How to Assess Dynamic Hyperinflation during CPET

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Learning Objectives

• Understand Dynamic Hyperinflation (DH)
• Review Mechanisms of Dyspnea
• Identify DH on CPET
  • FVLs versus VE/MVV
Dynamic Hyperinflation

• In airway disease:
  • End-expiratory lung volume (EELV) ↑
  • Airways collapse at low lung volumes
  • ↑ with obstruction/ventilation
• “Air-trapping” with ↑ ventilation

Dynamic Hyperinflation

Ann ATS 2018; 15:1096–1104
Dynamic Hyperinflation

- Consequences
  - ↑ Inspiratory work
  - Mechanical limitation
  - Neuromechanical uncoupling
Dyspnea

### TABLE 2. POSSIBLE AFFERENT SOURCES FOR RESPIRATORY SENSATION*

<table>
<thead>
<tr>
<th>Source of Sensation</th>
<th>Adequate Stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medullary respiratory corollary discharge</td>
<td>Drives to automatic breathing (hypercapnia, hypoxia, exercise)</td>
</tr>
<tr>
<td>Primary motor cortex corollary discharge</td>
<td>Voluntary respiratory drive</td>
</tr>
<tr>
<td>Limbic motor corollary discharge</td>
<td>Emotions</td>
</tr>
<tr>
<td>Carotid and aortic bodies</td>
<td>Hypercapnia, hypoxemia, acidosis</td>
</tr>
<tr>
<td>Medullary chemoreceptors</td>
<td>Hypercapnia</td>
</tr>
<tr>
<td>Slowly adapting pulmonary stretch receptors</td>
<td>Lung inflation</td>
</tr>
<tr>
<td>Rapidly adapting pulmonary stretch receptors</td>
<td>Airway collapse, irritant substances, large fast (sudden) lung inflations/deflations</td>
</tr>
<tr>
<td>Pulmonary C-fibers (I-receptors)</td>
<td>Pulmonary vascular congestion</td>
</tr>
<tr>
<td>Airway C-fibers</td>
<td>Irritant substances</td>
</tr>
<tr>
<td>Upper airway “flow” receptors</td>
<td>Cooling of airway mucosa</td>
</tr>
<tr>
<td>Muscle spindles in respiratory pump muscles</td>
<td>Muscle length change with breathing motion</td>
</tr>
<tr>
<td>Tendon organs in respiratory pump muscles</td>
<td>Muscle active force with breathing motion</td>
</tr>
<tr>
<td>Metaboreceptors in respiratory pump muscles</td>
<td>Metabolic activity of respiratory pump</td>
</tr>
<tr>
<td>Vascular receptors (heart and lung)</td>
<td>Distention of vascular structures</td>
</tr>
<tr>
<td>Trigeminal skin receptors</td>
<td>Facial skin cooling</td>
</tr>
<tr>
<td>Chest wall joint and skin receptors</td>
<td>Tidal breathing motion</td>
</tr>
</tbody>
</table>

*Reviewed, for example, in References 24–26 and 39–41.
Dyspnea in Asthma and COPD

- Asthma/COPD
  - Chest tightness = bronchoconstriction
  - Respiratory effort = neuromechanical coupling (IRV/IC)
  - Can’t get a full breath in = (IRV/IC)

- Common complaints
  - Activity limitation (most common in uncontrolled asthma)
  - Exercise limitation
  - Dyspnea

Vermeulen et al. Respiratory Medicine 2016; 117: 122-130
Casaburi, Rennard. AJRCCM 2015; 191:874-876
• FEV$_1$ and PEF weakly correlated with activity limitation
• ↑ aerobic capacity without $\Delta$ spirometry
• Resting spirometry is not a good predictor of DH during exercise

Vermeulen et al. Respiratory Medicine 2016; 117: 122-130
Lougheed et al. CHEST 2006; 130:1072–1081
Table 2—Responses to Methacholine at Baseline, PC<sub>20</sub>, and Maximum Response<sup>*</sup>

<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline</th>
<th>PC&lt;sub&gt;20&lt;/sub&gt;</th>
<th>Maximum Response</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borg score (overall dyspnea)</td>
<td>0.4 ± 0.06</td>
<td>2.0 ± 0.14</td>
<td>4.1 ± 0.19</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Borg score (inspiratory difficulty)</td>
<td>0.4 ± 0.06</td>
<td>2.1 ± 0.14</td>
<td>4.4 ± 0.20</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;, L</td>
<td>2.91 ± 0.06 (88)</td>
<td>2.19 ± 0.05 (66)</td>
<td>1.57 ± 0.05 (48)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PEF, L/s</td>
<td>6.86 ± 0.15 (101)</td>
<td>5.15 ± 0.12 (76)</td>
<td>3.87 ± 0.11 (56)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>FEF&lt;sub&gt;50&lt;/sub&gt;, L/s</td>
<td>2.78 ± 0.1 (58)</td>
<td>1.71 ± 0.06 (36)</td>
<td>1.05 ± 0.05 (22)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>FVC, L</td>
<td>4.02 ± 0.08 (95)</td>
<td>3.39 ± 0.08 (80)</td>
<td>2.69 ± 0.07 (64)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>TLC, L</td>
<td>6.01 ± 0.11 (105)</td>
<td>5.89 ± 0.12 (103)</td>
<td>6.06 ± 0.13 (106)</td>
<td>0.38</td>
</tr>
<tr>
<td>IC, L</td>
<td>2.89 ± 0.07 (107)</td>
<td>2.32 ± 0.06 (85)</td>
<td>1.90 ± 0.06 (70)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>IC/TLC, %</td>
<td>48.3 ± 0.0 (101)</td>
<td>40.6 ± 0.01 (75)</td>
<td>31.7 ± 0.01 (62)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>FRC, L</td>
<td>3.09 ± 0.07 (103)</td>
<td>3.55 ± 0.09 (118)</td>
<td>4.15 ± 0.11 (138)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>O&lt;sub&gt;2&lt;/sub&gt; saturation, %</td>
<td>97.0 ± 0.2</td>
<td>97.0 ± 0.2</td>
<td>96.8 ± 0.4</td>
<td>0.66</td>
</tr>
<tr>
<td>Specific airways resistance, %</td>
<td>11.2 ± 0.8 (264)</td>
<td>27.0 ± 2.0 (649)</td>
<td>39.0 ± 2.7 (932)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

<sup>*</sup>Data are presented as mean ± SEM or mean ± SEM (% of predicted).

Figure 2. Descriptor clusters (n = 116) are similar but more prevalent at maximum response (Max) than at the dose nearest to PC<sub>20</sub> during methacholine-induced bronchoconstriction. *p < 0.05, **p < 0.01, ***p < 0.001 maximum response vs PC<sub>20</sub>.
Dyspnea in Asthma and COPD

Vermeulen et al. Respiratory Medicine 2016; 117: 122-130
Casaburi, Rennard. AJRCCM 2015; 191:874-876
Heart or Lungs? Uncovering the Causes of Exercise Intolerance in a Patient with Chronic Cardiopulmonary Disease
Heart or Lungs? Uncovering the Causes of Exercise Intolerance in a Patient with Chronic Cardiopulmonary Disease
• MVV
  • Voluntary maneuver
  • FEV1 x 35-40
• Linearly related to dyspnea
• Blunt measure of mechanical limitations
• Cannot determine location
CPET FVLs

Time: 00:10:08
Work: 152 Watts
Event: 3
EELV: 1.78 Liters
IC: 3.94 Liters

Flow

TLC
FRC
EELV

IRV
ERV
IC
Flow limitation = \frac{V_{FL}}{V_T}
Hyperinflation and Dyspnea

Flow limitation = \( \frac{V_{FL}}{V_T} \)

Johnson et al. Chest 1999;116;488-503
CPET FVLs
CPET FVLs - DH
### Table 1—Assessment of Ventilatory Constraint Based on the extFVL Relative to the MFVL

<table>
<thead>
<tr>
<th>Variables</th>
<th>No Constraint</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow limitation, % of VT</td>
<td>0</td>
<td>&lt; 50</td>
<td>30–50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>EILV, % of TLC</td>
<td>&lt; 85</td>
<td>85–90</td>
<td>90–95</td>
<td>&gt; 95</td>
</tr>
<tr>
<td>EELV, change from rest</td>
<td>&lt; rest</td>
<td>= rest</td>
<td>≥ rest</td>
<td>&gt; rest</td>
</tr>
<tr>
<td>Inspirator flow reserve, % capacity</td>
<td>&lt; 75</td>
<td>75–85</td>
<td>85–95</td>
<td>&gt; 95</td>
</tr>
<tr>
<td>$\dot{V}e/\dot{V}ecap$, %</td>
<td>&lt; 70</td>
<td>70–85</td>
<td>85–95</td>
<td>&gt; 95</td>
</tr>
</tbody>
</table>

Johnson et al. Chest 1999;116;488-503
CPET FVLs

- ↑ EELV not specific for DH
  - CHF, hyperventilation, obesity
  - High requirement/capacity
- IC/VE slope
  - Improved accuracy
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Questions?