Don't Hold Your Breath:

Outpatient perspectives on inspiratory muscles

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I have no relevant financial relationships to disclose

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Objectives

1. Describe the role of the inspiratory muscles and the work of breathing
2. Identify the patient populations most likely to benefit from inspiratory muscle training (IMT)
3. Discuss and observe assessment techniques

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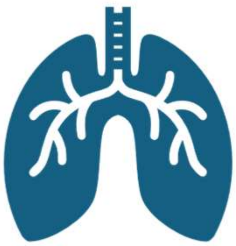

Inspiratory muscles generate negative pressure to overcome the work of breathing

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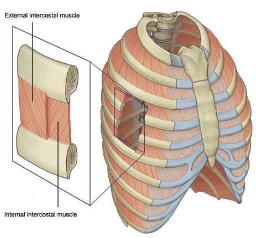
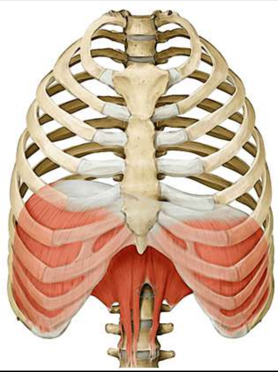
Inspiratory muscles





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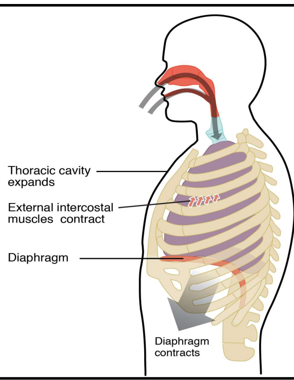
Negative pressure

Creates gradient for airflow

Surrogate for inspiratory muscle performance



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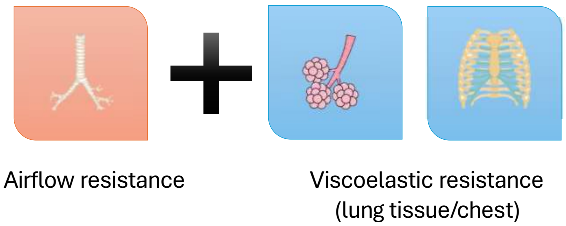
Work of breathing



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Ventilation

Condition	Healthy Respiratory Muscles % of Total VO_2	COPD Respiratory Muscles % of Total VO_2
At-Rest	2-3%	10-20%
Maximal Effort (Stress Test)	10-15%	

Pleil JD *et al.*, Journal Breath Research, 2021

Dempsey, JA *et al*, Journal of Applied Physiology, 1992

Ammous, OF *et al*, Cochrane Database Syst Rev, 2023

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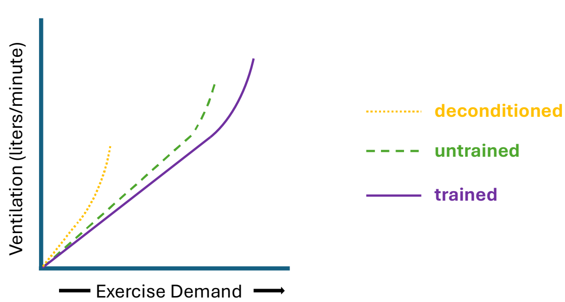
Ventilatory demands w/ exercise



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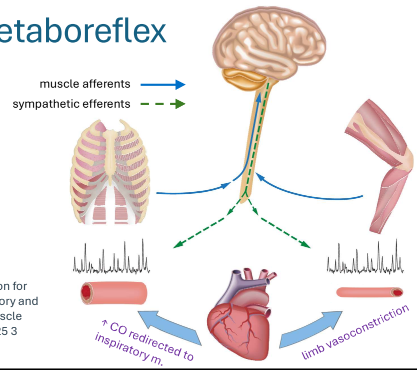
Respiratory metaboreflex



Sheel, Andrew William et al. "Competition for blood flow distribution between respiratory and locomotor muscles: implications for muscle fatigue." *Journal of applied physiology* 125 3 (2018): 820-831.

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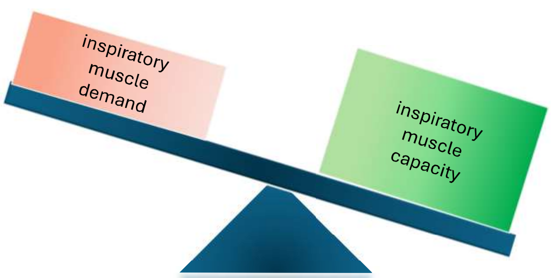
Healthy states / **"balance"**



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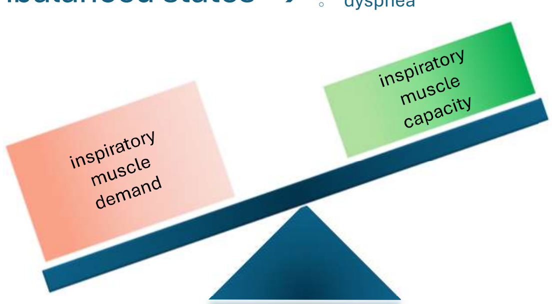
Imbalanced states →

- exercise/activity intolerance
- dyspnea



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Imbalanced States

Aging[2]
COPD[3-8]
Heart failure[6, 9-13]
Neuromuscular disease[14]
Obesity[15]
Following mechanical ventilation[16]

Evidence in favor of inspiratory muscle training

Highly trained endurance athletes[17-18]

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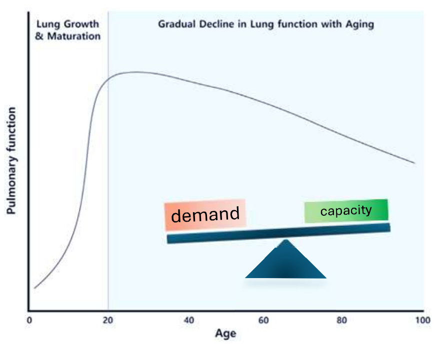
Aging

↓ functional lung volume
↓ airway flow
↓ viscoelastic recoil
↓ inspiratory muscle force



Cho HE. Understanding Changes in the Respiratory System with Ageing. Ann Cardiopulm Rehabil 2023;3(2):27-34. https://doi.org/10.53476/acpr.2023.3.2.27

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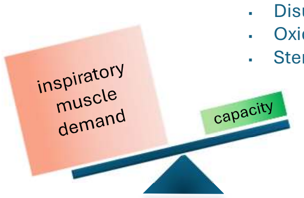
COPD

Expiratory flow limitation
Lung hyperinflation

Diaphragm shortening
Systemic muscle weakness
- Disuse
- Oxidative stress
- Steroids



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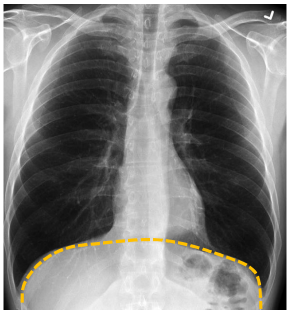

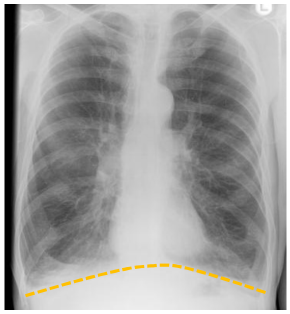

https://radiopaedia.org/cases/normal-chest-x-ray?lang=us

https://radiopaedia.org/cases/marked-lung-hyperinflation#image-537002

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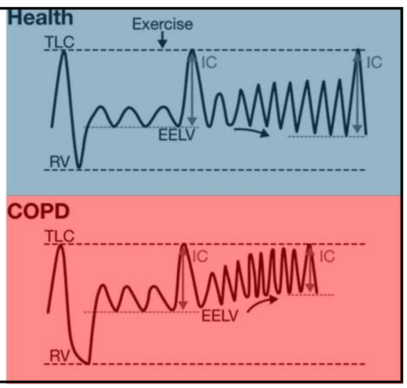
"Dynamic" Hyperinflation



Van Helvoort, WH *et al.*,
Prim Care Resp Med, 2016

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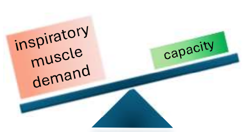
Heart Failure

Exaggerated ventilatory response
Rapid/shallow breathing

Profound and consistent respiratory muscle impairment with many suggested mechanisms



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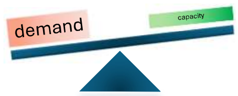
Neurological Disease

- Weakness in inspiratory and expiratory muscles
- Dependent on disease type but typically leads to restrictive patterns



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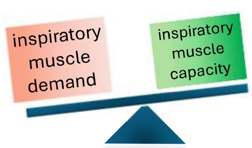
Obesity

- Respiratory system is "mechanically" overloaded
- ↓ chest wall compliance
- Worse in supine

- Inspiratory muscles may be normal or *better* than controls[16]



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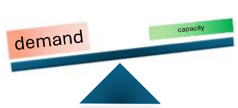
Following Mechanical Ventilation

- Diaphragm much more susceptible to disuse atrophy than limb muscles[22,23]



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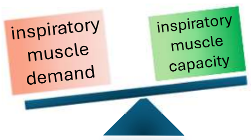
Highly Trained Endurance Athletes

↑ VO_{2max} adaptations through these systems:
- Cardiac
- Circulatory
- Muscular

"Underbuilt" respiratory system[18]



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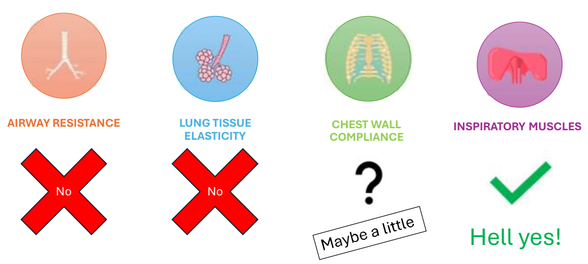
What can we optimize as rehab providers?



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How do we assess the inspiratory muscles?

Testing the inspiratory muscles is not much different than these techniques

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Maximal Inspiratory Pressure (MIP)

- Normal values depend on age, gender and body size
- Used to help prescribe load for IMT
- Monitor improvement or worsening

Analog manometer (calibrated for cmH2O)

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MicroRPM Digital Manometer

- Designed specifically for MIP and MEP
- Used in clinical and research practices for decades
- Cost ~ $1500

https://mdspiro.com/product/microrpm-respiratory-pressure-meter/

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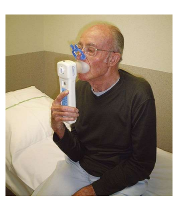
MIP Technique

- Subjects need coaching for multiple repetitions
- Requires cooperation and effort
- Seated, maximal inspiratory effort at or near RV
- Maximum of 3 maneuvers is recorded



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Maximal Inspiratory Pressure (MIP)

- Full inflation of the alveoli requires ~ -40 cm H_20
- TV breathing requires ~ -5-10 cmH_20
- Cutoff for "weakness" is generally < -60 cmH_20

Analog manometer (calibrated for cmH2O)

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Digital Manometer for $39

Curtis, J.A., Mocchetti, V. and Rameau, A. (2024), Concurrent Validity of a Low-Cost Manometer for Objective Assessments of Respiratory Muscle Strength. The Laryngoscope, 134: 1831-1836. https://doi.org/10.1002/lary.31106

https://www.amazon.com/Manometer-Professional-Pressure-Differential

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Sphygmomanometer (for free)

Don't forget to add the extra units!
1 mmHg to cmH2O = 1.35951 cmH2O

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TABLE 4
Maximal inspiratory pressure (MIP) for men and women in different age groups derived from the random-effects model used in the meta-analysis

	Men		Women	
Age group, years	Studies, n/sample size, n	MIP, cmH_2O, mean (95% CI)	Studies, n/sample size, n	MIP, cmH_2O, mean (95% CI)
18–29	6/96	128.0 (116.3–139.5)	6/92	97.0 (88.6–105.4)
30–39	6/69	128.5 (118.3–138.7)	6/66	89.0 (84.5–93.5)
40–49	6/72	117.1 (104.9–129.2)	6/71	92.9 (78.4–107.4)
50–59	5/61	108.1 (98.7–117.6)	5/60	79.7 (74.9–84.9)
60–69	5/65	92.7 (84.6–100.8)	5/66	75.1 (67.3–82.9)
70–83	5/63	76.2 (66.1–86.4)	5/59	65.3 (57.8–72.7)

Sclauser Pessoa IM, Franco Parreira V, Fregonezi GA, Sheel AW, Chung F, Reid WD. Reference values for maximal inspiratory pressure: a systematic review. Can Respir J. 2014 Jan-Feb;21(1):43-50.

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MIP Reference Equations

Men

MIP ± standard error of the estimate (SEE) = 126 − 1.028 × age + 0.343 × weight (kg) ± (22.4)

Women

MIP. ± SEE = 171 − 0.694 × age + 0.861 × weight (kg) − 0.743 × height (cm) ± (18.5).

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