# Asma, BPCO ed Esercizio Fisico
# Ferrara, 6-7 novembre 2015

# Limiti ventilatori nella BPCO


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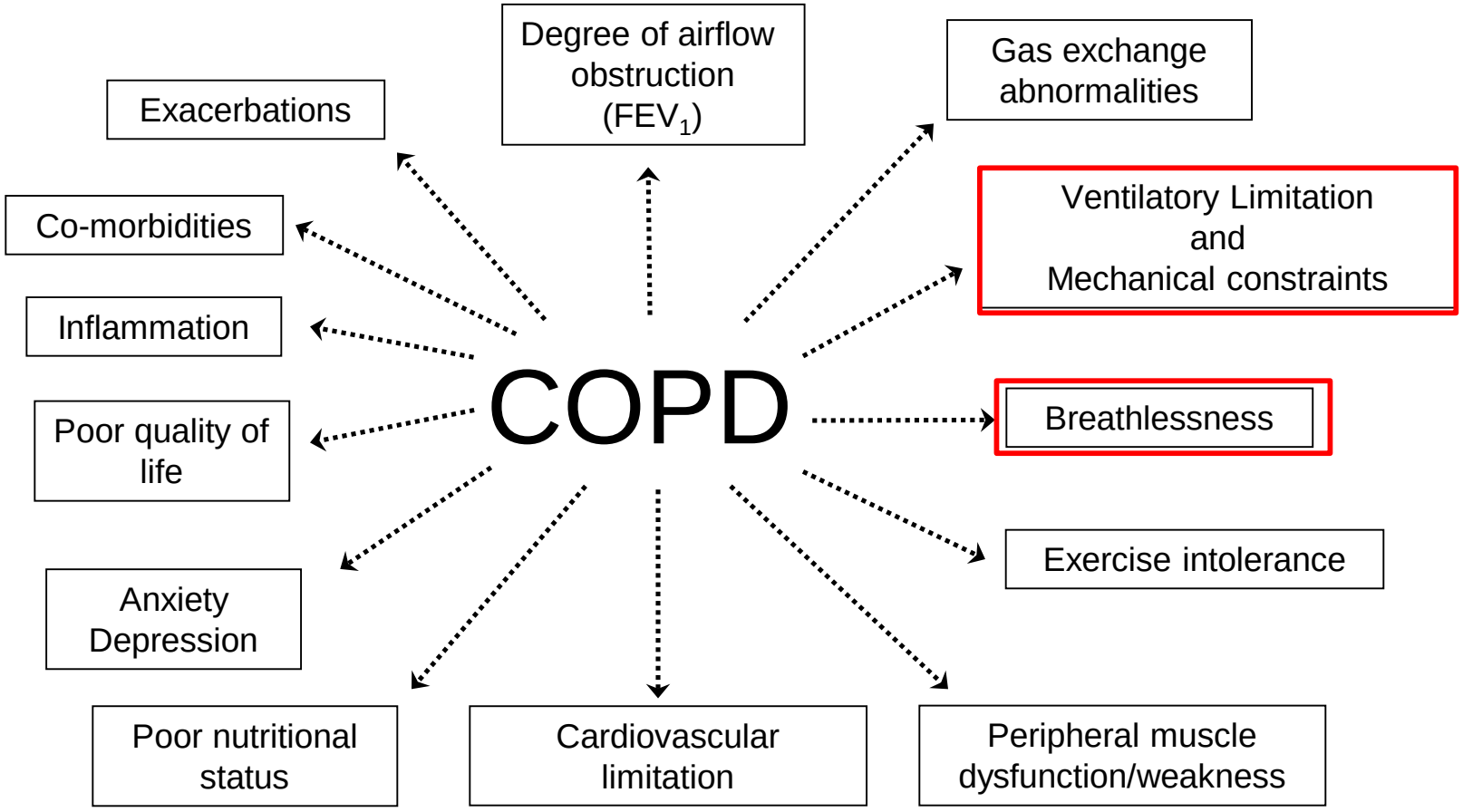
Neurophysiologie Respiratoire Expérimentale et Clinique

# Conflicts of interest

- Nothing to disclose

# COPD




Laveneziana P and Palange P, Eur Respir J. 2012

# AGENDA

- **Ventilatory Mechanics**
  - ✓ **Ventilatory response and limitation**
  - ✓ **Flow-Volume Loops**
  - ✓ **Lung Hyperinflation**
  - ✓ **Tidal volume constraints**

- **Exertional Dyspnoea**

- Expiratory flow-limitation → ↑ EELV
- Functional respiratory muscle weakness
- ↑ Ventilatory muscle mechanical loading

- Metabolic demand

$$V'_E = \frac{863 * V'CO_2}{PaCO_2 * (1 - V_D/V_T)}$$

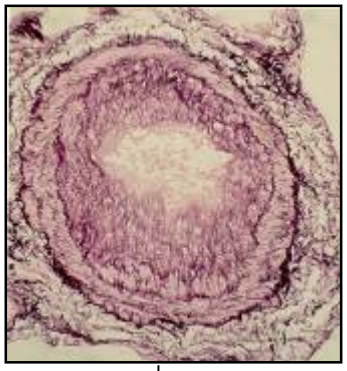
$CO_2$ set-point

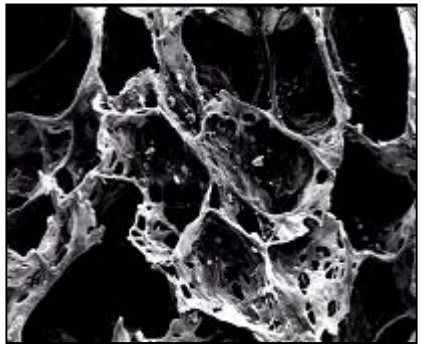
Reflexes:
chemo,metabo, ergo

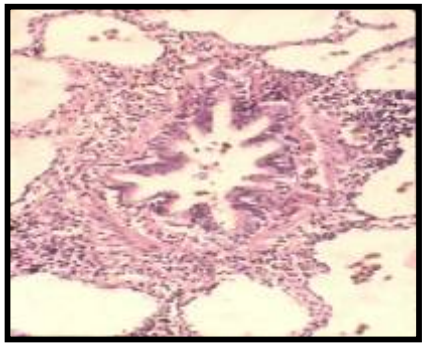
- Alveolar-capillar gas diffusion
- Physiological dead space → V/Q abnormalities
- Gas exchange efficiency

Laviolette L and Laveneziana P, Eur Respir J. 2014

# COPD







Alveolar Wall Destruction
Air Spaces Enlargement

Alveolar Attachments
Loss

Capillary Network
Reduction

Small Airways
Narrowing-Distortion

Nonhomogeneous
Inspired Air Distribution

Reduced Ventilation
In Dependent Alveoli

**HIGH $V_A/Q$ RATIOS**

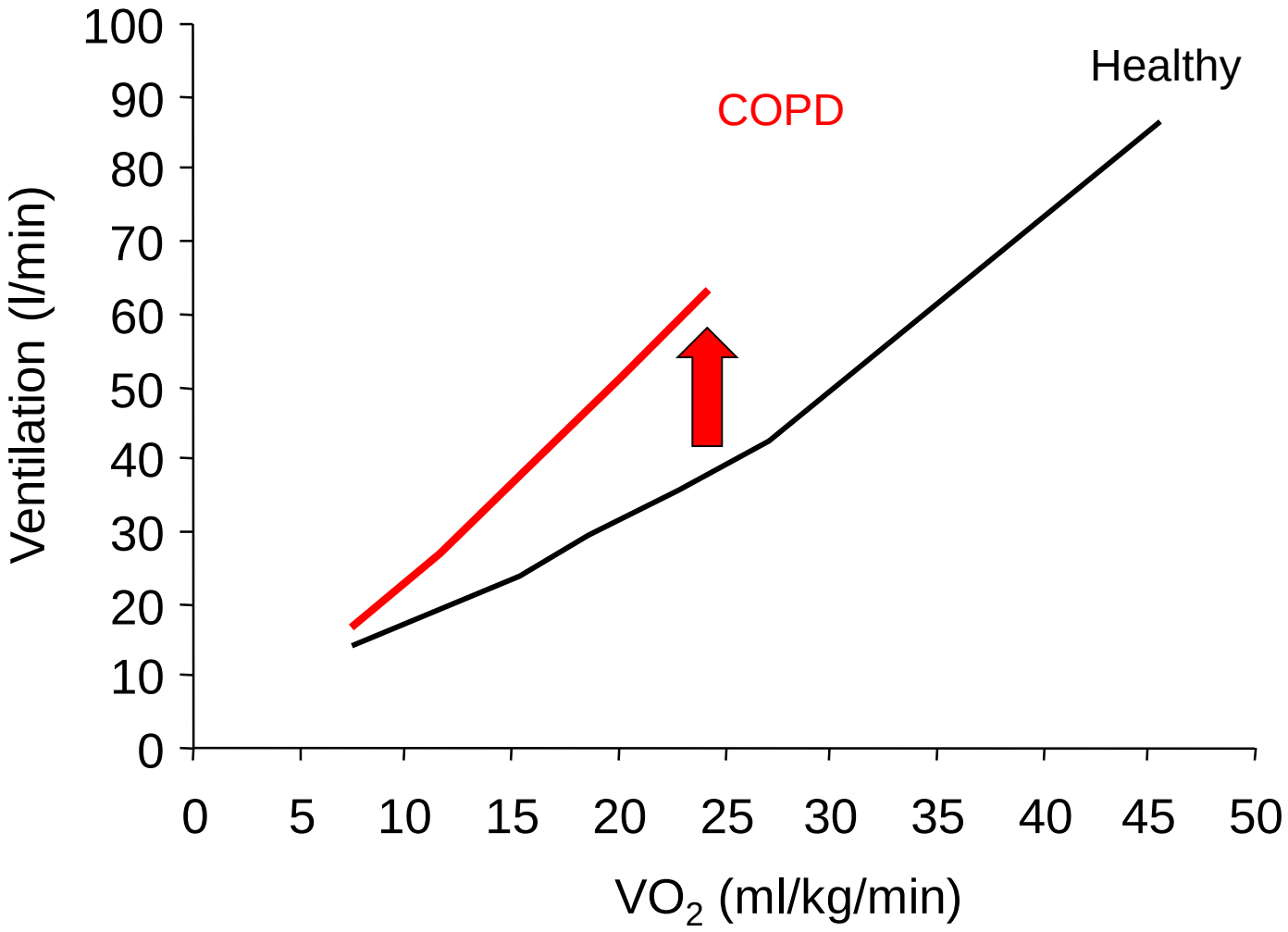
**LOW $V_A/Q$ RATIOS**

*Barberà JA et al. , ARRD 1990*

# COPD

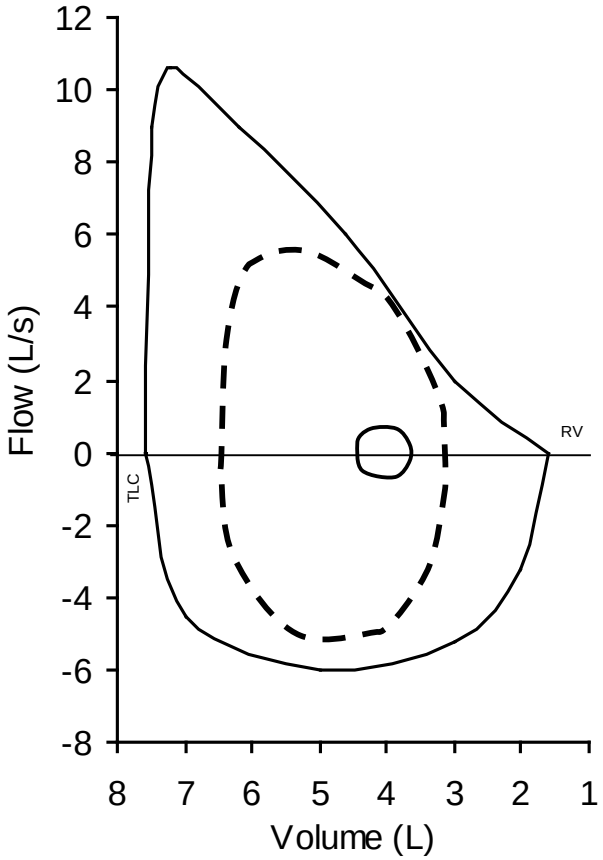
- **Excessive submaximal $V'_E$**
- **↑ $V_D/V_T$ which does not decrease during exercise or normal $V_D/V_T$**
- **Mild drop in exercise $PaO_2$ or normal $PaO_2$**
- **$PaCO_2$ normal or ↑**

# Ventilatory response to exercise




Laviolette L and Laveneziana P, Eur Respir J. 2014

# Ventilatory (or breathing) reserve = VE peak/MVV, %




## MVV (MVC) = $FEV_1$ x 40 (30-40)

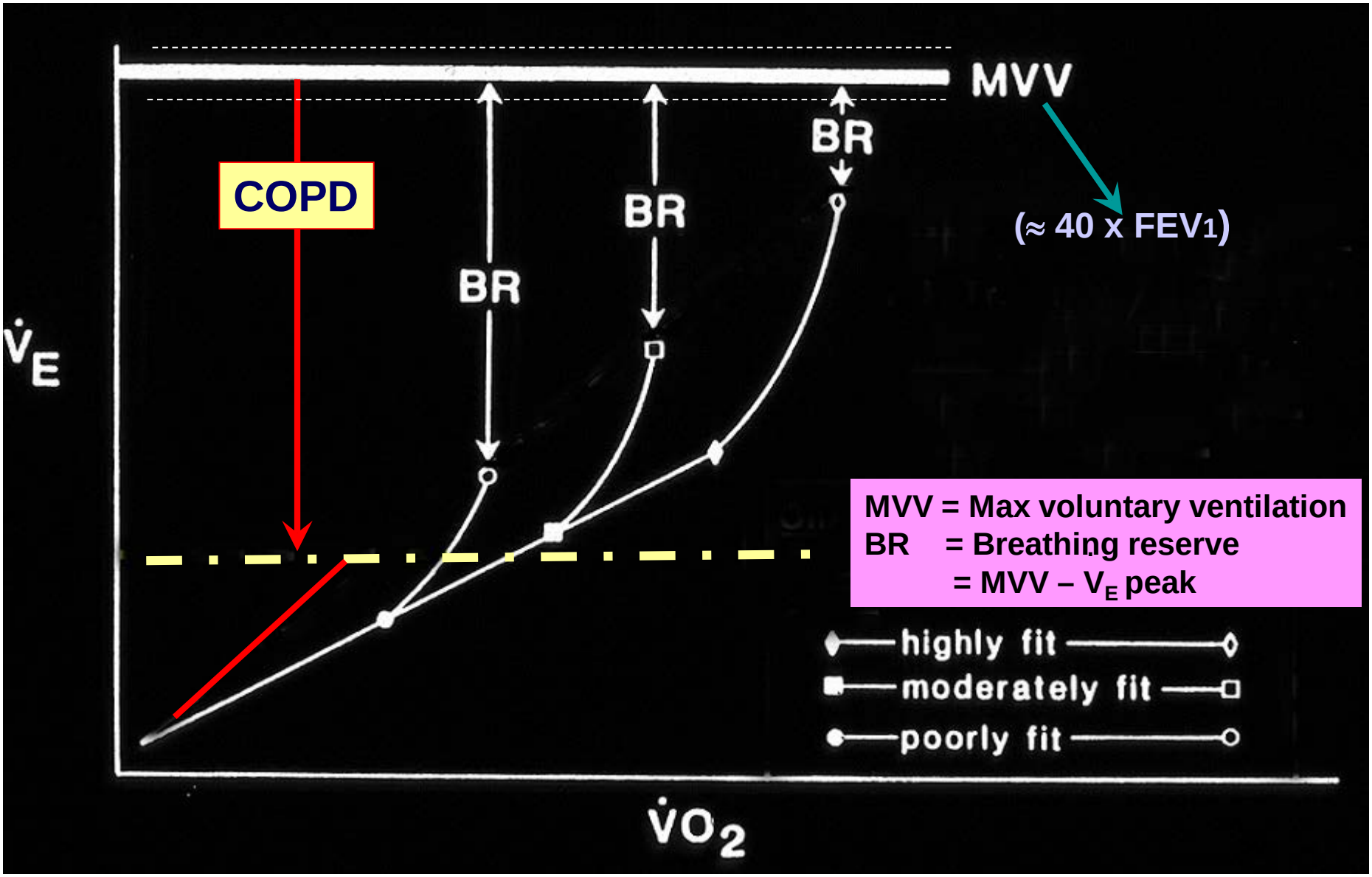
MVV = maximal voluntary ventilation
MVC = maximal ventilatory capacity

$FEV_1$ = 3.0L → 120L

$FEV_1$ = 1.5L → 60L

$FEV_1$ = 0.5L → 20L

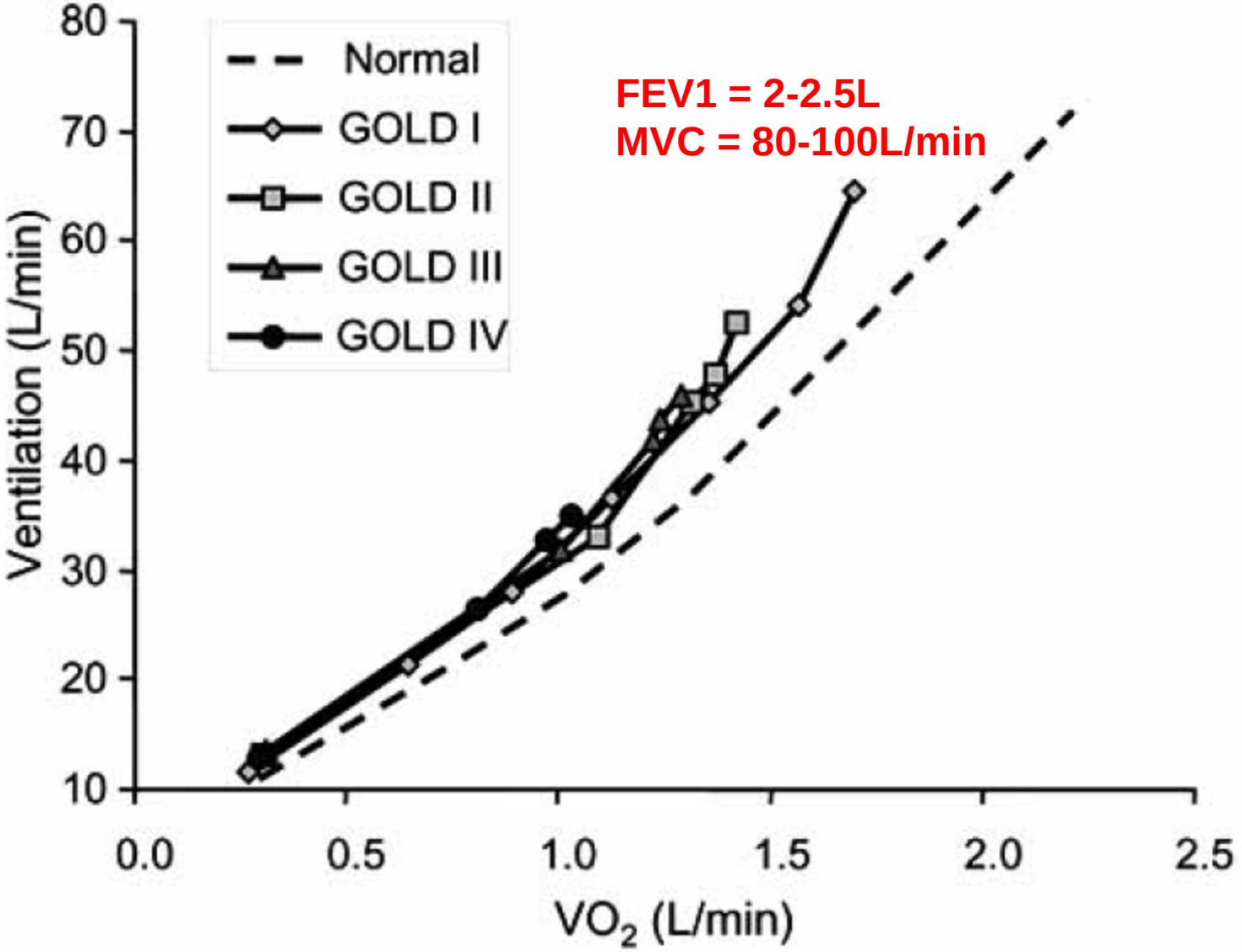
Gandevia B , Hugh-Jones P. Thorax 1957




VE peak = 72±15%
VE peak = <80-85%
VR (or BR) > 20% or > 15 L

ATS-ACCP statement on CPET, AJRCCM 2003
ERS Task Force on CPET, ERJ 2007

# Ventilatory Limitation




Laveneziana P et al, Current Respiratory Medicine Reviews 2008

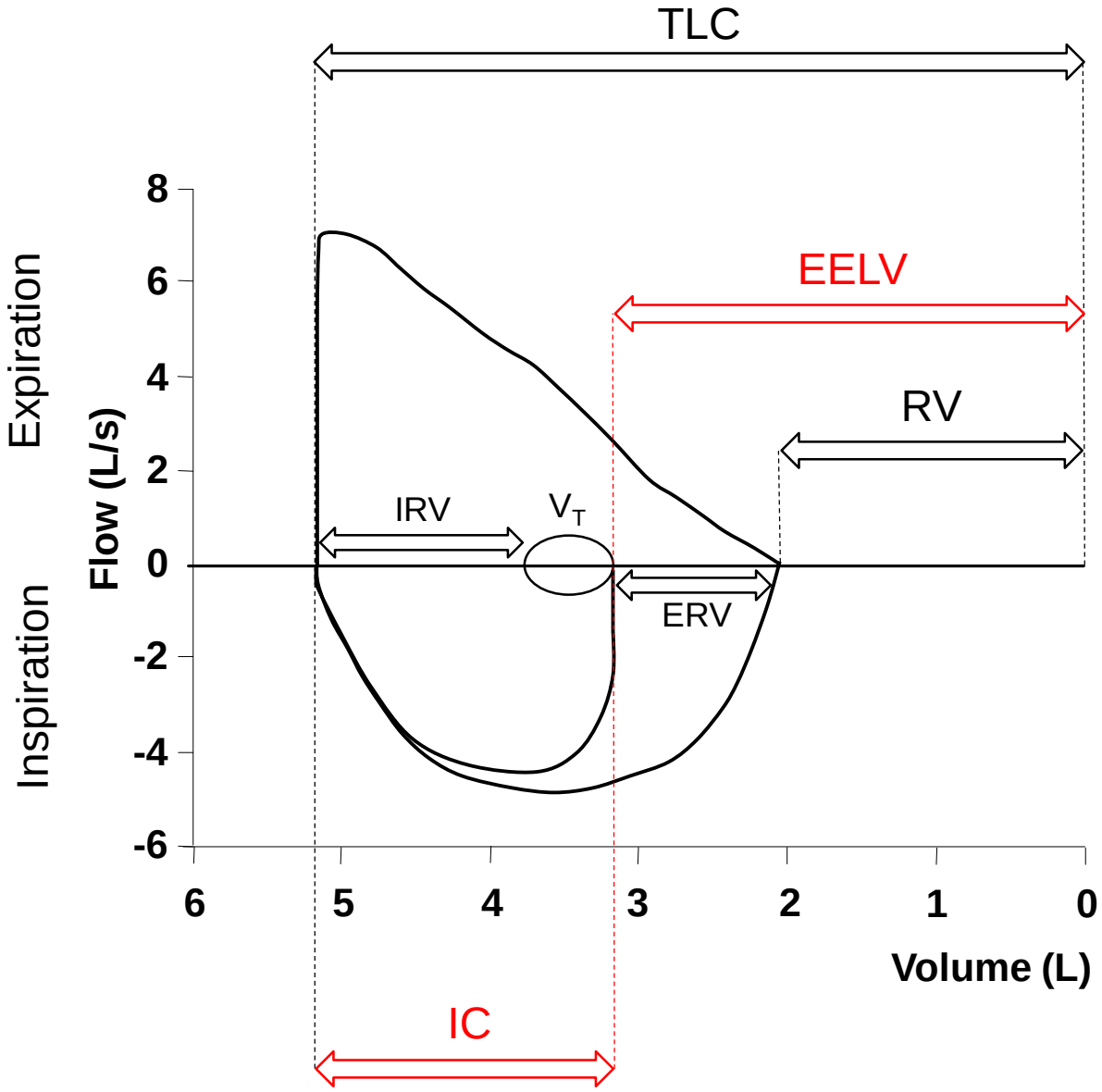
# *Ventilatory Limitation ???*

**VE peak <80-85%**
**VR (or BR) > 20% or > 15 L**

- **mild COPD**
- **asthma**
- **CHF**
- **PAH**


**Ofir et al, AJRCCM 2008**
**Laveneziana P et al, JAP 2009**
**Laveneziana P et al, RESPNB 2013**
**Laveneziana P et al, RESPNB 2014**
**Laveneziana P et al, ERJ 2013 and 2015**

# Ventilatory Mechanics: Healthy



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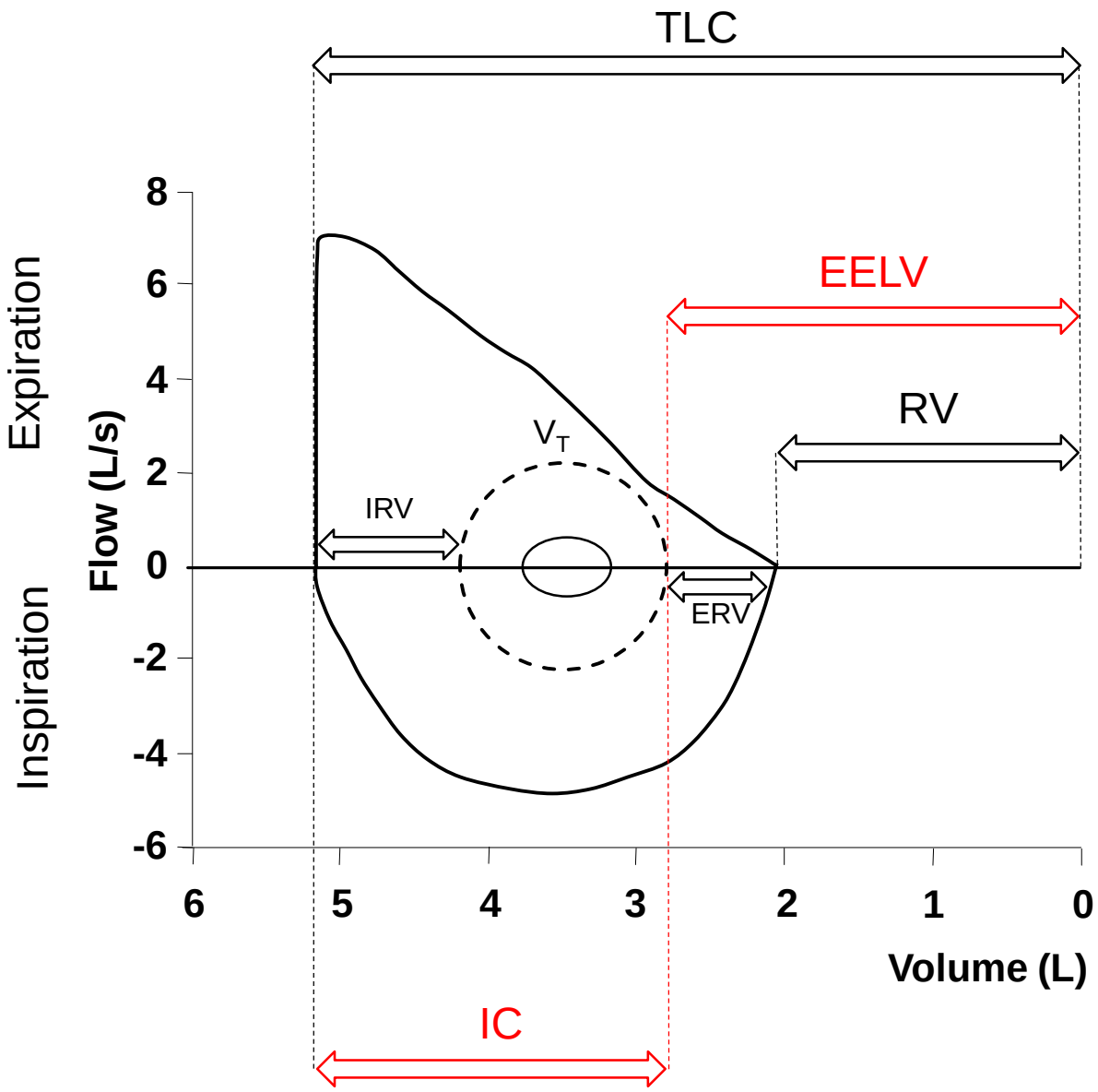
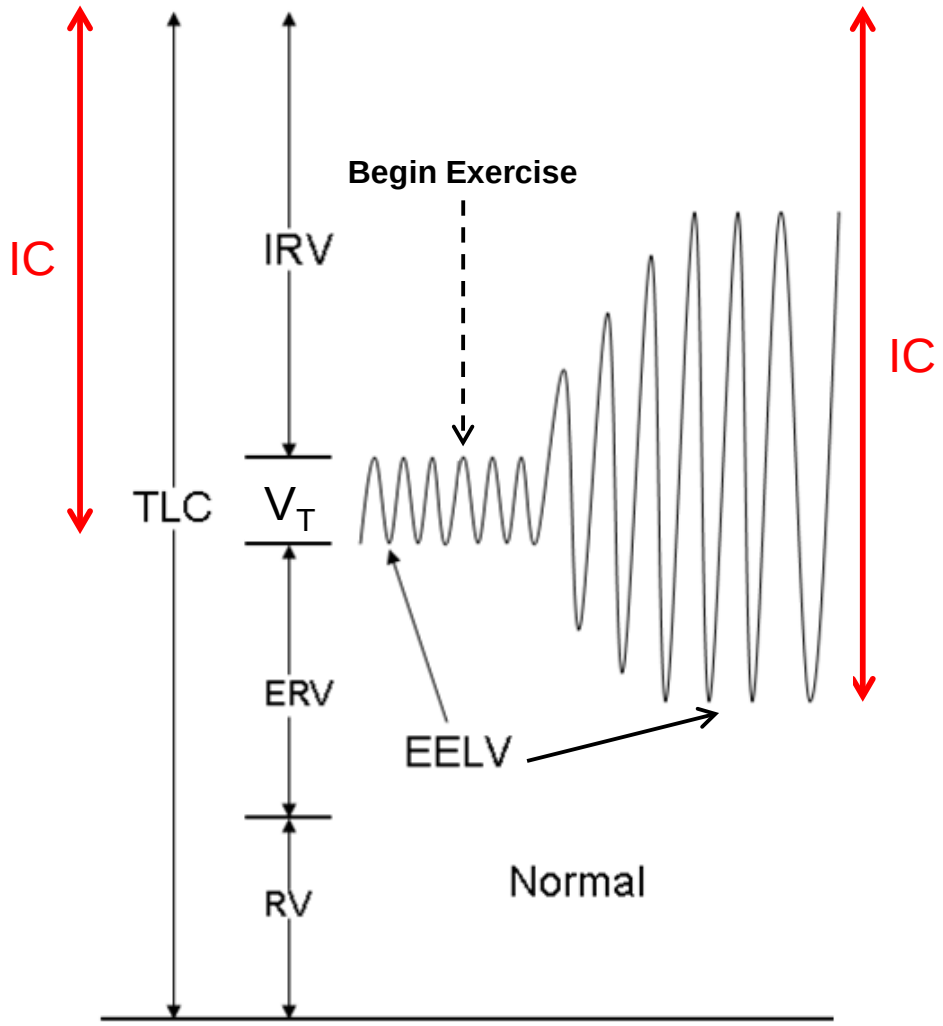


# Ventilatory Mechanics: Healthy

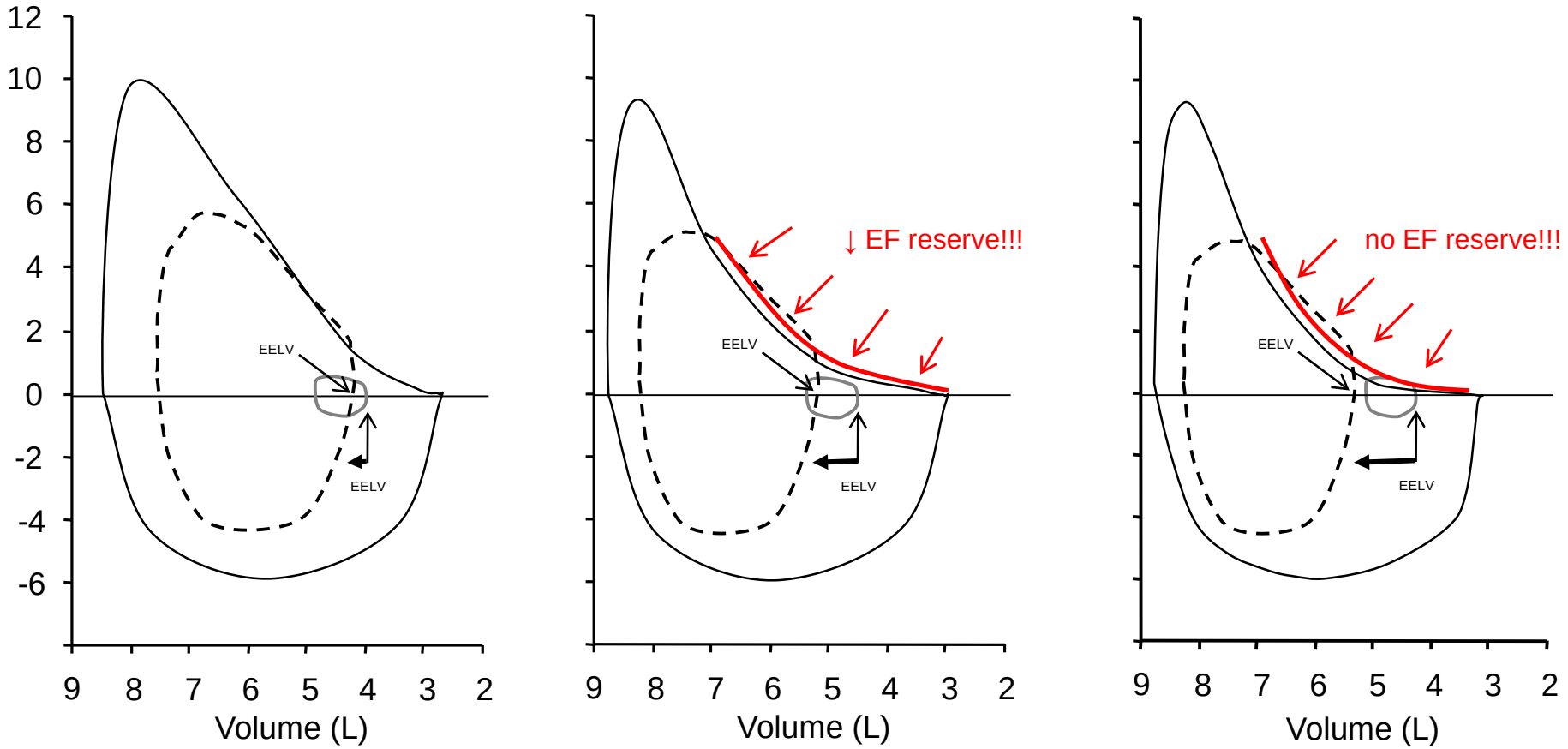


# Ventilatory Mechanics: Healthy vs COPD

**Older Male**
Age = 66 yrs

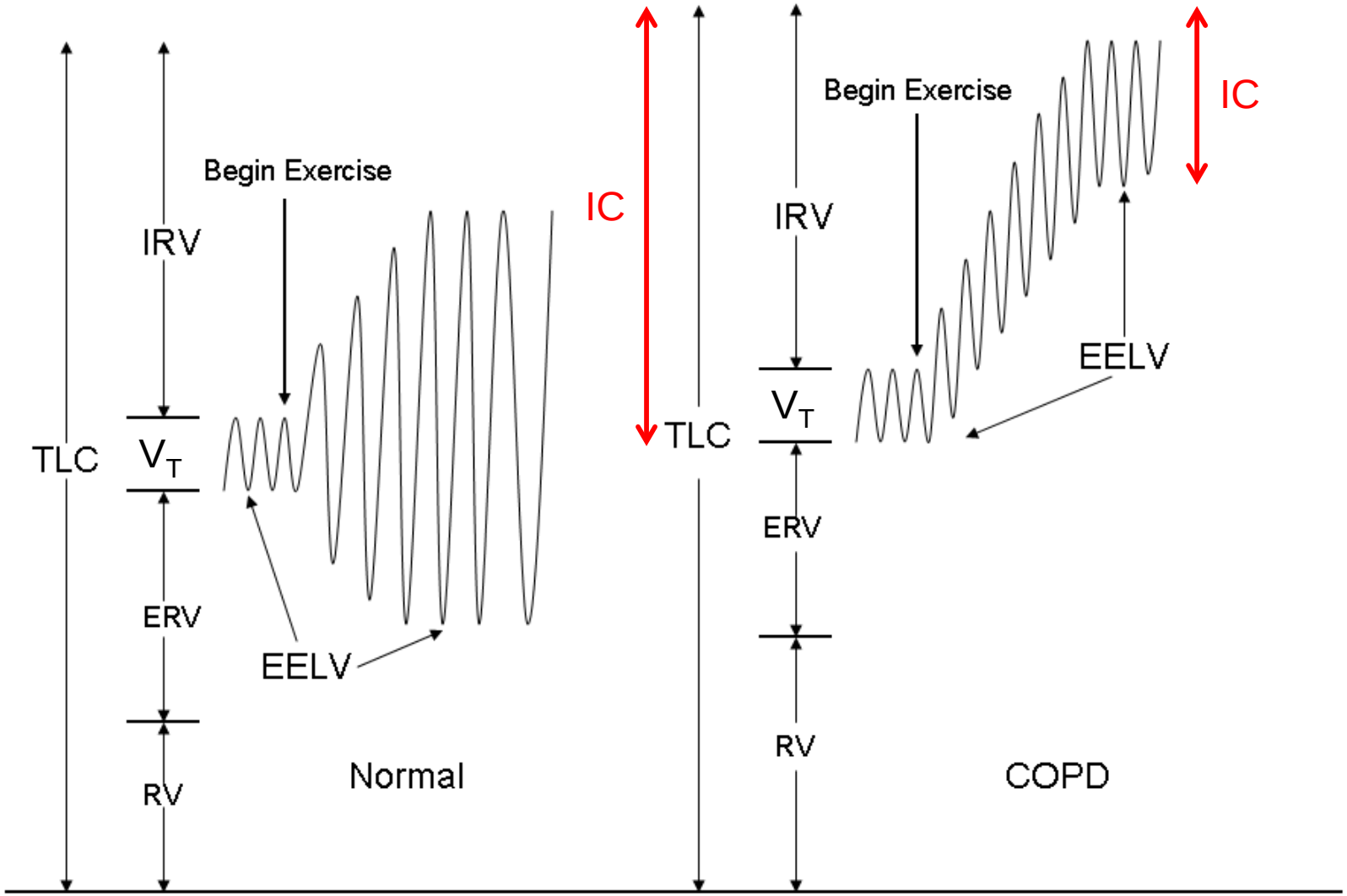
**Mild COPD**
Age = 67 yrs

**Severe COPD**
Age = 65 yrs




Laveneziana P, et al. Appl. Physiol. Nutr. Metab. 2007; 32: 1225-1238

# *Dynamic Lung Hyperinflation*

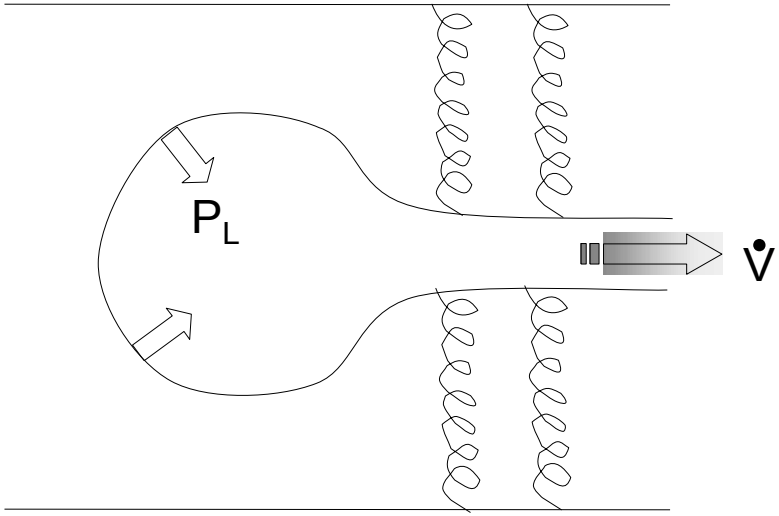


# *Ventilatory Mechanics: Healthy vs COPD*

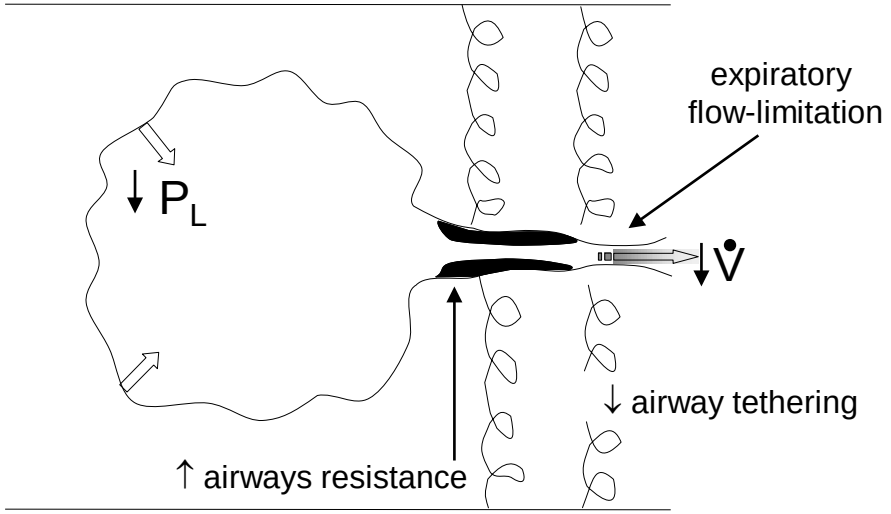
- **Dynamic hyperinflation: a temporary and variable increase in end expiratory lung volume (EELV) beyond its baseline value**

- **EELV: volume of gas left in the lung at the end of a quiet breath out**

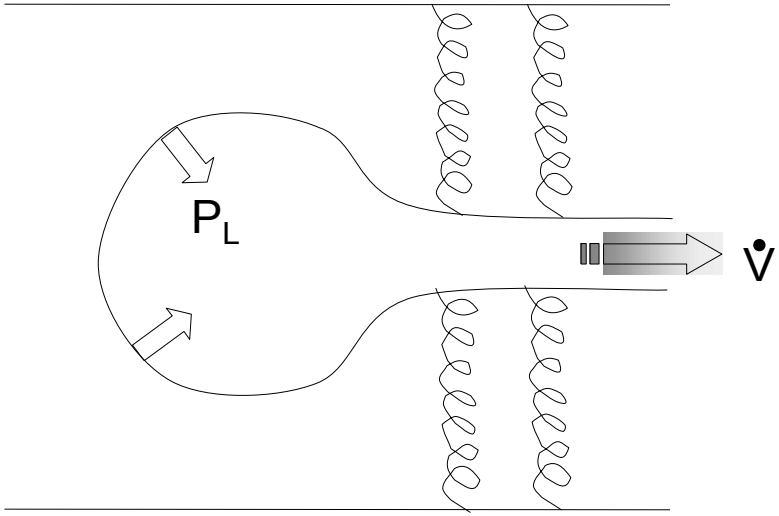
# Normal


$P_L$
$\dot{V}$

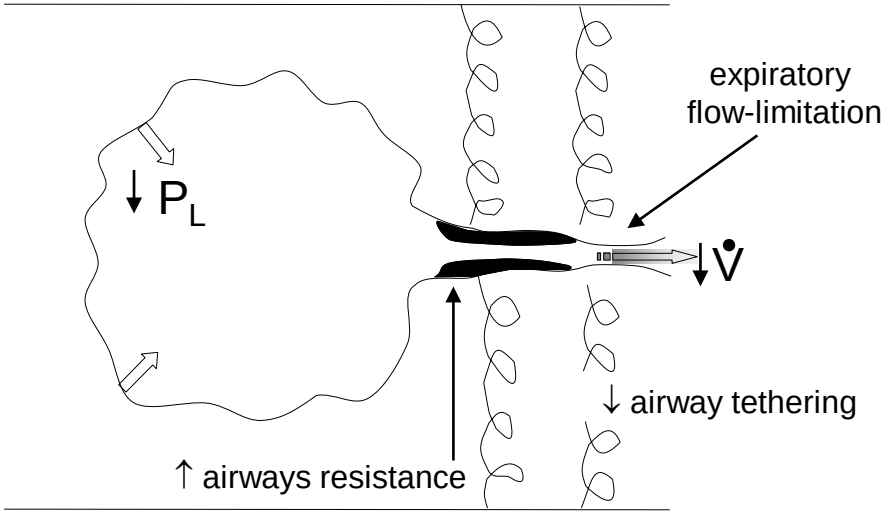
# COPD


expiratory
flow-limitation
↓ $P_L$
$\dot{V}$
↓ airway tethering
↑ airways resistance

# Normal




# COPD



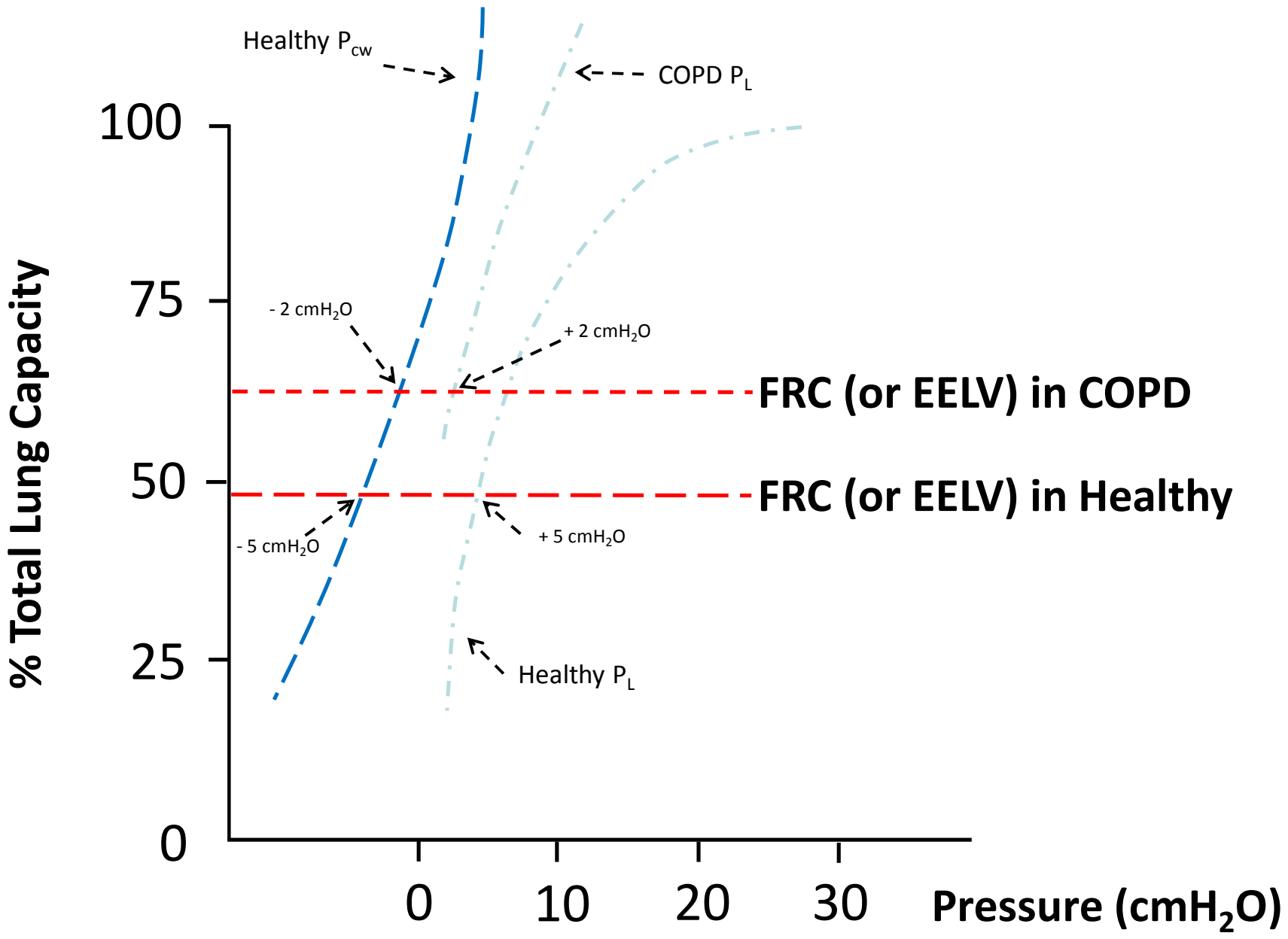

$\tau = C * R$

**Expiratory flow limitation**

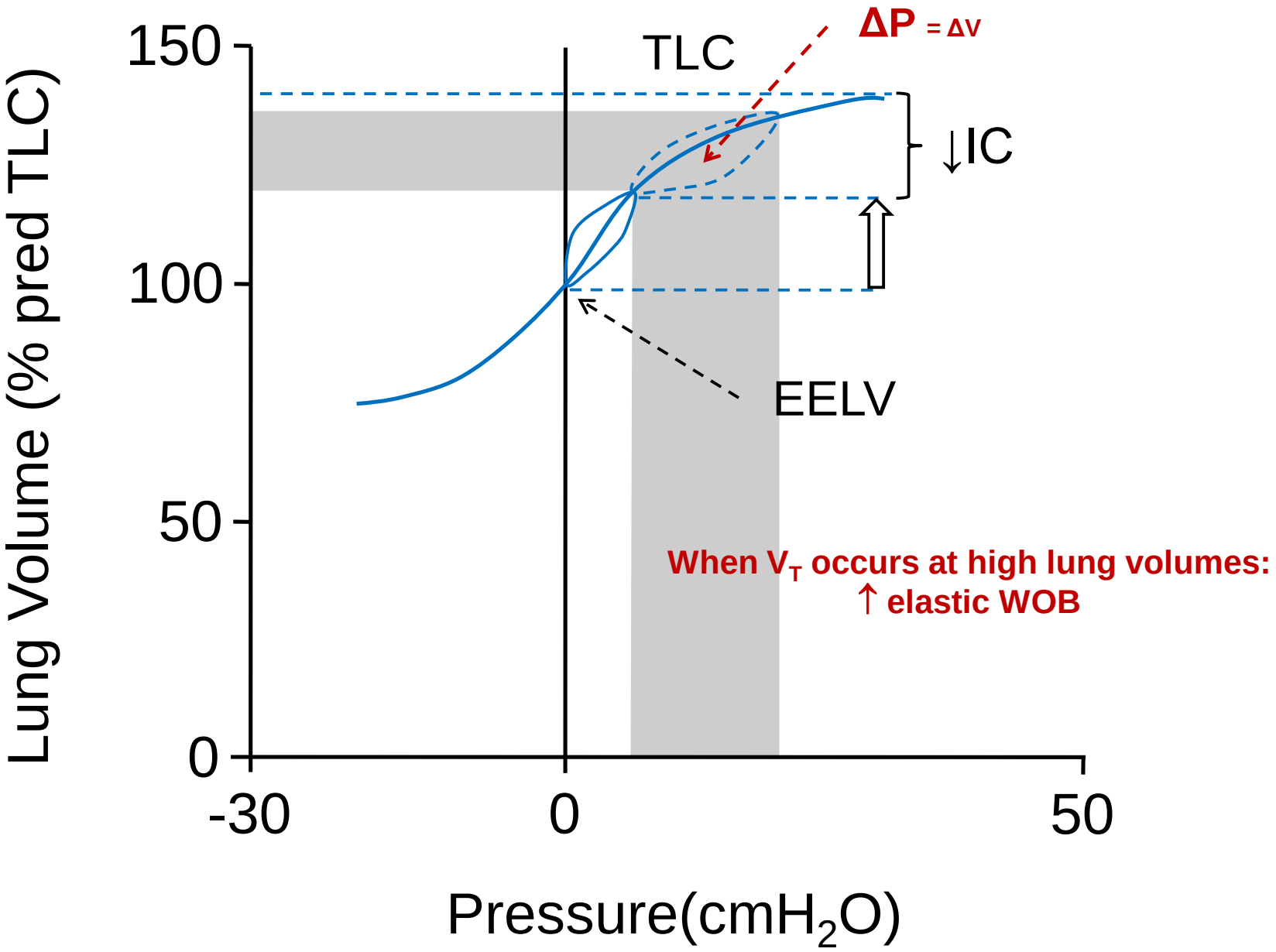
$V_T$ $T_E$

$$EELV - Vr = VT / (e^{Te/\tau rs} - 1)$$

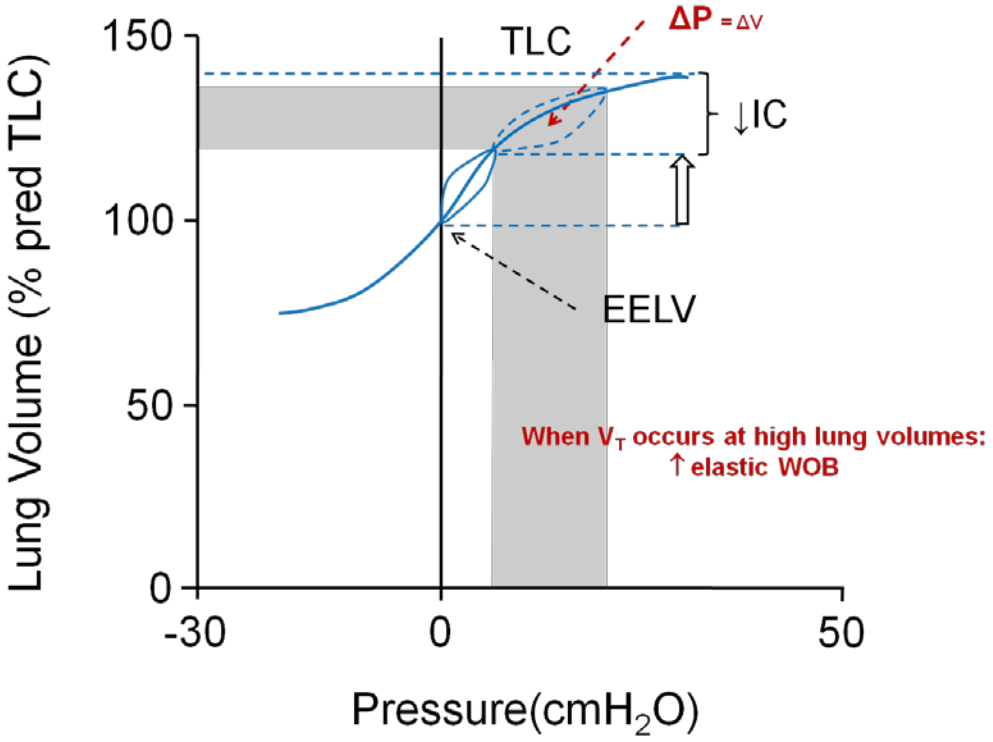
# Ventilatory Mechanics: Healthy vs COPD

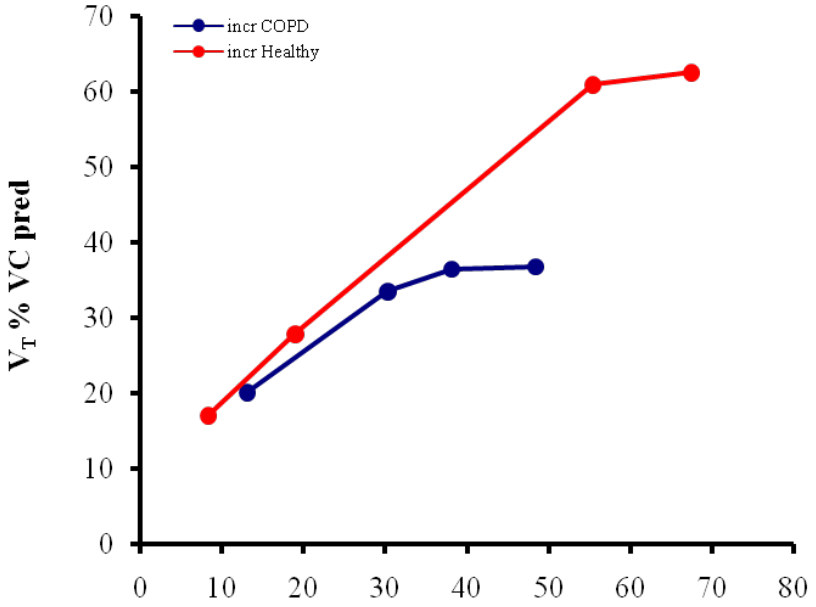


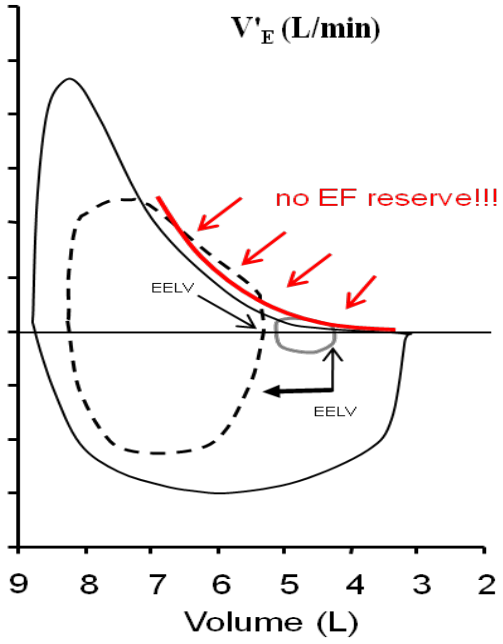
# *Ventilatory Mechanics: COPD*



# Ventilatory Mechanics: COPD

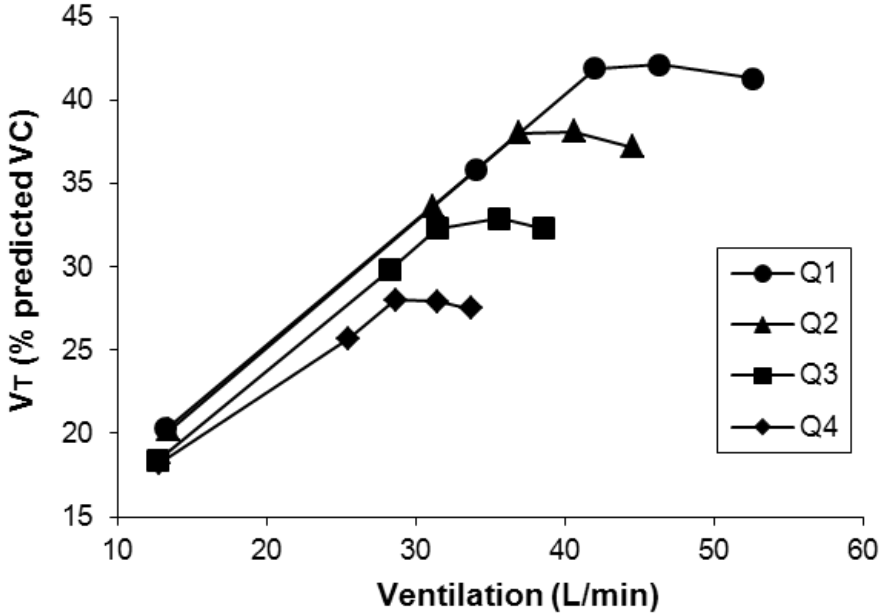


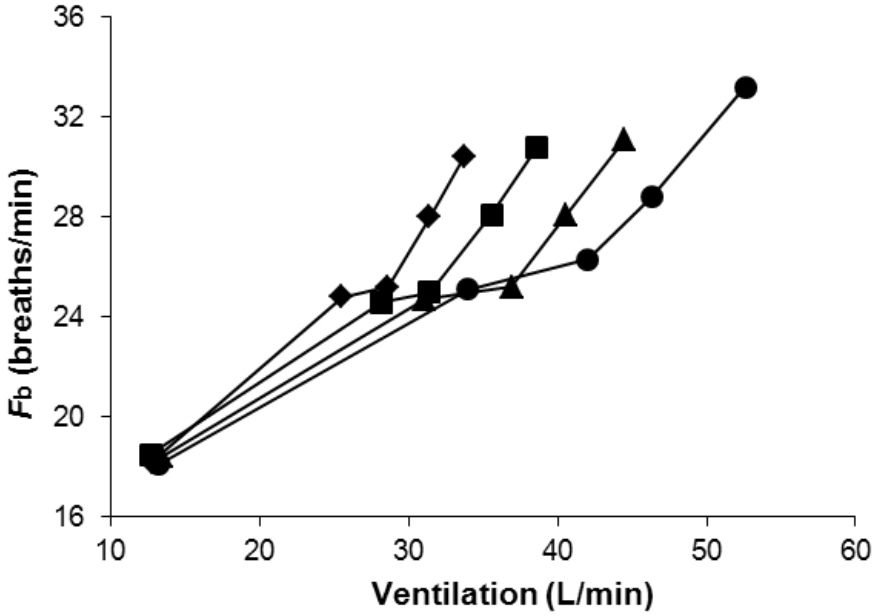



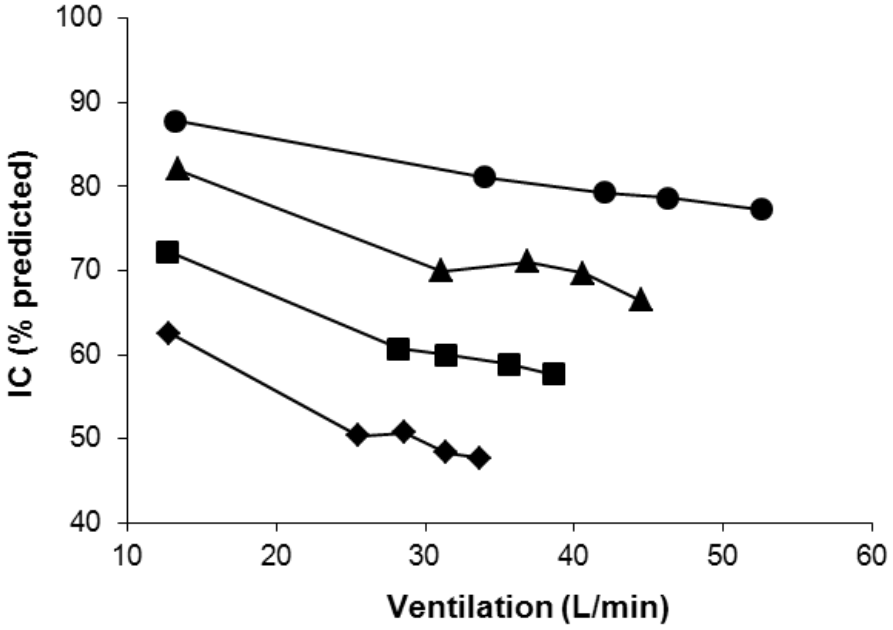



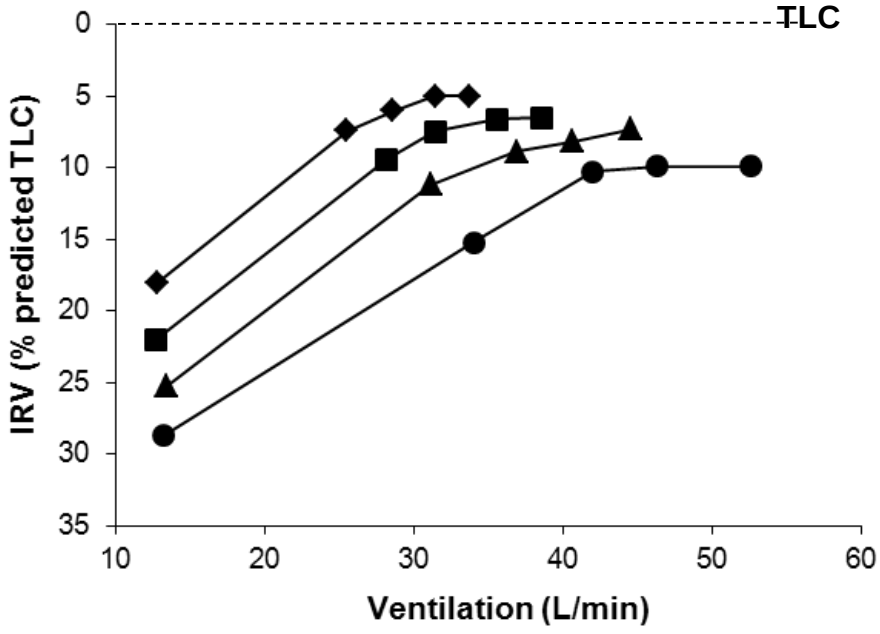

Laveneziana P et al, AJRCCM 2011
O'Donnell DE et al, JAP 2006

# Breathing Pattern during Exercise with Worsening $FEV_1$ Quartile




Courtesy from O'Donnell DE, et al.CHEST, 2011

## *Negative effects of DH during exercise*

- ↑ Elastic/threshold loads
- Inspiratory muscle weakness

} ↑$P_{es}/P_{Imax}$ 'effort'

- Reduced $V_T$ expansion

→ tachypnoea

} ↓$C_L dyn$
↑$V_D/V_T$
↑$PaCO_2$

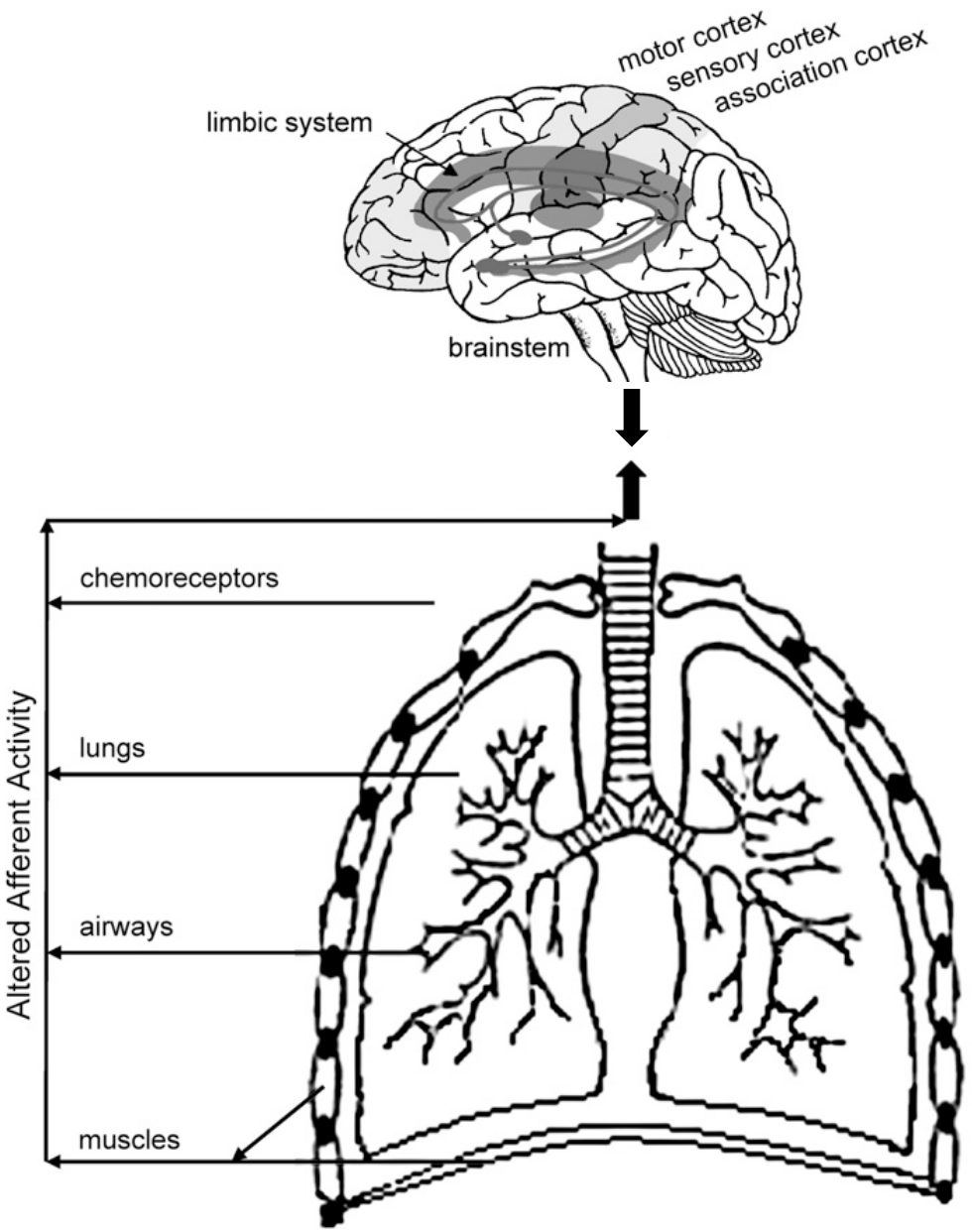
- Early ventilatory limitation to exercise
- Cardiac impairment
- ↑ Exertional dyspnoea

# AGENDA

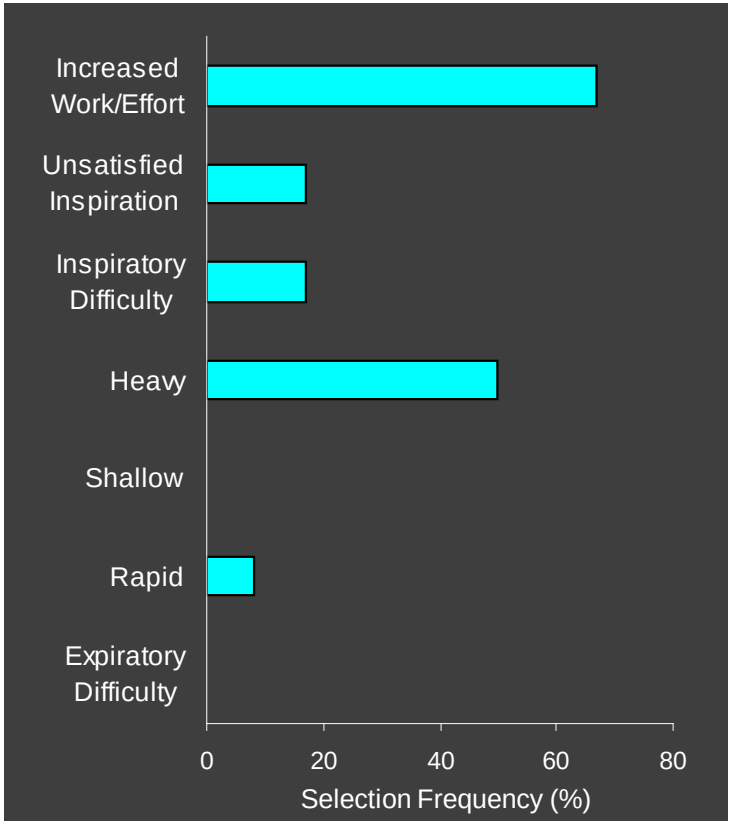
- **Ventilatory Mechanics**
  - ✓ **Ventilatory response and limitation**
  - ✓ **Flow-Volume Loops**
  - ✓ **Lung Hyperinflation**
  - ✓ **Tidal volume constraints**

- **Exertional Dyspnoea**

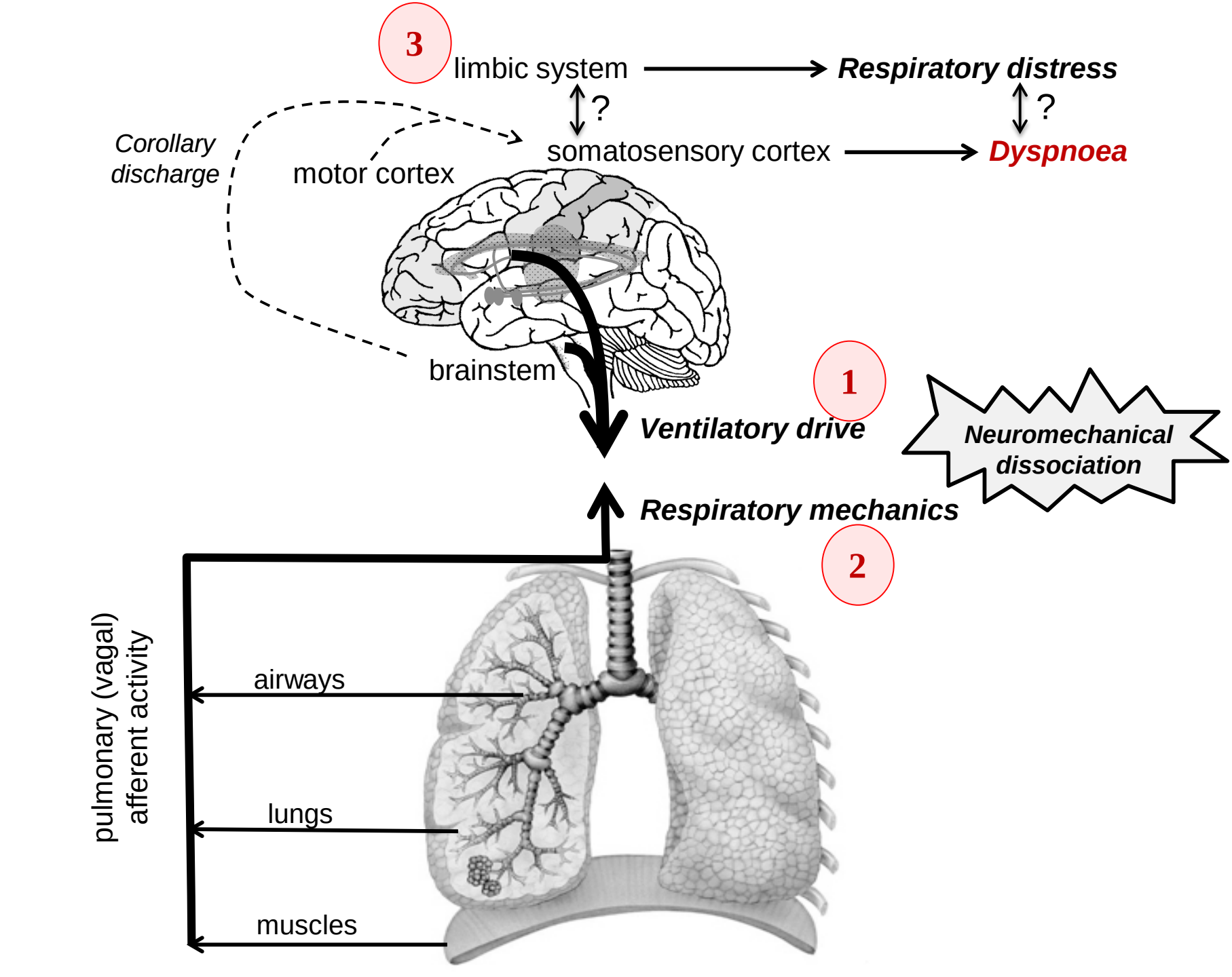
# Exertional Dyspnoea in Healthy during exercise




## Quality of Exertional Dyspnoea

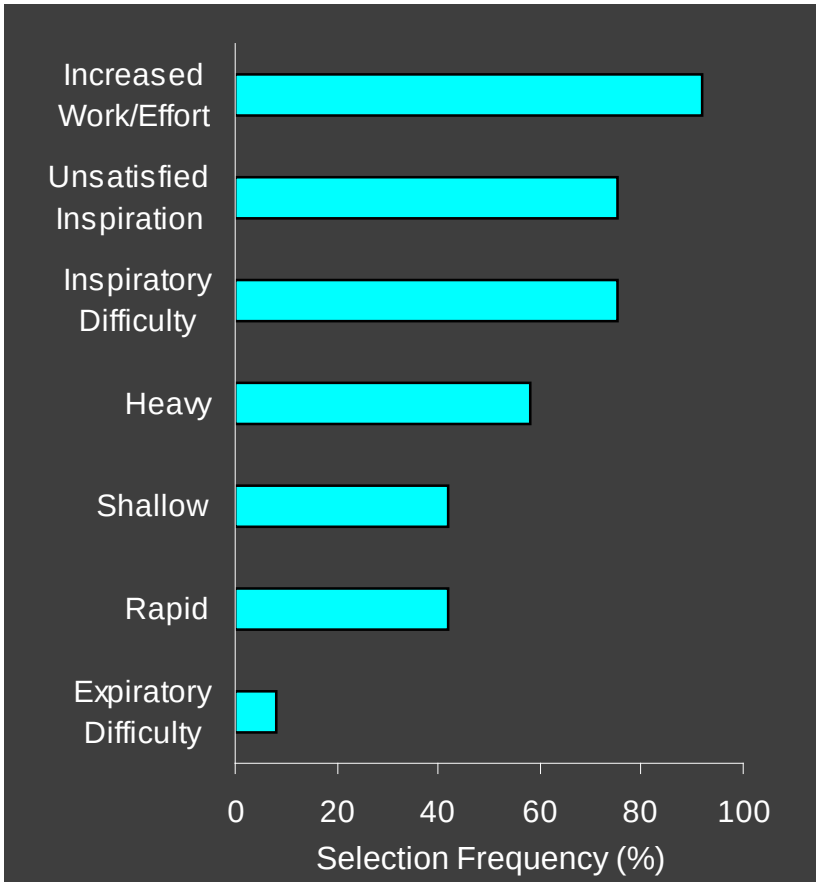


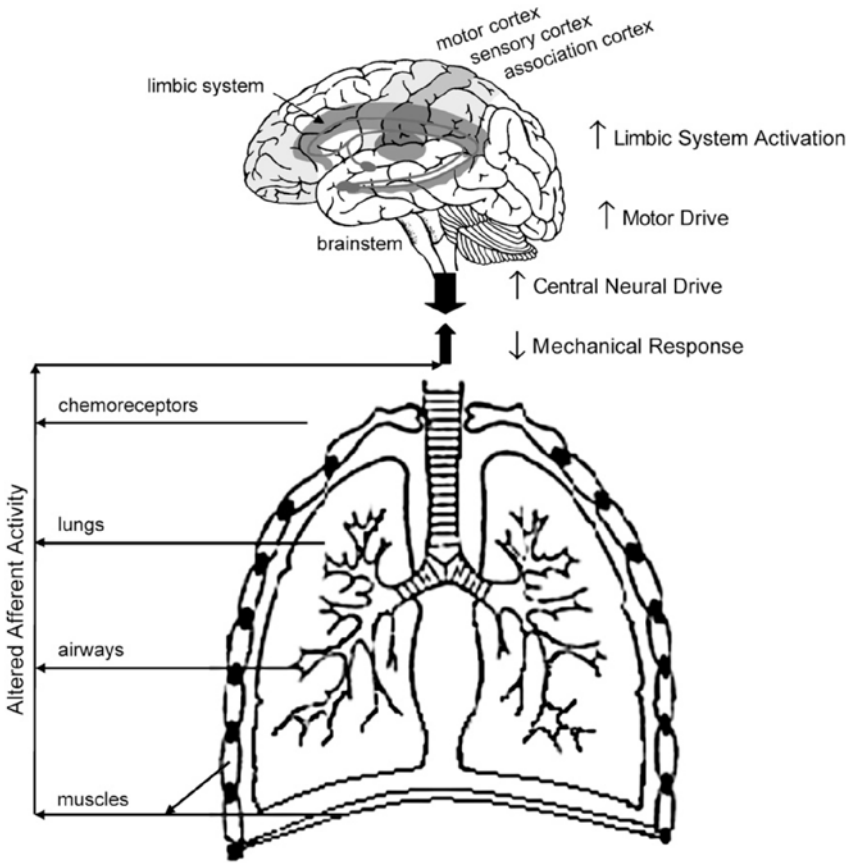

O'Donnell DE et al, Proc Am Thorac Soc 2007


3
limbic system
Respiratory distress
?
?
Corollary discharge
motor cortex
somatosensory cortex
Dyspnoea
brainstem
1
Ventilatory drive
Neuromechanical dissociation
Respiratory mechanics
2
pulmonary (vagal) afferent activity
airways
lungs
muscles

# *Exertional Dyspnoea in COPD during exercise*

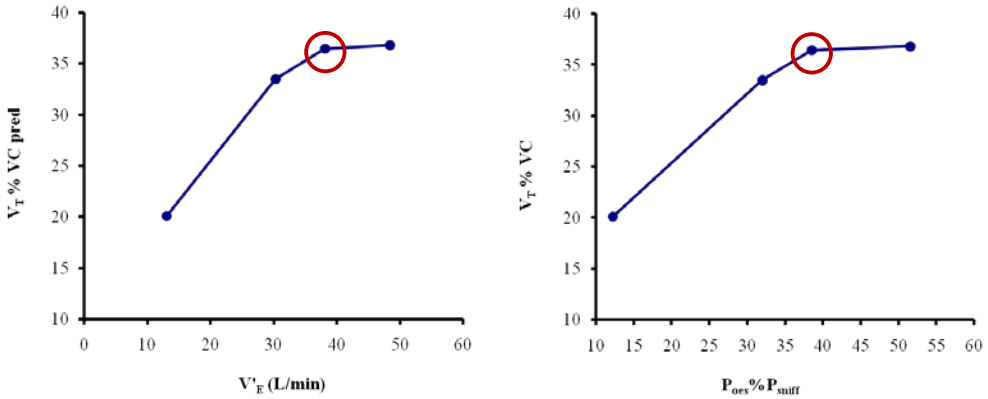
## Quality of Exertional Dyspnoea



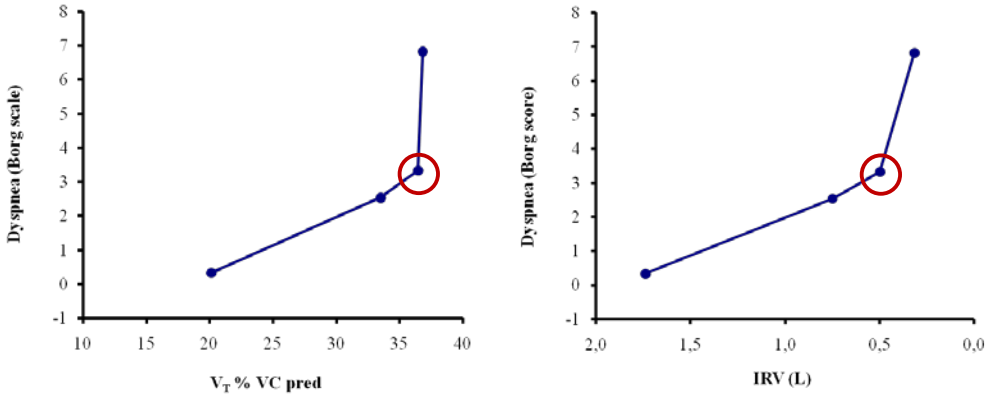

Laveneziana P et al, AJRCCM 2011

# Exertional Dyspnoea in COPD during exercise



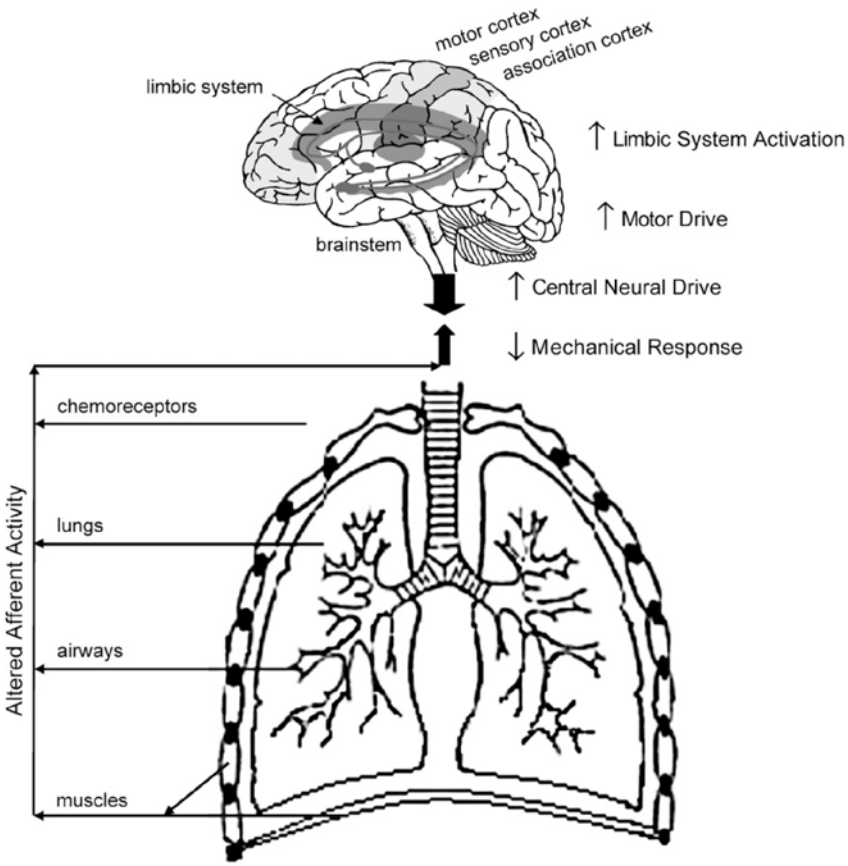


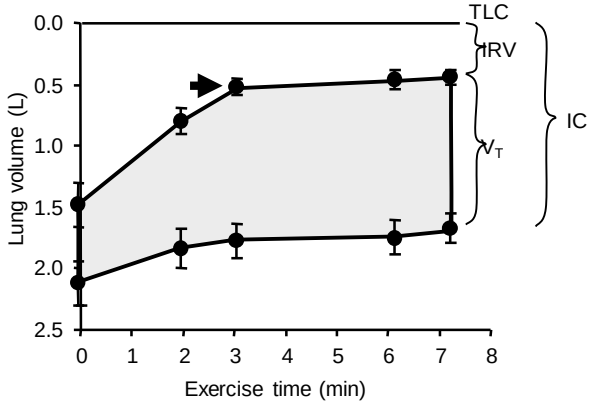






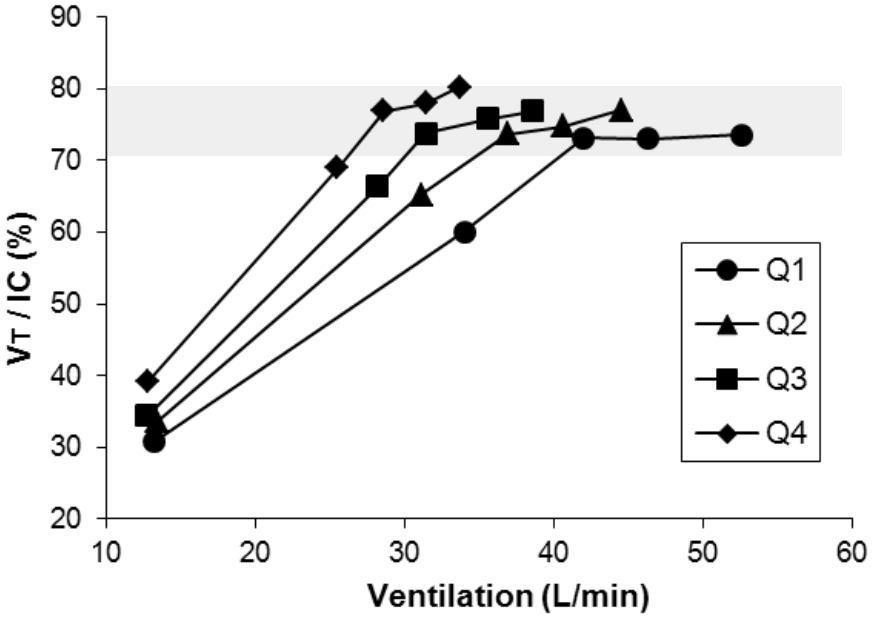


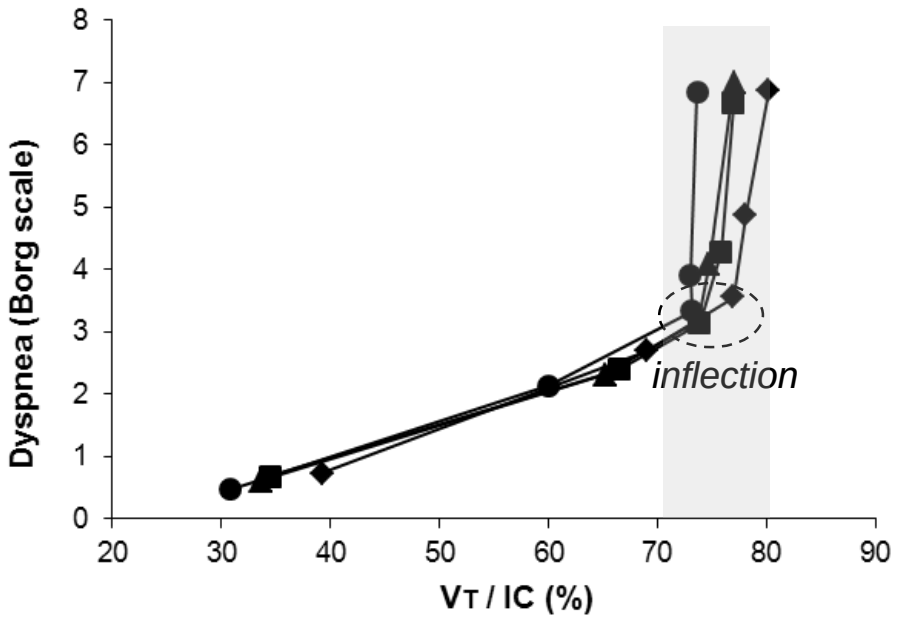


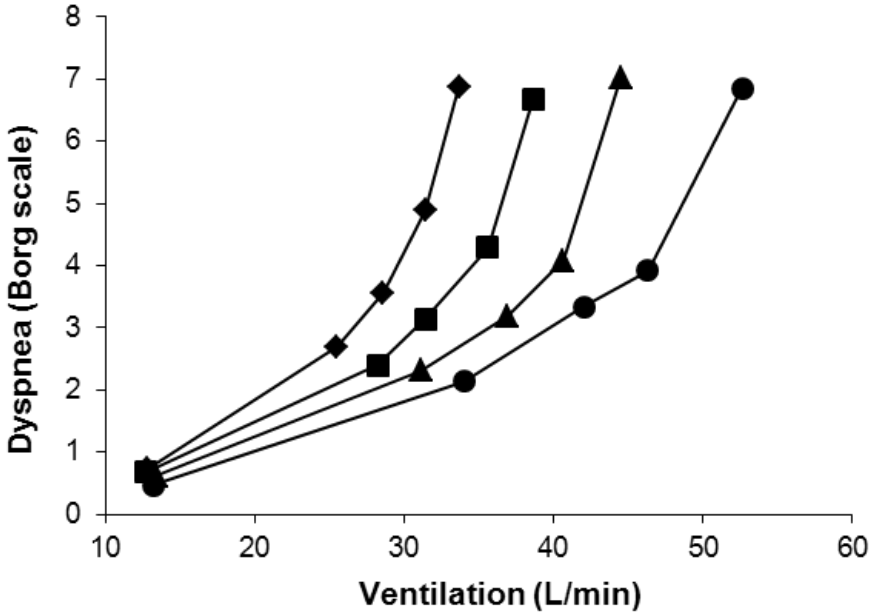



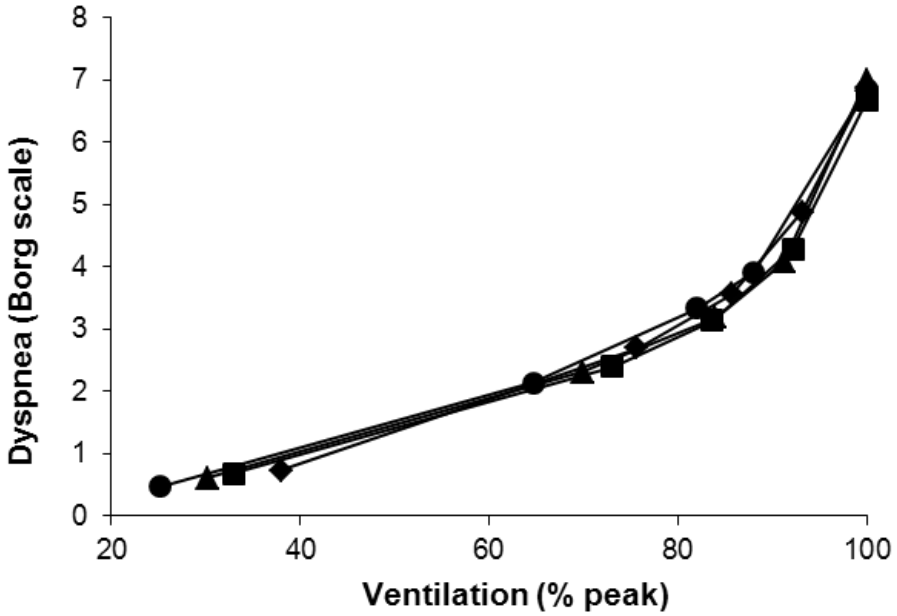

Laveneziana P et al, AJRCCM 2011

# Sensory-Mechanical Relations during Exercise with Worsening $FEV_1$ Quartile

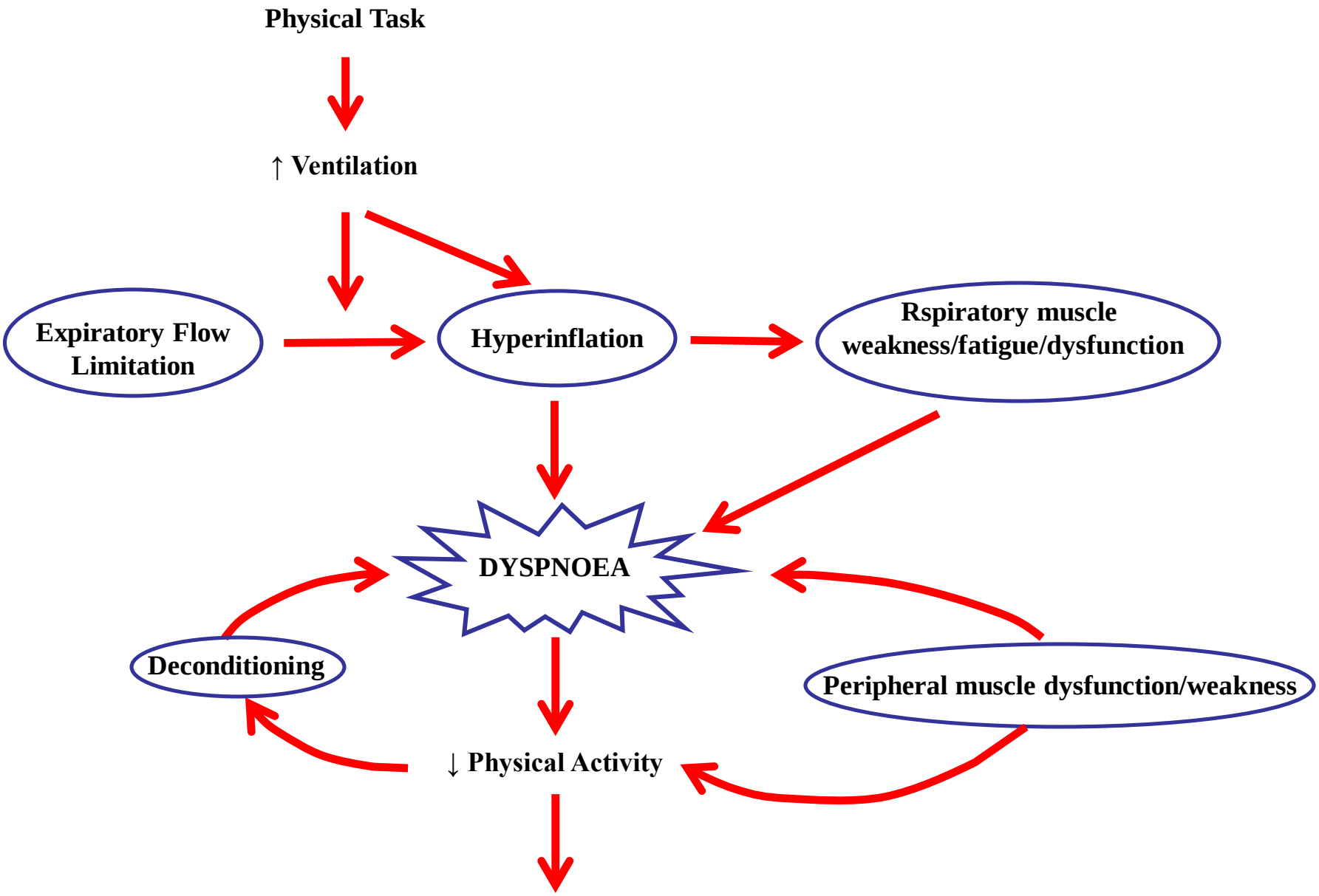


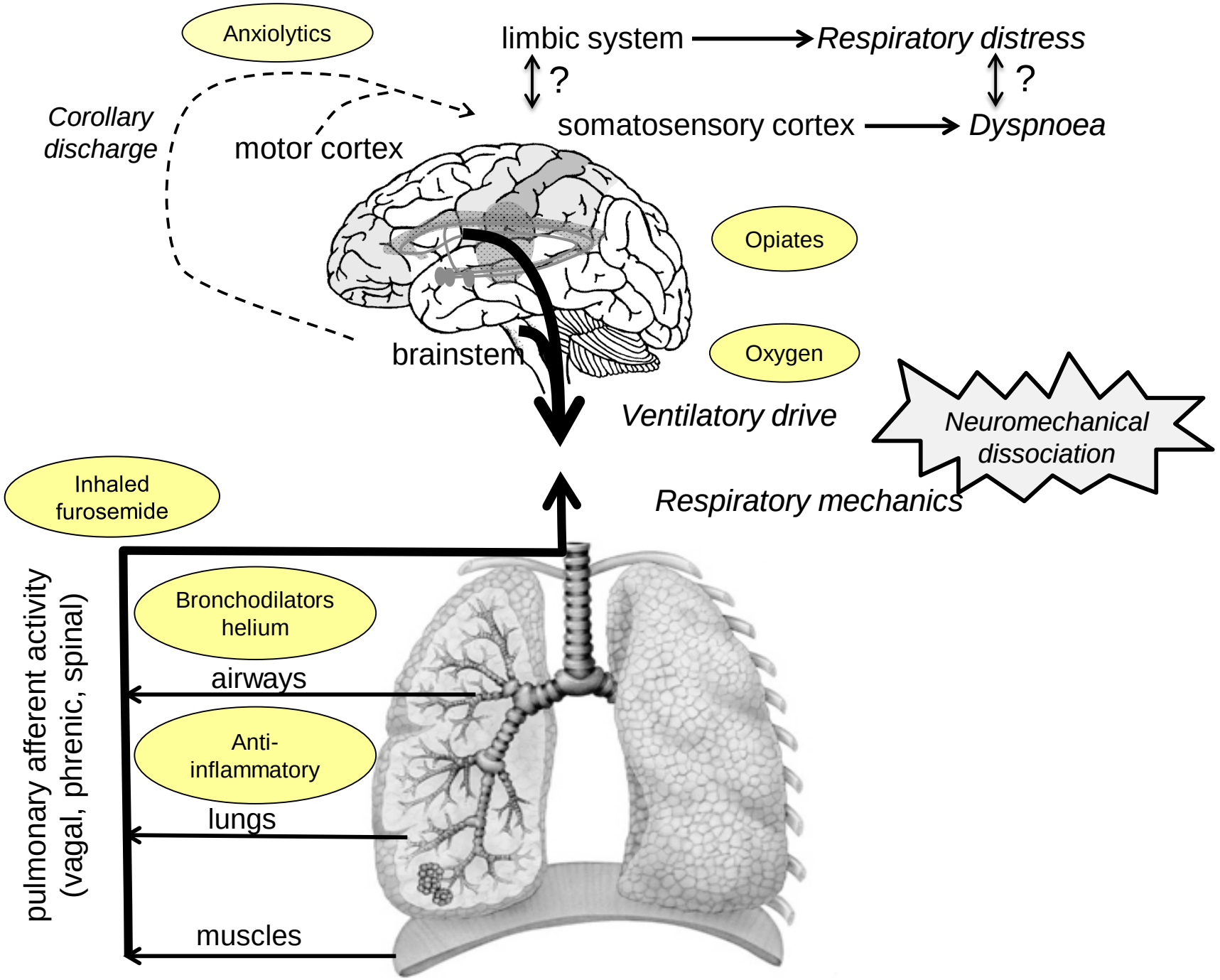




Courtesy from O'Donnell DE, et al.CHEST, 2011




Laviolette L and Laveneziana P, Eur Respir J. 2014


Anxiolytics
limbic system
Respiratory distress
?
?
Corollary discharge
motor cortex
somatosensory cortex
Dyspnoea
Opiates
Oxygen
brainstem
Ventilatory drive
Neuromechanical dissociation
Respiratory mechanics
Inhaled furosemide
Bronchodilators helium
airways
Anti-inflammatory
lungs
muscles
pulmonary afferent activity (vagal, phrenic, spinal)

Grazie
dell’attenzione!