x systolic BP)}\)
Six-Minute Walk Outcome Measurement

- Pre and post rehab 6MW tests
  - Determines exercise/functional capacity improvement
  - MCID: 30 meters (98.4 ft)
- 2012: 81 patients with pre and post rehab data
  - Average 37.5 meters (123 ft) improvement in 6MW distance
  - 11.87% improvement

“Walking is a man’s best medicine.”

-Hippocrates
Case Study # 1

- **Background:** HG is a 72yo M who presents w/ COPD, DOE, OSA, a-fib, and AVR. Former smoker who quit 23 yrs ago and has a 60pkyr hx.

- **Pre-rehab testing data**
  - FEV1: 1.27 (40% pred); FVC: 2.31 (53% pred); FEV1/FVC: 55 (71% pred)
  - ABG: pH: 7.37, PCO2: 46, PO2: 74

- **Pre-6MW:** 1048 ft; c/o leg soreness

- **CPET**
  - **Objective Data**
    - VO2 max: 10.3 mL/kg/min (44%pred)
    - HR max: 119 (79% pred)
    - RER: 1.01
    - Max workload: 2.9 METs, 7:00, Modified Naughton Protocol
    - Lowest SpO2: 91%
    - BR: 38.2%
  - **Subjective Data:** Pt terminated test due to leg/hip pain; c/o chest tightness associated with SOB
Case Study # 1

- Exercise Prescription
  - TM: 1.2 mph, 10:00
  - Bike: 8 watts, 10:00
  - UBE: 120 RPM, 6:00
  - Wt training: arms: 1lb, 10x1; legs: 0lb 10x1

- 1st rehab session workloads: 1.9 METs

- Final rehab session workloads: 3.3 METs
  - TM: 2.7 mph, 0.5%, 30:00
  - Bike: 46 watts, 15:00
  - UBE: 45 RPMs, 14:00
  - Wt training: arms: 7lbs, 12x2; legs: 2lbs, 15x1

- Post-rehab 6MW: 1148 (+100 ft), c/o leg/hip pain

- Patient’s perspective: “I am doing a lot more with exercise and in my daily routine now than when I first started.” Patient joined CWP for maintenance 3 days/week
Case Study # 2

- Background: LC is a 57 yo M who presents with ILD, DOE, and is O2 dependent. PMH: COPD, OSA, HTN, and + family hx of IPF. LC is a former smoker who quit 9 years ago and has a 102 pkyr hx

- Pre-rehab testing data:
  - FEV1: 2.42 (63%); FVC: 3.42; FEV1/FVC: 71
  - ABG: pH: 7.44, PCO2: 41, PO2: 55

- Pre-6MW: 1394 ft, FIO2: 37% (4L), desaturated to 63%

- CPET
  - Objective Data
    - VO2 max: 17.2 mL/kg/min (66% pred)
    - HR max: 141 bpm (87% pred)
    - RER: 1.20
    - Max workload: 4.9 METs, 10:00, Mod Naughton protocol
    - Lowest SpO2: 92%, FIO2: 41% (5L)
    - BR: 7.6%
  - Subjective Data: pt terminated test due to SOB 4/4
Case Study # 2

- Exercise Prescription:
  - TM: 2.1 mph, 10:00
  - Bike: 8 watts, 10:00
  - UBE: 120 RPM, 6:00
  - Wt training: arms: 1lb, 10x1; legs: 0lb, 10x1

- 1st rehab session workload: 2.6 METs
- Final rehab session workload: 3.9 METs
  - TM: 3.2 mph, 1% incline, 30:00
  - Bike: 62 watts, 15:00
  - UBE: 90 RPM, 12:00
  - Wt training: arms: 8 lbs, 12x2; legs: 2lbs, 15x1

- Rehab interventions: pt required 15 L O2 HFNC with increasing workloads; set up high flow concentrator for home

- Post-rehab 6MW: 1578 ft (+184 ft)

- Patient’s perspective: “Exercise has made a big difference. Almost everything has improved.” LC continues to drive from Mt. Vernon to do maintenance exercise 3 days/wk, and home treadmill 4 days/wk.
Case Study # 3

- **Background**: TL is a 38 yo F who presents with Pulmonary Hypertension (PTHN), DOE, and O2 dependent. TL was never a smoker.

- **Pre-rehab testing data**
  - FEV1: 2.11 (76%); FVC: 2.44 (72% pred) FEV1/FVC: 87
  - ABG: pH: 7.4, PCO2: 37, PO2: 72

- **Pre-6MW**: 1657 ft
- **Post 6MW**: 1657 ft

- **Objective Data**
  - HR max: 138 bpm (76% pred)
  - Lowest SpO2: 96 %

- **Subjective Data**: Pre and Post 6MW are same distance, it was observed that TL “Could not have walked any faster without running.”
Case Study # 3

- **Exercise Prescription**
  - TM: 2.2 mph, 10:00
  - Bike: 12 Watts, 10:00
  - Wt training: Arms: 1lbs, 10x1: Legs: 0lbs, 10x1

- **1st rehab session workloads:** 2.6 Mets

- **Final rehab session workloads:**
  - TM: 2.6 mph, 1% incline, 10:00
  - Bike: 35 watts, 20:00

- **Post 6MW:** 1657 ft

- **Rehab interventions:** TL required 2 L O2 at rest/exertion, two weeks prior to rehab completion pt was able to tolerate exercise w/o requiring O2. (SP02 remained above 90%)

- **Patient’s perspective:** “Overall quality of life has improved from day 1. Still enjoying exercise; Remembering to use gradual warm and cool down as part of workout routine.” TL continues to do maintenance 3 days/wk.
Case Study # 4

- Background: JR is a 76 yo M who presents with COPD and arrives to his CPET directly from being discharged from the hospital for a COPD exacerbation. PMH: Asthma, lung cancer, esophageal cancer (s/p esophagectomy), Smoking hx of 30 pkyrs (quit ~30 yrs ago)

- Pre-rehab testing data
  - FEV1: 2.68 (71% pred); FVC: 4.75 (92% pred); FEV1/FVC: 56

- Pre-6MW: 902 ft

- CPET
  - Objective Data
    - VO2 max: 17.2 (46% pred)
    - HR max: 130 bpm (90% pred)
    - RER: 0.96
    - Max workload: 4.9 METs, 4:38, Modified Naughton protocol
    - Lowest SpO2: 94% (RA)
    - BR: 50.7%
  - Subjective Data: pt terminated test due to SOB, anxiety, and fatigue.
Case Study # 4

- **Exercise Prescription**
  - TM: 1.7 mph, 10:00
  - Bike: 6 watts, 10:00
  - UBE: 120 RPM, 6:00
  - Wt training: arms: 1lb, 10x1; legs: 0lb, 10x1

- 1st rehab session workload: 2.3 METs

- Final rehab session workloads: 2.9 METs
  - TM: 2.0 mph, 1.5% incline, 30:00
  - Bike: 28 watts, 15:00
  - UBE: 90 RPMs, 10:00
  - Wt training: arms: 6 lbs, 12x2; legs: 1.5 lbs, 15x1

- Rehab interventions: PT referral for shoulder, nutrition counseling to help increase weight, Reglan rx to control nausea

- Post-rehab 6MW: 1345 ft (+ 443 ft)

- Patient’s perspective: “I am more active and my QOL has greatly improved. I am going back to work for the first time in 10 months.” Joined local YMCA to continue exercise.
Case Study #5

- Background: RH is a 36 yo F who presents with Pulmonary Hypertension (PTHN). RH didn’t require O2

- Pre-rehab testing data:
  - ABG: pH: 7.42, P02: 71, PCO2: 35

- Pre-6MW: 1237 ft

- Post- 6MW: 1666 ft (+429 ft)
  - Objective Data
    - HR max: 151 (83% pred)
    - Lowest SpO2: 91%

- Exercise Prescription:
  - TM: 1.8 mph, 10:00
  - Bike: 8 watts, 10:00
  - Wt training; arms, 1lb, 10x1; Legs 0 lbs 10x1

- 1st rehab session workloads: 2.4 Mets

- Final rehab session workloads:
  - TM: 3.0 mph, 2% incline, 35 mins
  - Bike: 40 watts, 20mins
  - Wt training; arms, 6lbs 12x2; Legs 3lbs 15x1
Case Study #5

- Patient’s perspective: “ADLs are much better than before, now I can stand for longer periods of time”. Pt continues to do maintenance 3 days/wk and is was able to return back to work 5 days/wk from overall progression from PR.
References


WHEN HE COLLAPSES, YOU FOLKS CATCH HIM.