PEDIATRIC EXERCISE TESTING - A HIDDEN POTENTIAL

Rajeev Bhatia, MBBS, MD, Dch
Pediatric Pulmonologist
Medical Director, Clinical Exercise Physiology Lab
Akron Children’s Hospital, Akron, Ohio

Cincinnati Clinical Exercise Testing and Therapeutics Symposium
March 4th, 2017
“What fits your busy schedule better, exercising one hour a day or being dead 24 hours a day?”
Objectives

• Provide overview of different methods of exercise testing (submaximal and maximal) in children and adolescents

• Share our experience about submaximal and maximal exercise testing as a clinical and research tool in different disease conditions
Exercise

- Complex activity which requires integrative involvement of multiple organ systems:
  - Pulmonary
  - Cardiovascular
  - Hematopoietic
  - Musculoskeletal
  - Neuropsychological
Indications

In clinical practice, exercise testing in children may be performed for one or more of the following indications:

1) Evaluation of overall fitness level.
2) Evaluation of undiagnosed exercise limitation
3) Evaluation of exercise tolerance in a child with underlying respiratory or cardiovascular disease e.g. asthma, congenital heart disease.
4) Detection of exercise induced bronchoconstriction.
5) Detection of exercise induced arrhythmia.
6) Assessment for response to specific treatment or rehabilitation programme.
7) Evaluation before specific treatment for baseline status or suitability for treatment e.g. chemotherapy, lung transplantation.
8) Assessment post specific treatment for potential complications e.g. drug induced lung injury from chemotherapy.
Need for Oxygen....

• 11 year old male with Treacher Collins syndrome (tracheostomy dependent) and asthma

• Mother complained distress, change in color and frequent need to take rest in between with exercise

• Overnight pulse oximetry showed brief self resolving desaturations

• Insurance denied oxygen
Exercise Tests

• Submaximal exercise tests
  – 3 Minute Step Test (3 MST)
  – Modified Shuttle Test (MST)
  – Six Minute Walk Test (6 MWT)

• Maximal exercise tests
  – Cardiopulmonary Exercise testing (CPET)
  – 20 Meter Shuttle Test (20-MST)
6MWT

http://www.insightsonpah.com/Living_With_PAH/Quality_of_Life/
“The object of this test is to walk as far as possible for 6 minutes. You will walk back and forth in this hallway. Six minutes is a long time to walk, so you will be exerting yourself. You will probably get out of breath or become exhausted. You are permitted to slow down, to stop, and to rest as necessary. You may lean against the wall while resting, but resume walking as soon as you are able. You will be walking back and forth around the cones. You should pivot briskly around the cones and continue back the other way without hesitation”.
# Indications

## Pretreatment and posttreatment comparisons
- Lung transplantation (9, 10)
- Lung resection (11)
- Lung volume reduction surgery (12, 13)
- Pulmonary rehabilitation (14, 15)
- COPD (16–18)
- Pulmonary hypertension
- Heart failure (19, 20)

## Functional status (single measurement)
- COPD (21, 22)
- Cystic fibrosis (23, 24)
- Heart failure (25–27)
- Peripheral vascular disease (28, 29)
- Fibromyalgia (30)
- Older patients (31)

## Predictor of morbidity and mortality
- Heart failure (32, 33)
- COPD (34, 35)
- Primary pulmonary hypertension (10, 36)
6MWT Results

<table>
<thead>
<tr>
<th></th>
<th>HR</th>
<th>RR</th>
<th>BP(mmHg)</th>
<th>SpO₂</th>
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<tr>
<td>Pre-test</td>
<td>106/min</td>
<td>24/min</td>
<td>111/79</td>
<td>98%</td>
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<tr>
<td>Post-test</td>
<td>132/min</td>
<td>48/min</td>
<td>137/87</td>
<td>87%</td>
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</table>

- Distance Walked – 426 m
- Took almost a minute to return to SpO₂ of 96%
6MWT in Cystic Fibrosis (CF)

- Useful test in children with mild to moderate symptoms of CF to assess their exercise tolerance and endurance\(^1\)
- Both 6MWD ≤ 475 m and desaturation during the 6MWT were independent predictors of death or transplant \(^2\)
- Provides prognostic information in CF adults, especially in subjects with FEV\(_1\) ≤ 60% predicted \(^2\)

6MWT in CF Exacerbation

- 6MWT, CFQ-R and spirometry at admission, end of week 1 and end of week 2
- 6MWT, spirometry and CFQ-R domains improved significantly at week 2
- The physical domain change correlated with the 6MWT improvement, whereas the respiratory domain change correlated with the spirometry improvement at week 2

R Bhatia et al. Six-minute walk test and health-related quality of life: objective tools to assess improvement in Cystic Fibrosis patients hospitalized for pulmonary exacerbation. Pediatric Allergy, Immunology, and Pulmonology, 2012; 25 (2):86-91
QI initiative

• A subset of patients with severe CF disease may display minimal change in spirometry with the treatment of acute pulmonary exacerbation despite subjective improvement.

• Aim: To utilize 6MWT as an objective marker of clinical improvement in severe CF patients (> 6 yrs. of age) admitted for pulmonary exacerbation.
Methods

- Guidelines were reviewed with physical therapists
- Flow sheets for 6MWT and spirometry were built in hospital’s electronic charting system
- 6MWT was done at admission and then weekly thereafter until discharge during patient’s routine physical therapy (PT) sessions
- Spirometry was done as per protocol
<table>
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<tr>
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<tr>
<td>Heart Rate</td>
<td>105</td>
<td>101</td>
<td></td>
<td></td>
<td>115</td>
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<td>Resp Rate</td>
<td>27</td>
<td></td>
<td>30</td>
<td>27</td>
<td></td>
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<tr>
<td>Blood Pressure</td>
<td>116/76</td>
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<td>130/78</td>
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<td>111/67</td>
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<tr>
<td>SP02 (%)</td>
<td>96</td>
<td></td>
<td>93</td>
<td>90</td>
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<tr>
<td>Pre Breathing</td>
<td>1</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td>Reason</td>
<td>InPatient Stay</td>
<td></td>
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<td>Distance (ft)</td>
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<td>930</td>
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<td>Distance (m)</td>
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<td>283.5</td>
<td>438.3</td>
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<td>Average MPH</td>
<td>7.72</td>
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<td>10.57</td>
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<td>Blood Pressure</td>
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<td>125/88</td>
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<tr>
<td>SP02 (%)</td>
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<td></td>
<td>93</td>
<td>91</td>
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<td>Post breathing</td>
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<td>Recovery Information</td>
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<td>Increased cough with activity</td>
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<tr>
<td>FVC</td>
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<td>47</td>
<td>47</td>
<td>55</td>
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<td></td>
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<tr>
<td>FEF 25-75%</td>
<td>0.35</td>
<td>0.38</td>
<td>0.4</td>
<td>0.41</td>
<td>0.37</td>
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<td>FVC % PRED</td>
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<td>51</td>
<td>52</td>
<td>39</td>
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<td>FEV1 % PRED</td>
<td>27</td>
<td>28</td>
<td>28</td>
<td>25</td>
<td>28</td>
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<tr>
<td>FEV1/FVC % PRED</td>
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<td>47</td>
<td>47</td>
<td>55</td>
<td>49</td>
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<tr>
<td>FEF 25-75% PRED</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>9</td>
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</table>
Results

• Helped providers in making clinical decisions
• Implementation of 6MWT project did not cause any financial or clinical burden
• No adverse event
Longitudinal Evaluation

- 6MWT & CFQ-R (Quality of Life survey) with $\text{FEV}_1$ – Multiple Outcome measures in CF
- Aim - To investigate how do 6MWT, CFQ-R domains and spirometry change in a year time including during exacerbations and baseline health in moderate to severe CF
- Melissa Kaye, MD and Adria Robert, DO
- Presented at National CF meeting, 2016
A Regular Day in Clinic….

• A 16 year old F, competitive soccer player presents with chief complaint of Exercise Induced Dyspnea (EID)
• Symptoms start 10 min after the start of game
• Mid sternal chest tightness
• Not clear whether symptoms are during inhalation or exhalation
• Symptoms usually resolve with in 5 minutes when she stops exercising
The Puzzle Continues….

- Has acne and mild eczema
- No history of allergic rhinitis, hypertension or CHD
- No other significant past medical history
- Highly competitive athletically and scholastically
- No family history of asthma, atopy, sudden death before 50 or unusual heart problems
The Puzzle Continues….

- Once daily montelukast and prophylactic inhaled albuterol before exercise
- Recently started on Fluticasone and Salmeterol combination inhaler
- Referred to pulmonary for further management
The Puzzle Continues....

- Physical exam - normal

- Baseline Spirometry - normal

- Parents anxiously looking at you for answers
Exercise Challenge

• Running at 80-90% of the predicted HR_{max} for 6-8 minutes
• Standard spirometry immediately before and 5, 10 and 15 minutes post exercise
• + test for EIB-
  • >10-15% decline in FEV_{1}

Picture - Weiss and Rundell Allergy, Asthma & Clinical Immunology 2009 5:7
Exercise Challenge Testing

- *Exercise Challenge testing in children with exercise induced dyspnea – Is it good enough?*
- **Aim-** To review exercise challenge tests done at Akron Children’s Hospital in last 5 years and investigate any differences in the characteristics of patients with positive and negative tests
- *Emma Schwendeman – Summer Program Research Scholar Student*
# Demographics

<table>
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<tr>
<th>Full Sample</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
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<td>3.1</td>
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<td>Wt (kg)</td>
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<td>55.9</td>
<td>17.2</td>
<td>19.2</td>
<td>106.6</td>
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<td>Ht (cm)</td>
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<td>159.2</td>
<td>14.6</td>
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<td>192.0</td>
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<td>BMI</td>
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<td>21.6</td>
<td>4.6</td>
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<td>Duration</td>
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<td>9.3</td>
<td>14.7</td>
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<td>11.6</td>
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<td>130.0</td>
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<td>FVC % Pred</td>
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<td>102.6</td>
<td>11.4</td>
<td>68.0</td>
<td>144.0</td>
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<td>85.7</td>
<td>5.8</td>
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<td>97.8</td>
<td>21.6</td>
<td>46.0</td>
<td>166.0</td>
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Results

EIB >10% (-/+)

81%
Comparing the Groups

Table 3. T-Test

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<tr>
<th>EIB 10% Change</th>
<th>Method</th>
<th>Variance</th>
<th>DF</th>
<th>t-value</th>
<th>p-value</th>
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<td>0.095</td>
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<td>0.730</td>
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<td>p-value</td>
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<tr>
<td>EIB 10% Change x</td>
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<td></td>
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<tr>
<td>Gender</td>
<td>Chi²</td>
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<td>3.9985</td>
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<td>Asthma</td>
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<td>6.3809</td>
<td><strong>0.012</strong></td>
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<td>EIA / EIB</td>
<td>Chi²</td>
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<td>0.034</td>
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<td>typical Sx of EIB</td>
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<td>0.7218</td>
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<td>Chi²</td>
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<td>0.2935</td>
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<td>Albuterol</td>
<td>Fisher's</td>
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<td>0.053</td>
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<td>0.3783</td>
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*Fisher's p-value: Fisher's is considered to be conservative*
Conclusions

• Hx of asthma was the only significant difference between positive and negative results

• Dx of EIA, type of symptoms, albuterol use, or baseline spirometry did not predict positive test results

• Consider Cardiopulmonary Exercise Testing instead of challenge testing in patients without diagnosis of asthma
Principles of Exercise Testing and Interpretation
Including Pathophysiology and Clinical Applications
Fifth Edition

To Dr. Bhutia
Good wishes
Karl Wasserman
Cardiopulmonary Exercise Testing (CPET)

- It is a diagnostic procedure that analyzes the responses and cooperation of the heart, circulation, respiration, and metabolism during continuously increasing muscular stress
- Non invasive
- Maximal exercise test
Established in 2011-2012

Collaboration with Cardiology, Neurology and Sports Medicine

Tread mill as well as bike

2 separate monitors for metabolic parameters as well as for EKG
| STAGE | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 1 | 2 | 3 |
|-------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME (Mins) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SPEED (Km/hr) | 1.5 | 1.5 | 1.9 | 3 | 4 | 5 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2.6 | 1.9 | 1.9 |
| GRADE (%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 | 0 | 0 |
| HEART RATE | | | | | | | | | | | | | | | | | | |
| SpO2 (%) | | | | | | | | | | | | | | | | | | |

BREATH SOUNDS AT REST: ___________________________ BREATH SOUNDS DURING RECOVERY: ___________________________

REASON FOR TERMINATING EXERCISE: ___________________________

ADDITIONAL COMMENTS: ___________________________
Measurements

• Metabolic Rate.
  • Oxygen Consumption (V_{O_2}).
  • CO_{2} production (V_{CO_2}).
  • Respiratory Exchange Ratio.

• Cardiac Function.
  • Heart rate.
  • ECG.

• Respiratory Function.
  • Minute ventilation (V_E).
  • V_{E}/V_{O_2} and V_{E}/V_{CO_2}.
  • S_{aO_2} and P_{ETCO_2}.
IMG_0228.MOV
Aerobic Exercise

- Incremental exercise stress test.
- Workload increases steadily.
- Physiologic parameters measured.
- Measure fitness.
- Can separate cardiac and respiratory limitations to exercise.

Anaerobic Threshold

- Incremental exercise stress test.
- $V_E$ increases linearly with $Vo_2$ and $Vco_2$ until lactate is released into the circulation.
- Isocapnic buffering occurs.
- $Vco_2$ and $V_E$ increase more than $Vo_2$ or metabolic rate.

Aerobic Exercise

• Cardiac output increases linearly with workload.

• Cardiac output is determined by heart rate.

• Normally, maximum HR is achieved at maximum Workload.

• Normal limitation of exercise is the inability to deliver $\uparrow O_2$ to exercising muscle.
Breathing Reserve

- Breathing/ventilatory reserve = (MVV – $V_E$)/MVV
- Normal Breathing Reserve is 20%-40%.
- Thus, there is reserve at maximal exercise.
- Breathing Reserve is decreased in lung disease.

Maximum Voluntary Ventilation

• Calculated Maximum Voluntary Ventilation (MVV) (L/min) - FEV₁ X 40
• Measured MVV - 12 sec of rapid, deep breathing
• Calculated MVV Vs. Measured MVV - A Better Predictor of Maximum Ventilatory Capacity during Cardiopulmonary Exercise Testing in Children?
• Presented at “Poster Discussion session, American Thoracic Society, International Conference, San Francisco, May 2016 - Kelly L Colwell, RRT
Calculated MVV (L/min) vs. Peak $\dot{V}_E$ (L/min):
- Correlation: 0.73, p-value << 0.01

Measured MVV (L/min) vs. Peak $\dot{V}_E$ (L/min):
- Correlation: 0.57, p-value < 0.01

Calculated MVV (L/min) vs. Peak $\dot{V}_E$/$\dot{V}O_2$:
- Correlation: -0.35, p-value = 0.04

Measured MVV (L/min) vs. Peak $\dot{V}_E$/$\dot{V}O_2$:
- Correlation: -0.19, p-value = 0.27
Aerobic Exercise Limitation

- **Normal**: achieves maximal HR at normal maximal \( Vo_2 \).

- **Heart Disease (HD)**: achieves maximal HR at \( \downarrow \) maximal \( Vo_2 \).

- **Lung Disease (OAD)**: At \( \downarrow \) maximal \( Vo_2 \), HR is also below maximal.
4 Questions?

• Did the patient exercise at or near the physiological maximum?
• Did the patient have normal aerobic capacity and aerobic fitness?
• What limited exercise- heart as always or lungs?
• Did the patient have exercise induced bronchospasm (EIB) or any other abnormal response to exercise?
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<th>Cardiac Limitation</th>
<th>Pulmonary Limitation</th>
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<tbody>
<tr>
<td>Normal Subjects</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>ECG</td>
<td>Arrhythmia</td>
<td>Normal</td>
</tr>
<tr>
<td>Maximal HR</td>
<td>Normal</td>
<td>↓</td>
</tr>
<tr>
<td>Breathing Reserve</td>
<td>20%-40%</td>
<td>↓ (&lt;20%)</td>
</tr>
<tr>
<td>$V_E/V_{O_2}$</td>
<td>&lt;40</td>
<td>↑ (&gt;40)</td>
</tr>
<tr>
<td>$S_{a_2}O_2$</td>
<td>&gt;95%</td>
<td>↓</td>
</tr>
<tr>
<td>$P_{ETCO_2}$</td>
<td>&lt;40 torr</td>
<td>↑</td>
</tr>
</tbody>
</table>
Peek $\dot{V}O_2$, $\dot{V}_E/\dot{V}O_2$
Breathing Reserve

Max HR at $\downarrow$Peak $\dot{V}O_2$

Finally the Result...

- She exercised at or near the physiological maximum.
- She had normal aerobic capacity and aerobic fitness.
- Exercise was limited by normal cardiovascular mechanism.
- She did not show evidence of EIB or vocal cord dysfunction.
- EKG during exercise was normal.
Catching Point......
If not Asthma, then what?

- 142 patients (6-21 yrs with EID)
- In 117, EID symptoms reproduced during test
- Only 11 had EIA
- 74 had normal physiologic limitation
- 15 had restrictive abnormalities
- 13 had VCD, 2 had laryngomalacia and 1 had primary hyperventilation

CPET in EIB/Asthma

- Symptoms not consistent with exercise induced bronchoconstriction
- Differentiate EIB from other causes of dyspnea e.g. de-conditioning, physiological limitation, early restrictive abnormalities, exercise induced hyperventilation etc.
- Exercise induced dyspnea in known asthmatics despite appropriate treatment
Exercise Induced Dyspnea

Dx of asthma and/or symptoms suggestive of EIB

Trial of SABA before exercise

Atypical symptoms

Consider CPET

Improvement

Follow up / consider controller therapy / consider exercise challenge

No Improvement

Consider alternative diagnosis

CPET
Diagnosis

Laryngoscopy figures

Anterior

Vocal cords

Posterior glottic chink

Posterior

Figure C
Vocal cords during normal inspiration

Figure D
Vocal cords in a symptomatic VCD patient Note- presence of a posterior glottic chink

Flow volume loops

Asymptomatic

Symptomatic

Volume [L]

Flow [L-S^-1]

Expiration

Inspiration

FEF 50%

FVC

FIF 50%

Figure A

Figure B

Figure A - Normal inspiratory and expiratory loops
Figure B - Truncated inspiratory loop suggestive of variable extra thoracic large airway obstruction and normal expiratory loop.
This is pathognomonic of paradoxical vocal cord motion.

FVC - Forced vital capacity
FEF 50% - Forced expiratory flow 50%

<table>
<thead>
<tr>
<th>VCD</th>
<th>Asthma/EIB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extrathoracic</strong></td>
<td><strong>Intrathoracic</strong></td>
</tr>
<tr>
<td>Relatively Uncommon</td>
<td>Common</td>
</tr>
<tr>
<td>Start/stop abruptly</td>
<td>Gradual symptoms</td>
</tr>
<tr>
<td>Frequent ER/office visits</td>
<td>Frequent ER/office visits</td>
</tr>
<tr>
<td>Rare Hypoxemia</td>
<td>Hypoxemia +</td>
</tr>
<tr>
<td>Blunted Inspiratory loop</td>
<td>Reduced Expiratory Flow</td>
</tr>
<tr>
<td>Rx- Breathing techniques</td>
<td>Rx- Inhalers</td>
</tr>
</tbody>
</table>
Exercise Induced Hyperventilation

- Occurs when minute ventilation exceeds metabolic demands
- Often occurs in the context of acute anxiety
- No definite criteria to diagnose
- Abnormal drop in PETCO₂ during exercise supports the diagnosis
- Treatment includes breathing techniques and/or anxiolytic pharmacotherapy
Physiological Limitation

- Increased ventilation during exercise - primary means by which body regulates arterial gases and acid base status
- Tidal volume increases 3-5 times, Respiratory rate increases by 1-3 times
- Excessive psycho-physiological sensation of perceived WOB with increased ventilation
EID and Cardiac Disease

- Fatal cardiac events during exercise rarely occur in young athletes
- HCM, arrhythmias, premature atherosclerosis, valvular heart disease, and other CHD (anomalous coronary artery)
- Syncope, palpitations, and/or irregular heart beat
- Personal or family history of heart disease
- Exam finding suggestive of heart disease
- Abnormal parameters on CPET (e.g., low flat oxygen pulse, exercise induced arrhythmias etc)
Exercise-induced dyspnea can have many causes

by Rajeev Bhatia, M.D., FAAP

As more children and adolescents are choosing to exercise regularly, dyspnea associated with exercise is an increasingly common reason to see a physician.

In otherwise healthy children, exercise-induced dyspnea (EID) is commonly attributed to exercise-induced bronchospasm (EIB). In fact, EIB is present in just 8%-23% of otherwise healthy children complaining of dyspnea with exercise.

Following is a review of other clinical entities that mimic EIB and the role of cardiopulmonary exercise testing (CPET) in assessing children with this complaint. Helping a child with EID can be particularly challenging when more than one condition is contributing.

Physiologic limitation

In a study done by Abu-Hasan, et al. on 142 children and adolescents with EID, the most common cause of dyspnea was normal physiological limitation (52%) (Ann Allergy Asthma Immunol. 2005;94:366-371).

Measurements

- Metabolic Rate.
- Oxygen Consumption ($\dot{V}O_2$)
- CO$_2$ production ($\dot{V}CO_2$)
- Respiratory Exchange Ratio
- Cardiac Function.
- Heart rate
- ECG
- Respiratory Function.
- Minute ventilation ($V_E$)
- $V_{E}/V_{O_2}$ and $V_{E}/V_{CO_2}$
- $S_{O_2}$ and $P_{CO_2}$

During cardiopulmonary exercise testing to assess children with exercise-induced bronchospasm, multiple types of measurements are continuously recorded.

Exercise Induced Dyspnea can have many causes. AAP News. Volume 36. Number 1, Jan, 2015. http://aapnews.aappublications.org/content/36/1/11.1.full.pdf+html
Teenager with Chest Deformity…

- 13 year old male athlete with moderate pectus excavatum and exercise intolerance
- Saw surgeon for pectus evaluation
- Referred to pulmonary for further evaluation to help making decision regarding correction surgery
- Baseline Pulmonary Function Tests were normal with no evidence of restrictive lung disease
Pulmonary Abnormalities

- Chest wall or other musculoskeletal abnormalities can cause restrictive physiology leading to abnormal ventilatory response and/or cardiac response during exercise.

- 11% of patients in the series published by Abu-Hasan, et al. had chest wall restriction (due to mild pectus deformity or scoliosis) as a cause of EID.

- Tracheobronchomalacia or interstitial lung disease also could be rare causes of EID.
Results

- Normal aerobic fitness and capacity.
- Exercise was not limited by pulmonary mechanisms.
- No arterial oxygen desaturations during exercise.
- No evidence of exercise induced bronchospasm following exercise.
- *Cardiovascular mechanisms contributed abnormally in exercise limitation.*
- *Low flat oxygen pulse with left shifted steep HR-VO$_2$ slope*
CPET in Cystic Fibrosis

• Routinely performed in many pediatric CF centers
• Assessment of overall fitness and exercise tolerance
• Good prognostic tool
• Basis for prescribing an aerobic exercise conditioning program
• Recent statement from European Cystic Fibrosis group

CPET in Cystic Fibrosis

- 109 CF patients 7-35 years of age
- Underwent PFT and exercise testing and followed for 8 years
- Survival rate were greatest in patients with the highest level of aerobic fitness

Survival among 109 patients with cystic fibrosis, according to fitness level (circle, high fit; [black up pointing small triangle], medium fit; [black small square], low fit). Nixon, P.A. et al., N. Engl. J. Med. 1992;327:1785-1788.
• Exercise intolerance is well known feature
• In adults, exercise testing is used as a test to evaluate mitochondrial myopathy
• Also useful in monitoring the therapy
• However, data in children is lacking
Research Project

- **To evaluate oxygen consumption at peak exercise (peak VO$_2$), and circulatory and ventilatory response to maximal exercise on cycle ergometer in children (and adults) with certain or probable cases of mitochondrial myopathy**
Conclusion

- Significantly lower aerobic fitness, ventilatory and cardiovascular responses during exercise as compared to controls especially lower $\dot{V}O_2/Work$ slope which is usually independent of age, sex and height
CHD and Exercise Intolerance

• 23-year-old with pulmonary atresia, intact ventricular septum and hypoplastic right ventricle, S/P lateral tunnel Fontan procedure
• Complained of worsening exercise intolerance
• Morbid obese
• Baseline Echo- non concerning
CPET in CHD

- Evaluate fitness level
- Mechanism of cardiac causes of exercise intolerance
- Evaluate for other coexisting causes of exercise intolerance
- Determine the need for surgical intervention
- Exercise prescription
CPET in CHD

- Low flat oxygen pulse, abnormal HR-VO$_2$ slope
- Abnormal Pulmonary parameters
  - Abnormal $V_D/V_T$ response, Elevated $V_E/V_{CO_2}$ @AT, Elevated peak $V_E/VO_2$
  - Baseline obstruction (smoker); low breathing reserve
  - Restrictive pattern (Unable to double TV, increased RR)
- Obesity
- Deconditioning
- Asthma
Low AT

Elevated peak $\dot{V}_E / VO_2$
Inefficient ventilation

Excessive peak respiratory rate
Normal oxygen pulse
Results

- Significantly decreased aerobic fitness based on actual body weight (49% predicted)
- However normal based on ideal body weight (80% predicted)
- Inefficient ventilation (elevated $V_E / VO_2$)
- Normal oxygen pulse (128% predicted)
- Interpreted as obesity contributing significantly towards exercise intolerance
- Exercise EKG non concerning
Conclusions

- There were significant pulmonary and metabolic abnormalities seen in our small group of patients which impacted their clinical care and decision making especially regarding any surgical interventions.
Future Directions

- Non invasive cardiac output measurement

\[
\text{Cardiac Output} = \frac{\text{oxygen consumption}}{\text{arteriovenous oxygen difference}}
\]

- Obstructive sleep apnea and exercise physiology
- Functional endpoint in drug trials
- Exercise prescription
- Exercise Intervention
Exercise Intervention in CF
RT Team

- Susan Kelly, RT
- Kit Gibson, RT
- Connie Stout, RT
Pulmonary Division at Akron Children’s Hospital

John McBride, MD
John Lane, MD
Bruce Cohen, MD
Ashish Saini, MD
References

- R Bhatia et al. Six-minute walk test and health-related quality of life: objective tools to assess improvement in Cystic Fibrosis patients hospitalized for pulmonary exacerbation. Pediatric Allergy, Immunology, and Pulmonology, 2012; 25 (2):86-91
- Clinical stress testing in the pediatric age group: a statement from the American Heart Association Circulation. 2006 Apr 18;113(15):1905-20
"Hey, we have one of those. You hang your laundry on it."