How to Assess Dynamic Hyperinflation during CPET

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Conflict of Interest

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Learning Objectives

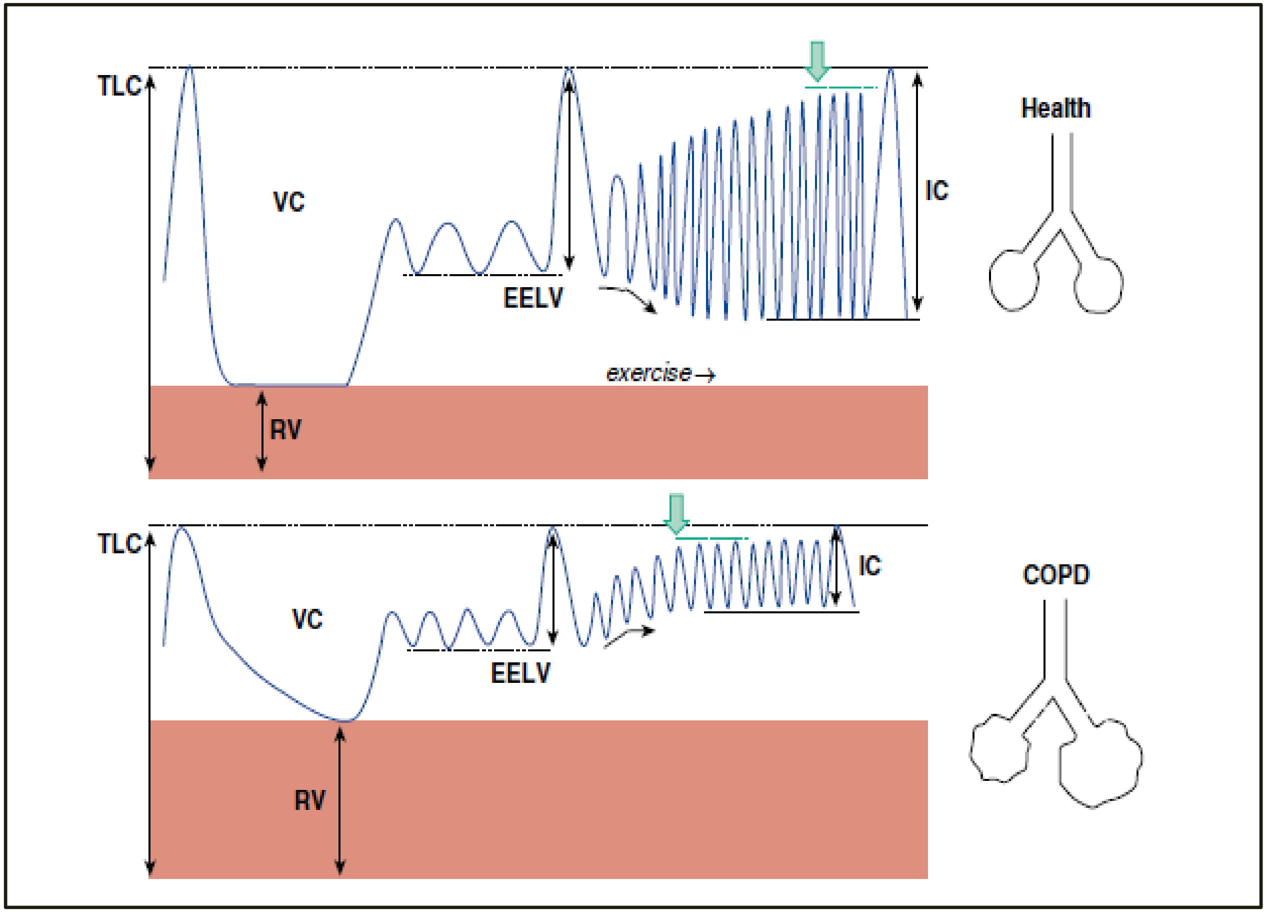
- Understand Dynamic Hyperinflation (DH)
- Review Mechanisms of Dyspnea
- Identify DH on CPET
  - FVLs versus VE/MVV

Dynamic Hyperinflation

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

Dolmage et al. Res Med 2013; 107: 953-958

Dynamic Hyperinflation

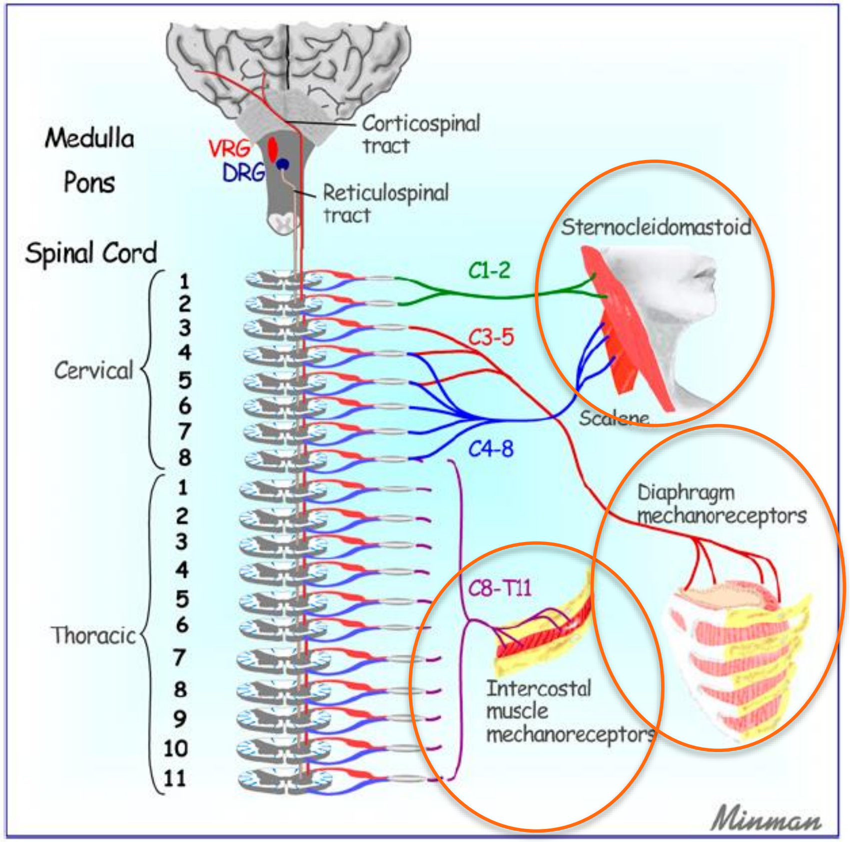


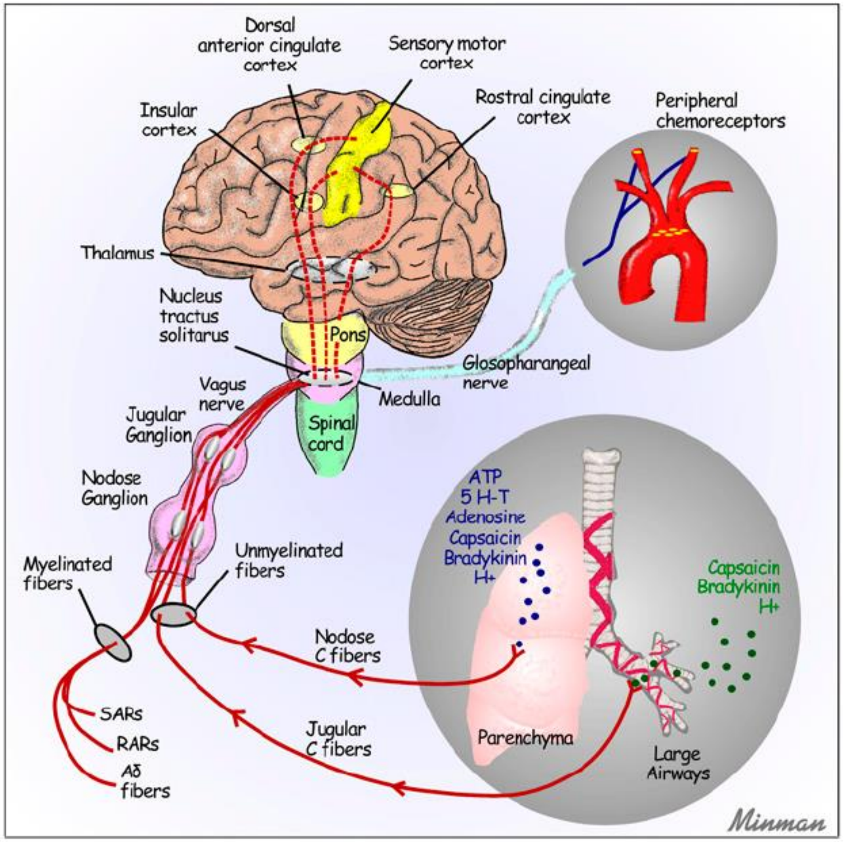
Ann ATS 2018; 15:1096–1104

Dynamic Hyperinflation

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

Dyspnea





Nauserhwan, Lee. Chest 2010;138: 1196-1201

Dyspnea

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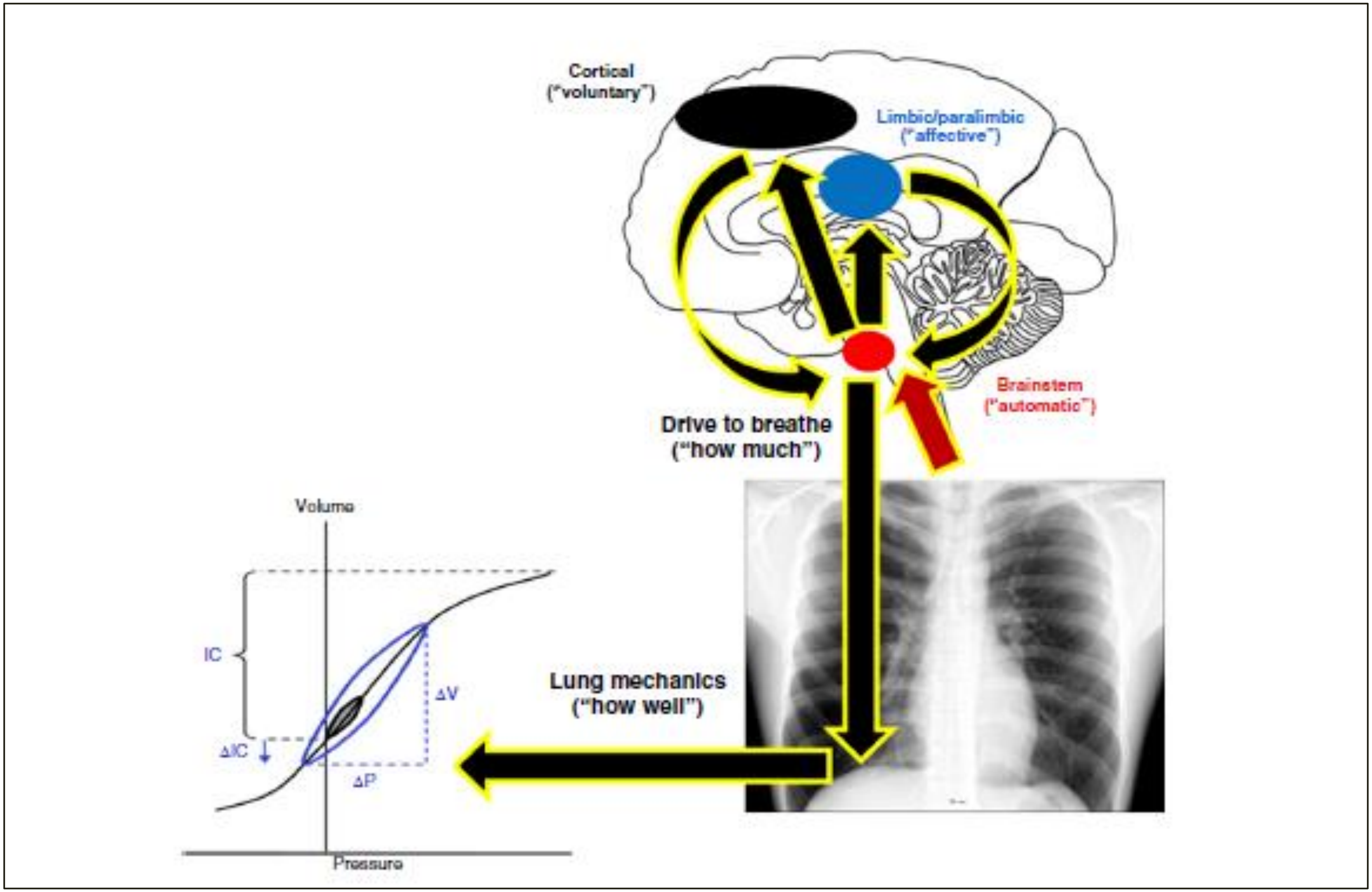
TABLE 2. POSSIBLE AFFERENT SOURCES FOR RESPIRATORY SENSATION*

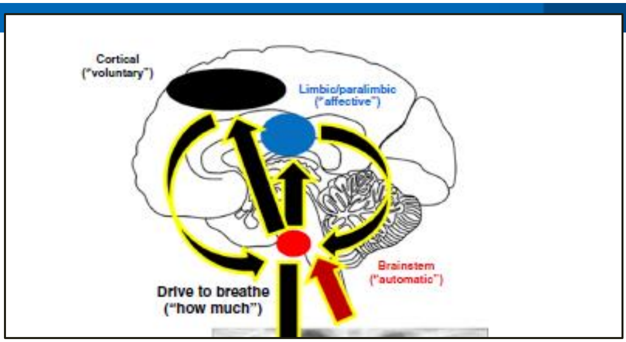
Source of Sensation	Adequate Stimulus
Medullary respiratory corollary discharge	Drives to automatic breathing (hypercapnia, hypoxia, exercise)
Primary motor cortex corollary discharge	Voluntary respiratory drive
Limbic motor corollary discharge	Emotions
Carotid and aortic bodies	Hypercapnia, hypoxemia,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

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

Parshall et al. AJRCCM 2012; 185: 435-452



Ann ATS 2018; 15: 1096–1104


Cortical
("voluntary")
Limbic/paralimbic
("affective")
Brainstem
("automatic")
Drive to breathe
("how much")

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

DH and Asthma

- FEV_1 and PEF weakly correlated with activity limitation
- ↑ aerobic capacity without Δ spirometry
- Resting spirometry is not a good predictor of DH during exercise

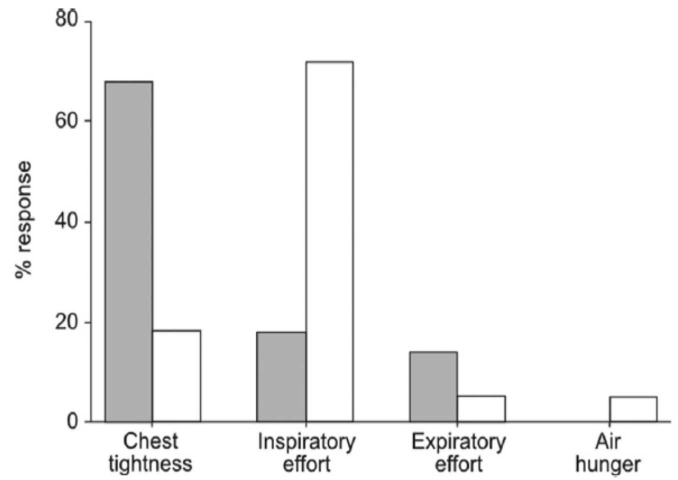


Fig. 2. Percent responses of descriptors selected after metacholine inhalation (grey columns) and short cardiopulmonary exercise test (white columns). From Ref. [73], with permission.

Vermeulen et al. Respiratory Medicine 2016; 117: 122-130
Lougheed et al. CHEST 2006; 130:1072–1081

DH and Asthma

Table 2—*Responses to Methacholine at Baseline, PC_{20}, and Maximum Response**

Variables	Baseline	PC_{20}	Maximum Response	p Value
Borg score (overall dyspnea)	0.4 ± 0.06	2.0 ± 0.14	4.1 ± 0.19	< 0.001
Borg score (inspiratory difficulty)	0.4 ± 0.06	2.1 ± 0.14	4.4 ± 0.20	< 0.001
FEV_1, L	2.91 ± 0.06 (88)	2.19 ± 0.05 (66)	1.57 ± 0.05 (48)	< 0.001
PEF, L/s	6.86 ± 0.15 (101)	5.15 ± 0.12 (76)	3.87 ± 0.11 (56)	< 0.001
FEF_{50}, L/s	2.78 ± 0.1 (58)	1.71 ± 0.06 (36)	1.05 ± 0.05 (22)	< 0.001
FVC, L	4.02 ± 0.08 (95)	3.39 ± 0.08 (80)	2.69 ± 0.07 (64)	< 0.001
TLC, L	6.01 ± 0.11 (105)	5.89 ± 0.12 (103)	6.06 ± 0.13 (106)	0.38
IC, L	2.89 ± 0.07 (107)	2.32 ± 0.06 (85)	1.90 ± 0.06 (70)	< 0.001
IC/TLC, %	48.3 ± 0.0 (101)	40.6 ± 0.01 (75)	31.7 ± 0.01 (62)	< 0.001
FRC, L	3.09 ± 0.07 (103)	3.55 ± 0.09 (118)	4.15 ± 0.11 (138)	< 0.001
O_2 saturation, %	97.0 ± 0.2	97.0 ± 0.2	96.8 ± 0.4	0.66
Specific airways resistance, %	11.2 ± 0.8 (264)	27.0 ± 2.0 (649)	39.0 ± 2.7 (932)	< 0.001

*Data are presented as mean ± SEM or mean ± SEM (% of predicted).

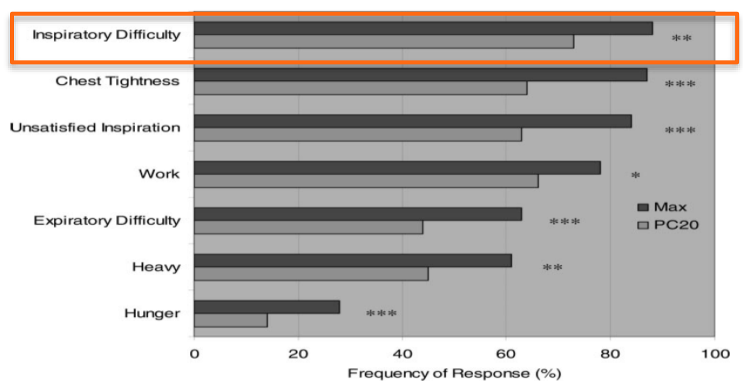
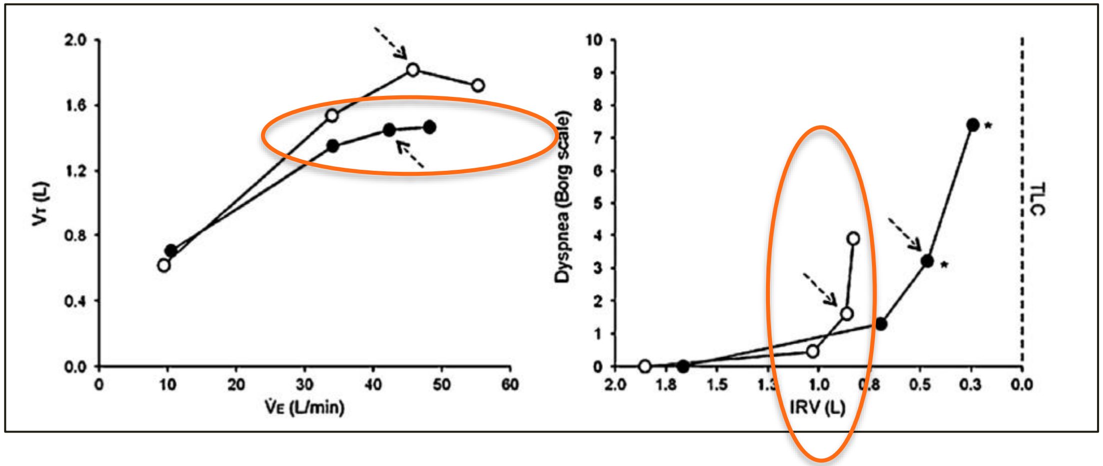
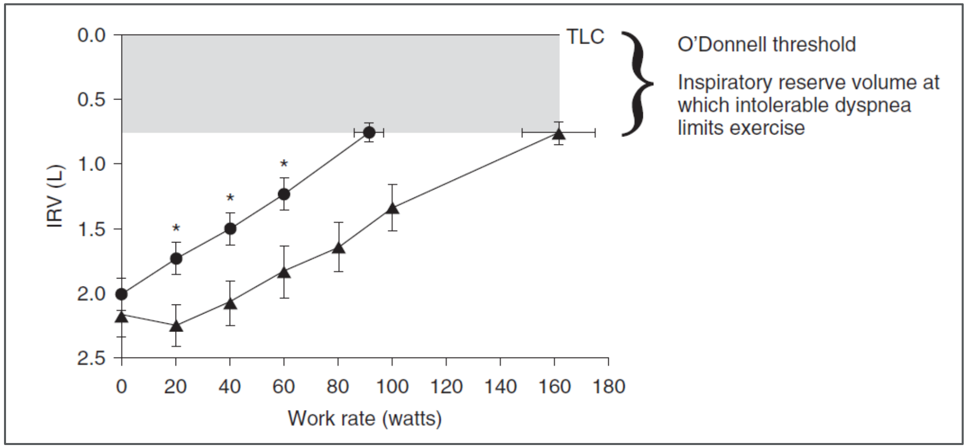


FIGURE 2. Descriptor clusters (n = 116) are similar but more prevalent at maximum response (Max) than at the dose nearest to PC_{20} during methacholine-induced bronchoconstriction. *p < 0.05, **p < 0.01, ***p < 0.001 maximum response vs PC_{20}.

Lougheed et al. CHEST 2006; 130:1072–1081

Dyspnea in Asthma and COPD





Vermeulen et al. Respiratory Medicine 2016; 117: 122-130
Casaburi, Rennard. AJRCCM 2015; 191:874-876
Potter et al. J Clin Invest 1971; 50: 910-919

Heart or Lungs? Uncovering the Causes of Exercise Intolerance in a Patient with Chronic Cardiopulmonary Disease

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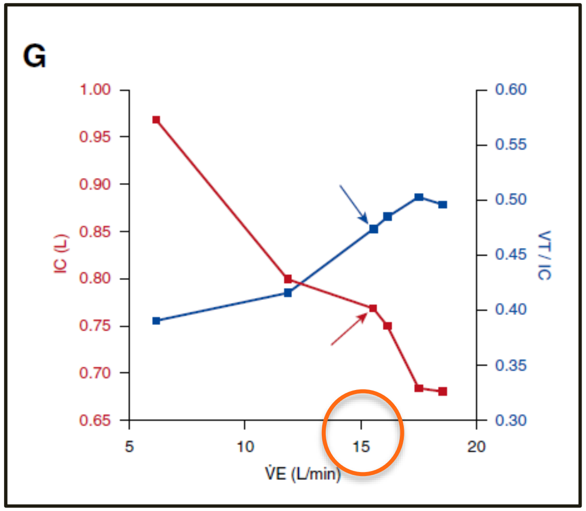

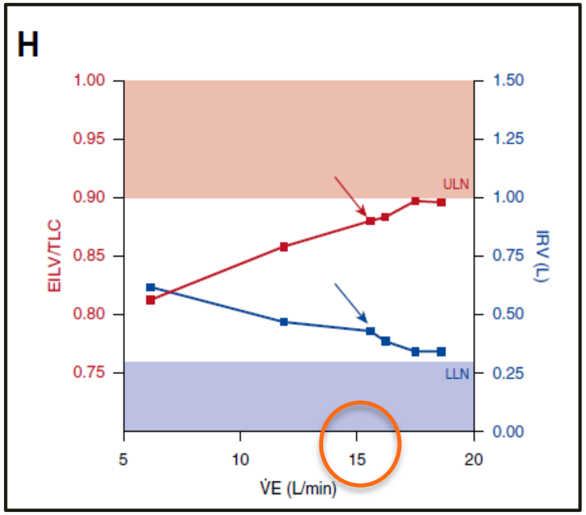

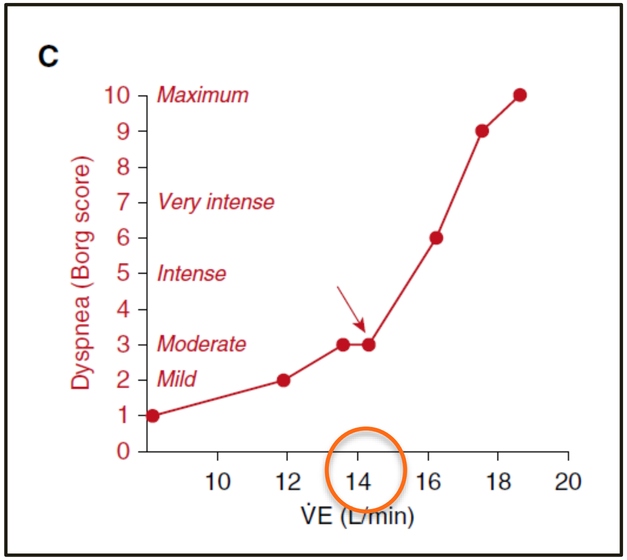

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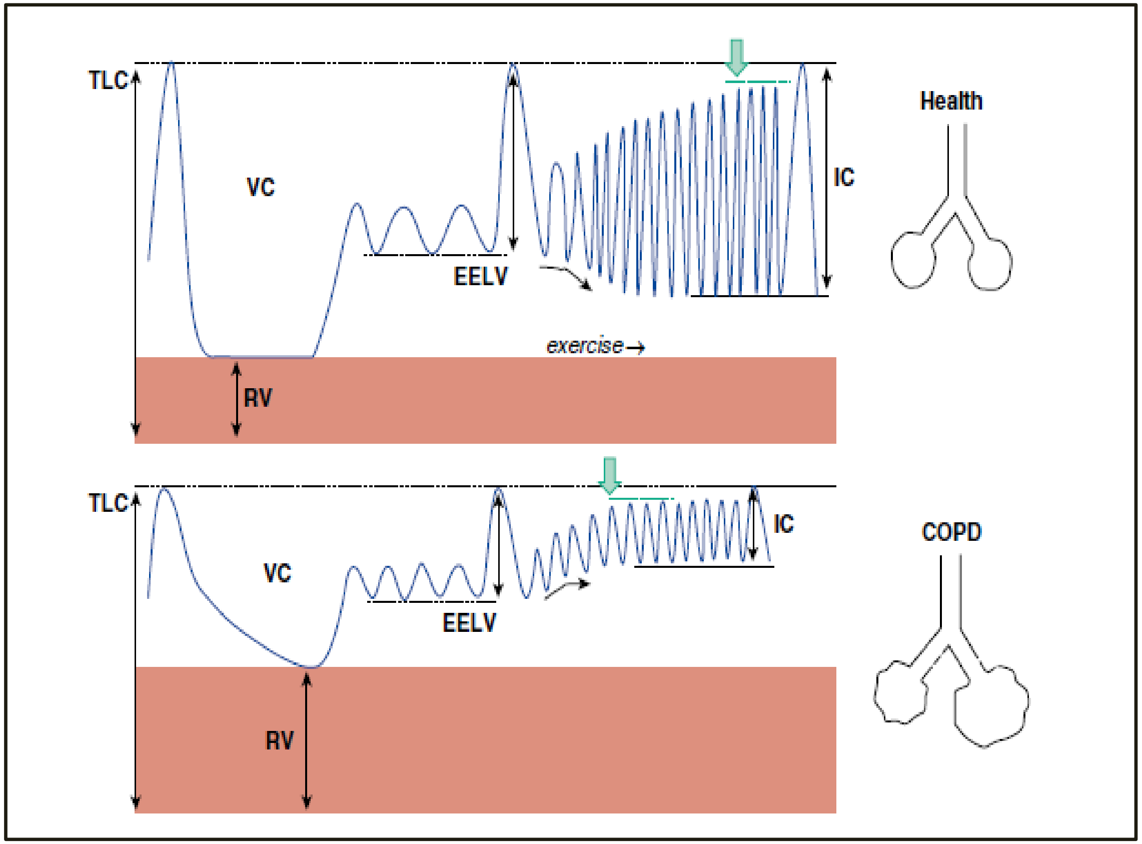
Heart or Lungs? Uncovering the Causes of Exercise Intolerance in a Patient with Chronic Cardiopulmonary Disease

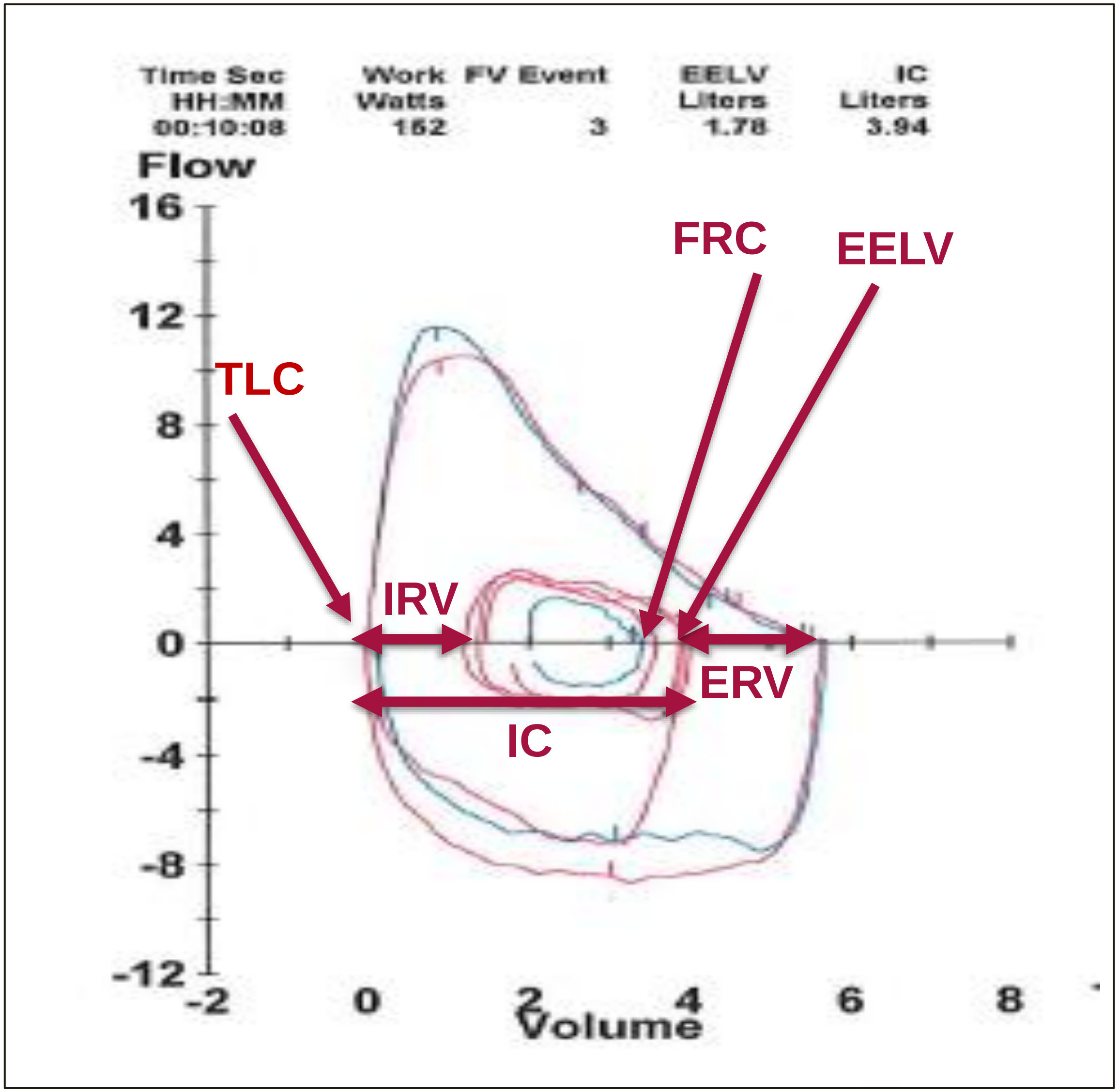


Ann ATS 2018; 15:1096–1104

VE / MVV

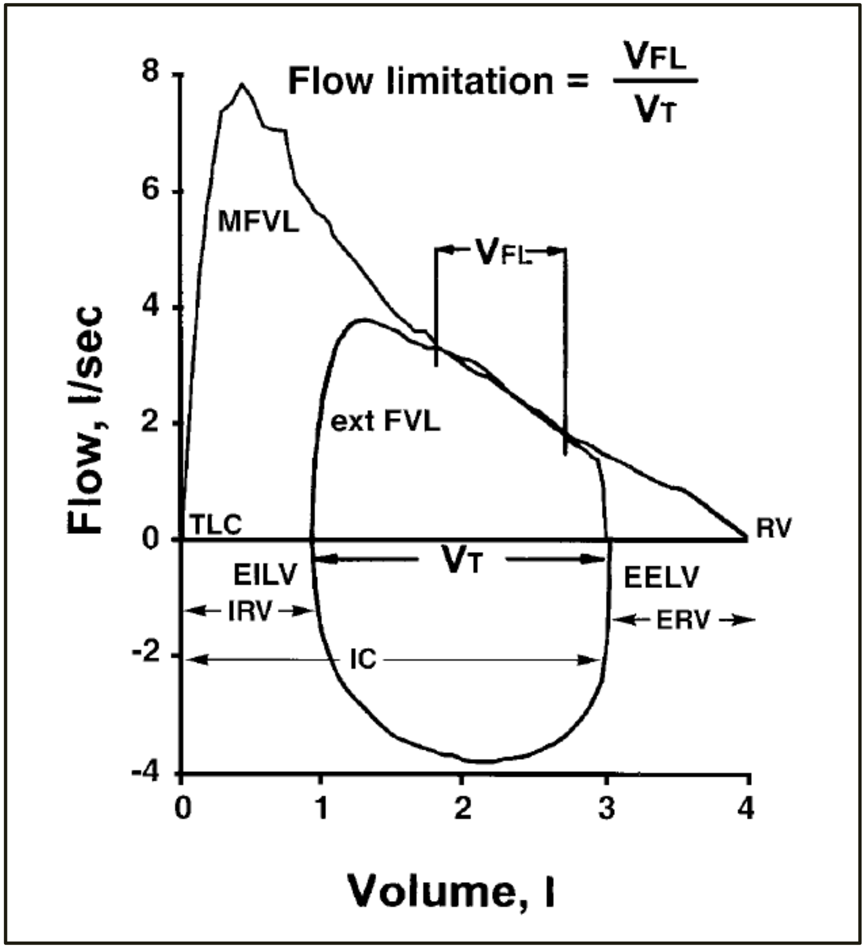
- MVV
  - Voluntary maneuver
  - FEV1 x 35-40
- Linearly related to dyspnea
- Blunt measure of mechanical limitations
- Cannot determine location

CPET FVLs



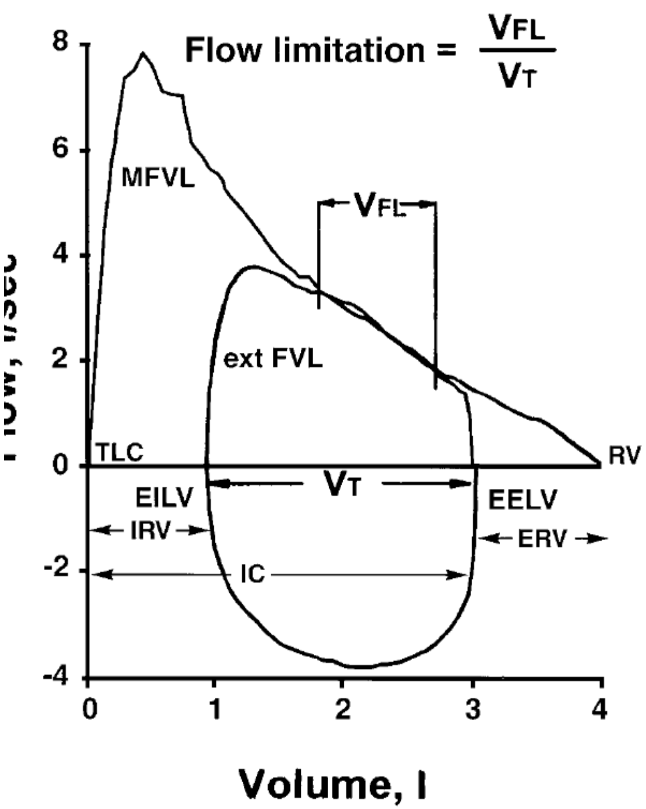
Time Sec
HH:MM
00:10:08
Work
Watts
152
FV Event
3
EELV
Liters
1.78
IC
Liters
3.94
Flow
16
12
8
4
0
-4
-8
-12
-2
0
2
4
6
8
Volume
TLC
IRV
IC
FRC
EELV
ERV

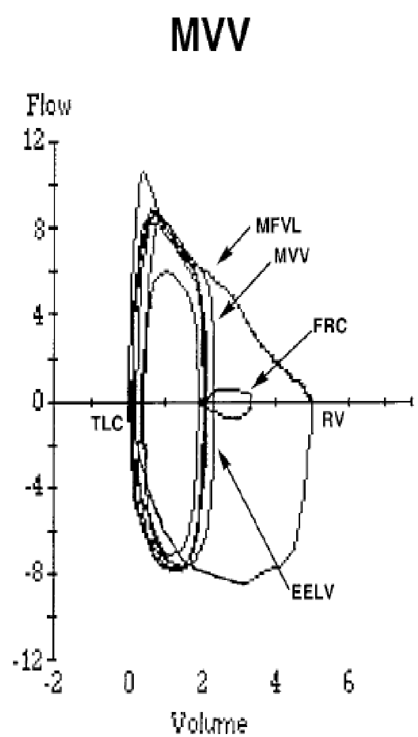
MVV versus FVLs

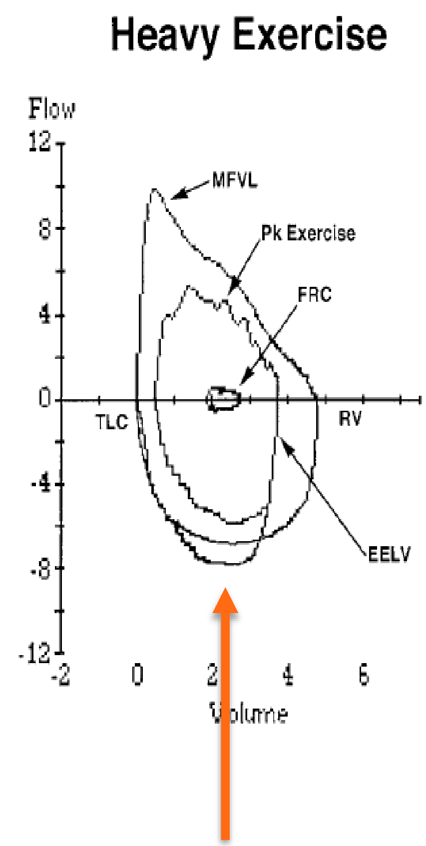


Johnson et al. Chest 1999;116;488-503

Hyperinflation and Dyspnea







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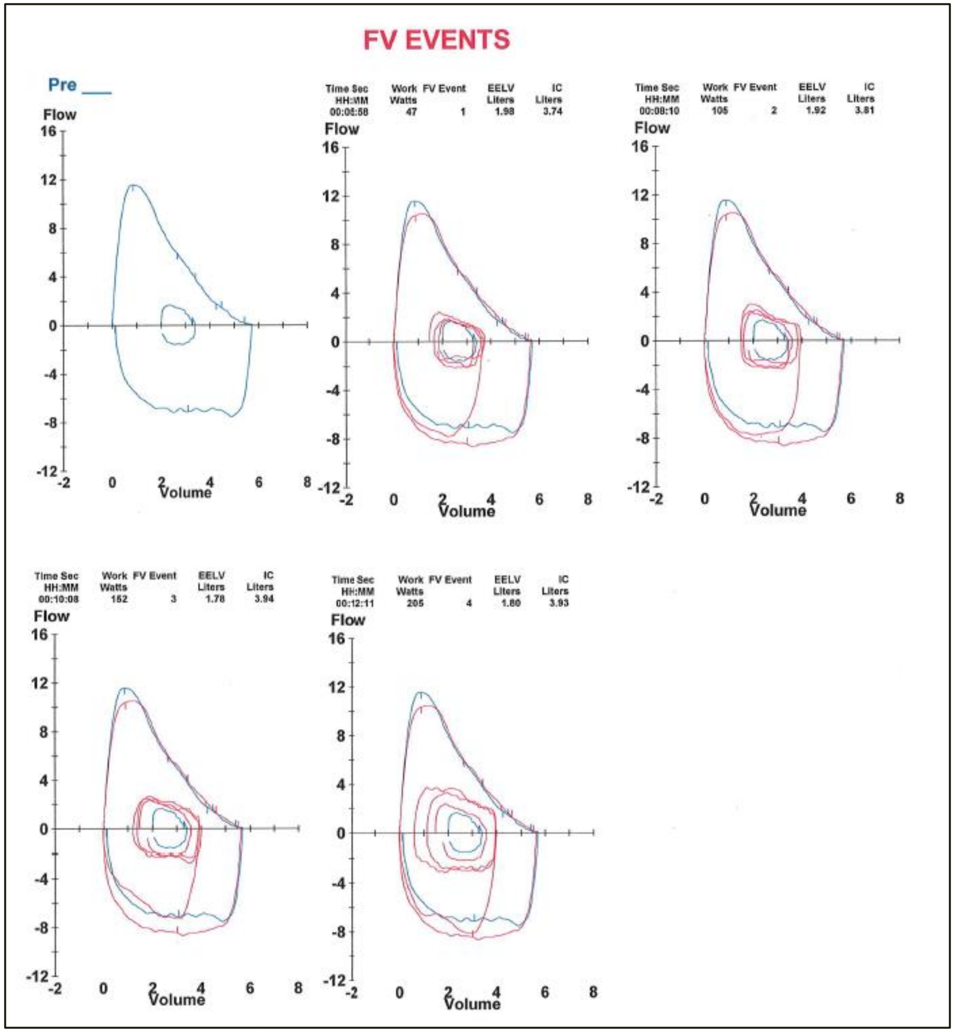
CPET FVLs


FV EVENTS
Pre
Flow
Volume
Time Sec HH:MM 00:05:58
Work Watts 47
FV Event 1
EELV Liters 1.98
IC Liters 3.74
Time Sec HH:MM 00:08:10
Work Watts 105
FV Event 2
EELV Liters 1.92
IC Liters 3.81
Time Sec HH:MM 00:10:08
Work Watts 152
FV Event 3
EELV Liters 1.78
IC Liters 3.94
Time Sec HH:MM 00:12:11
Work Watts 205
FV Event 4
EELV Liters 1.80
IC Liters 3.93

MedGraphics

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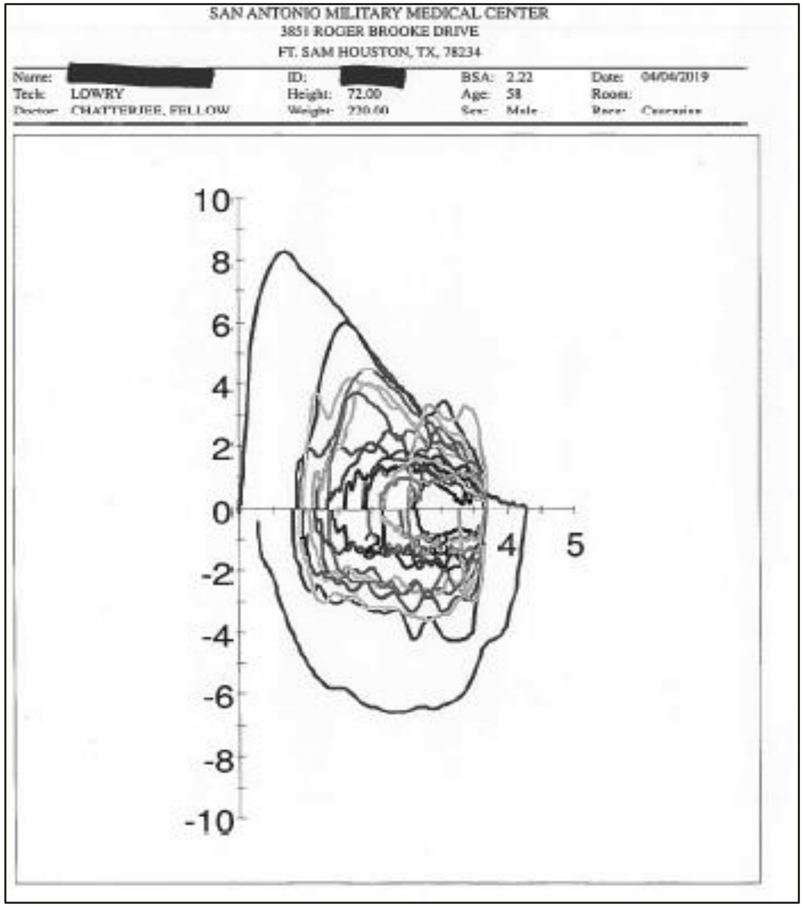
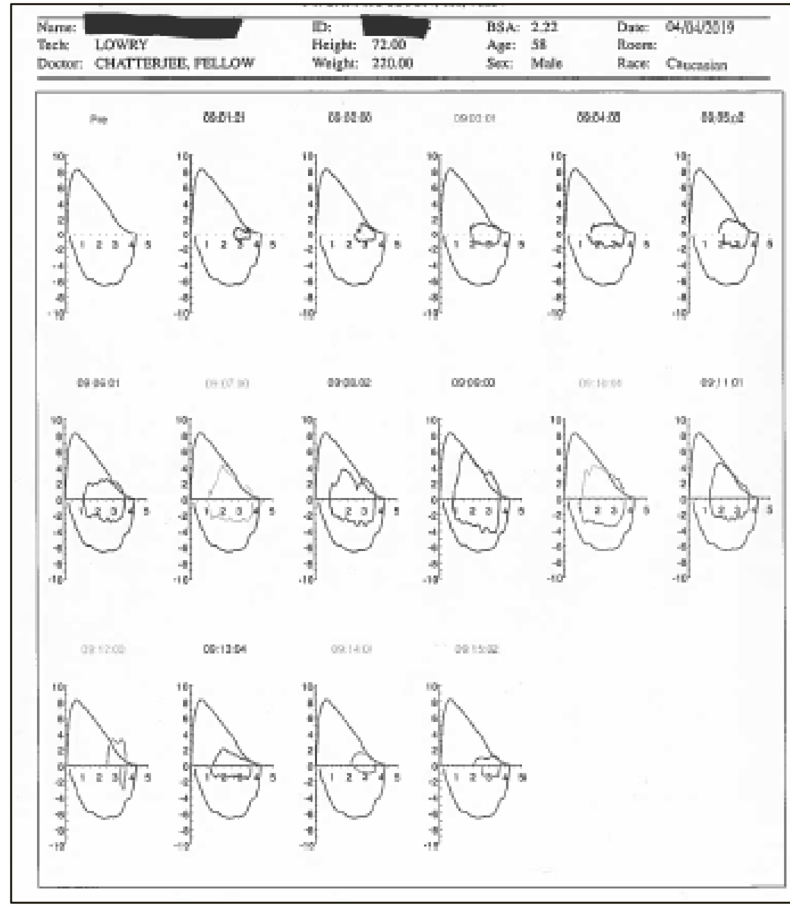
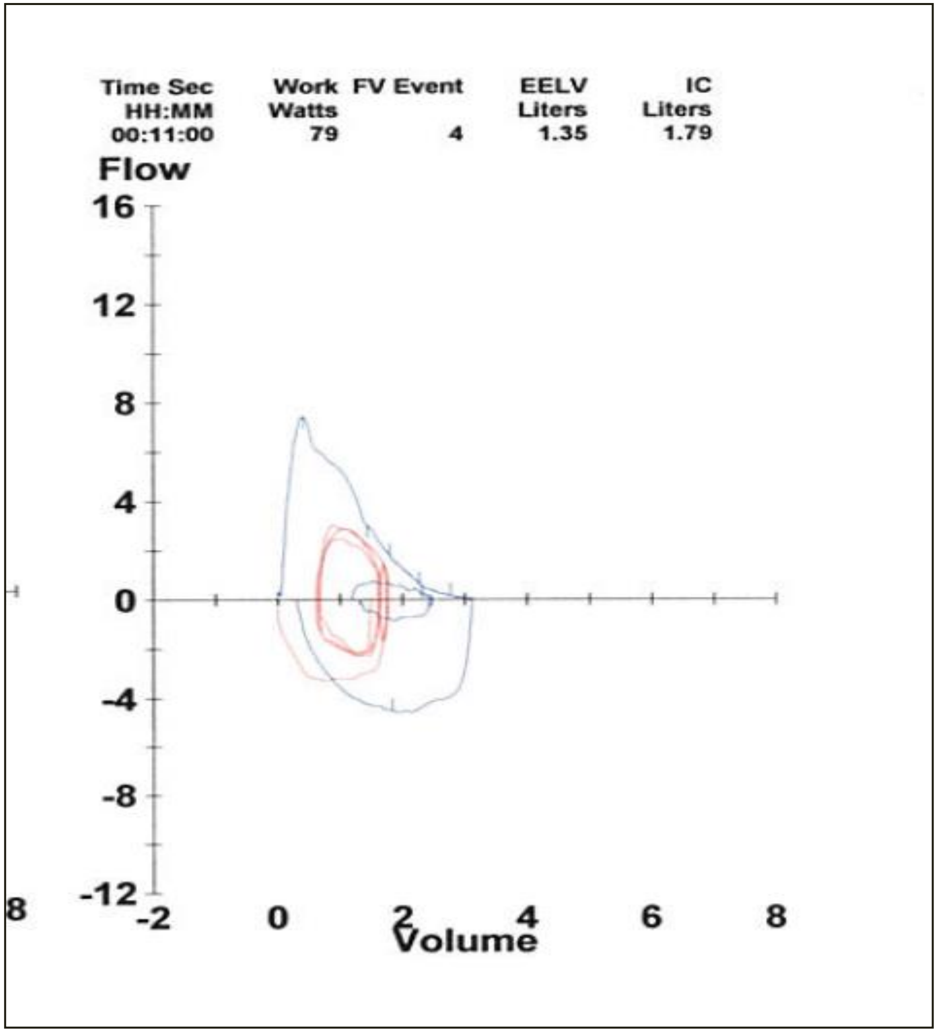




CPET FVLs - DH



Time Sec
HH:MM
00:11:00
Work
Watts
79
FV Event
4
EELV
Liters
1.35
IC
Liters
1.79
Flow
16
12
8
4
0
-4
-8
-12
8
-2
0
2
4
6
8
Volume

CPET FVLs

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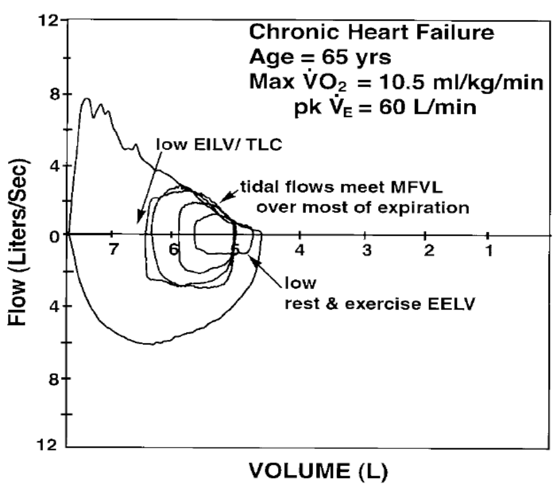
Table 1—*Assessment of Ventilatory Constraint Based on the extFVL Relative to the MFVL*

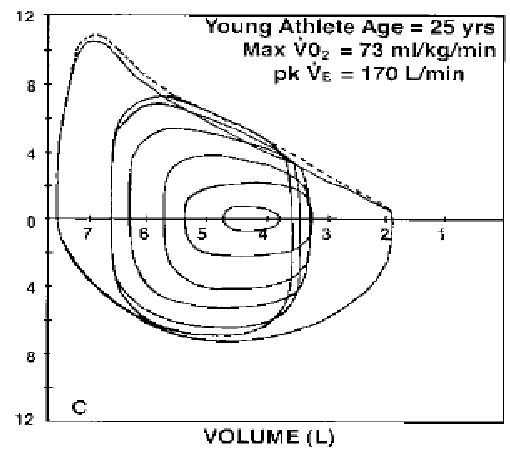
Variables	No Constraint	Mild	Moderate	Severe
Flow limitation, % of V_T	0	< 50	30–50	> 50
EILV, % of TLC	< 85	85–90	90–95	> 95
EELV, change from rest	< rest	= rest	≥ rest	> rest
Inspirator flow reserve, % capacity	< 75	75–85	85–95	> 95
$\dot{V}_E/\dot{V}_ECAP$, %	< 70	70–85	85–95	> 95

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?