Respiratory Problems in Ultramarathon Participants

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Disclosures

- Unfortunately, I have no financial disclosures.
  All my $$s go to my wife.
- This talk will include some mathematics, which may lead to fatigue, fear, ennui, or other symptoms in audience participants.
- I am a clinician, I am also not a “card carrying Physiologist”
- I am a **Pediatric** Pulmonary Specialist…

Objectives

- Discuss common pre-existing respiratory conditions in Ultramarathon runners.
  - Asthma and Exercise-induced Bronchospasm
  - Vocal Cord Dysfunction
- Discuss the effects of UltraEndurance events on the respiratory system
  - Airways
  - Respiratory muscles

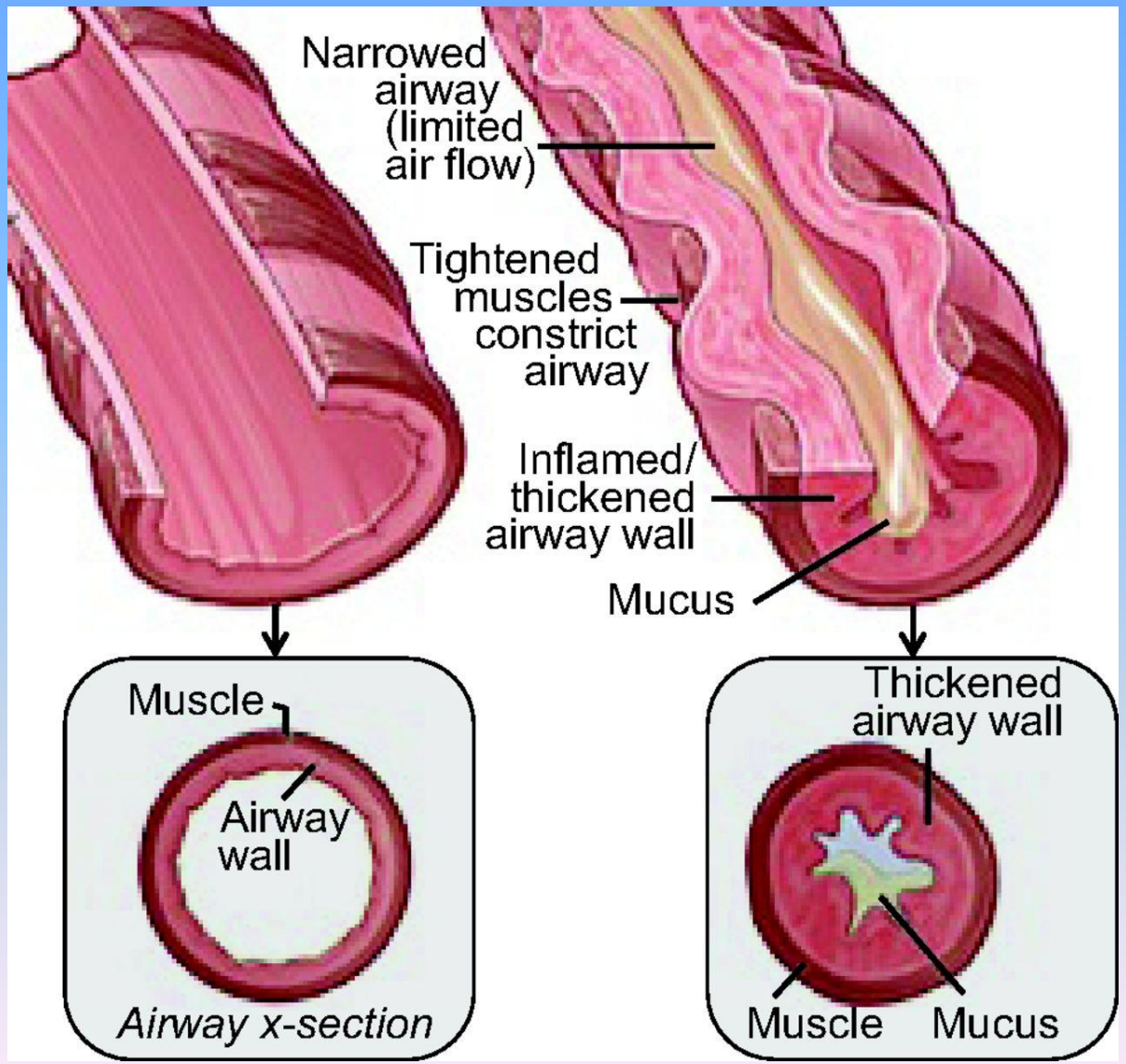
Pre-existing Respiratory Illnesses in Ultra-Runners

- Asthma
  - Common (~ 7% of adults; 8% of children)
  - Expiratory airflow obstruction
  - May occur with exercise: “Exercise Induced Bronchospasm” (EIB)
- Vocal Cord Dysfunction
  - Common…but often unrecognized
  - Inspiratory airflow obstruction
  - Most commonly occurs with exercise

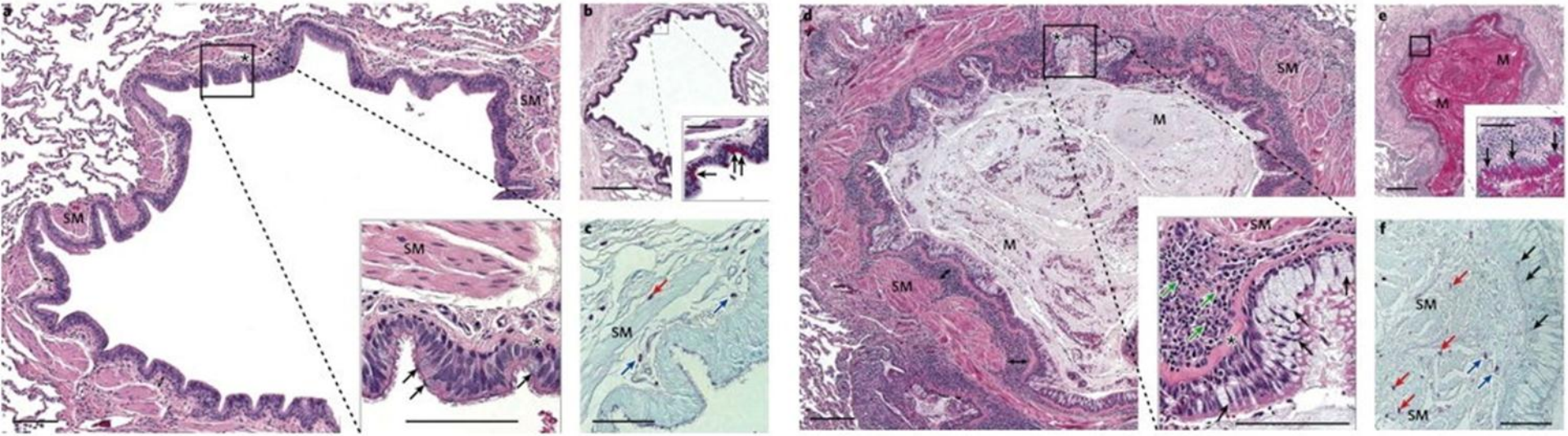
What is asthma?

- Episodic disease, characterized by airflow obstruction.
- Symptoms during episodes are typified by
  - Dyspnea/shortness of breath
  - Cough-usually “dry” and non-productive
  - Wheezing that is diffuse, polyphonic, and medium-to-high pitched during episodes.
- Between episodes, the examination is often normal.

What do airways in patients with asthma look like?



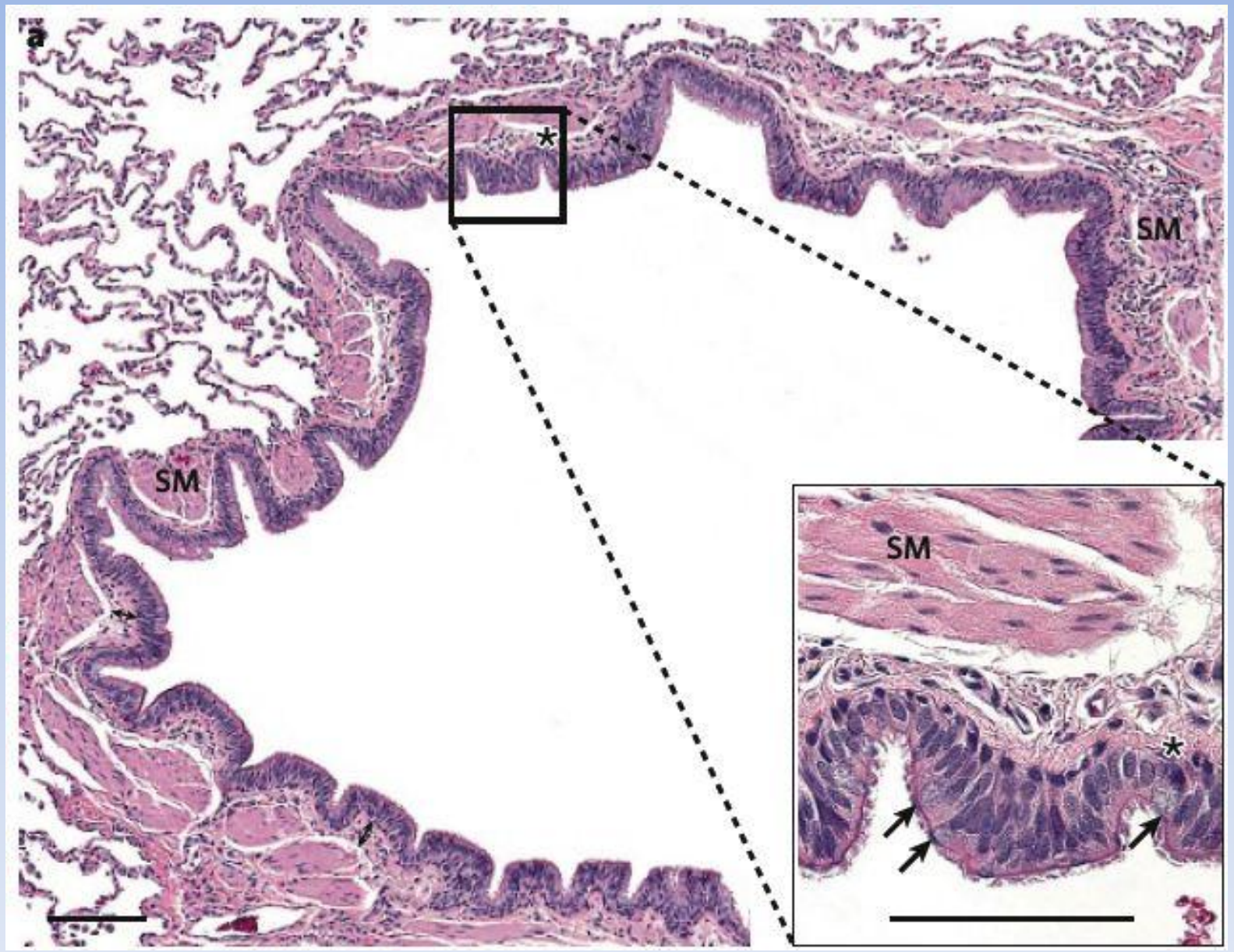
The pathology of asthma



a–c, (left panels). A normal bronchus. **d–f**, (right panel). A bronchus from a subject with severe asthma.

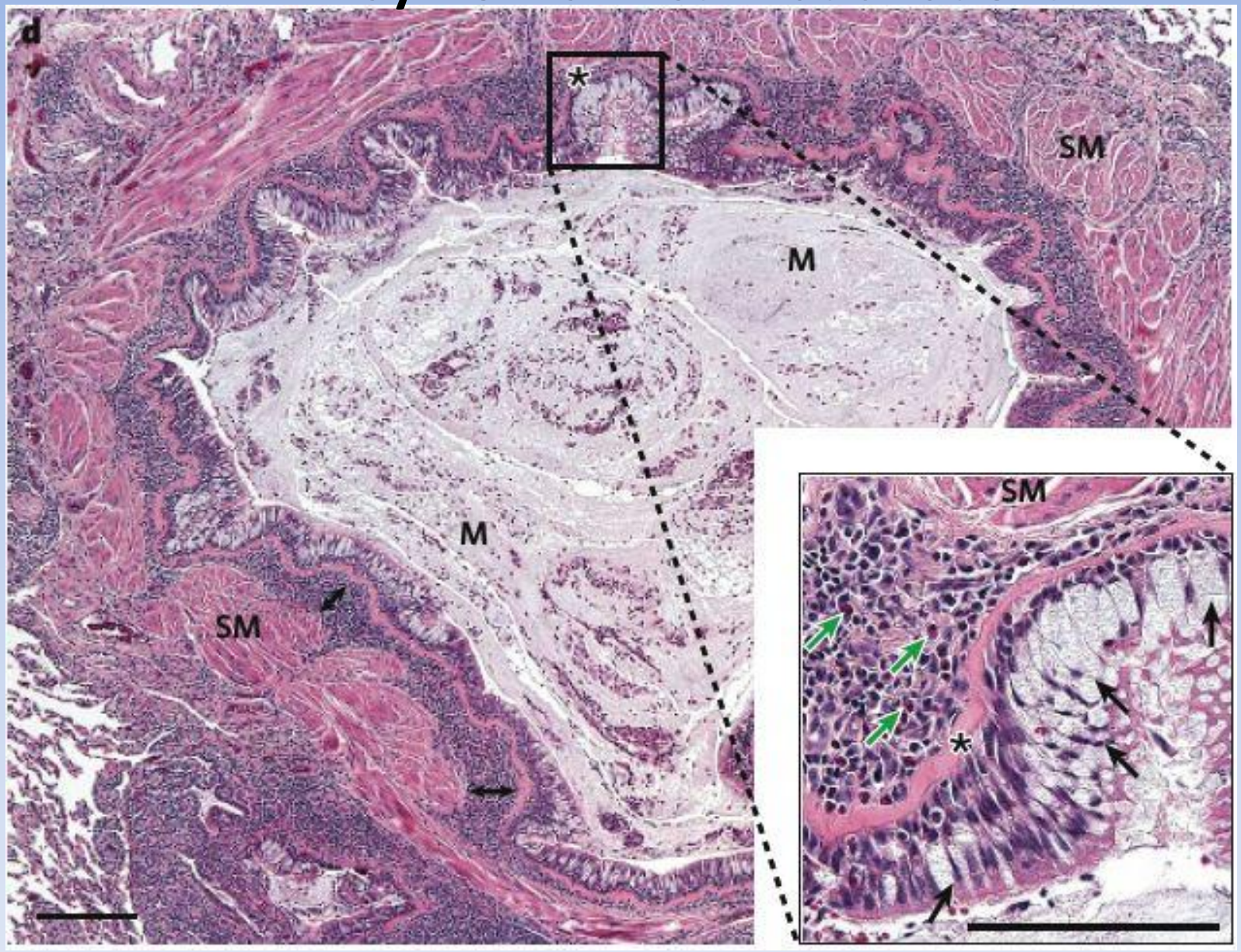
d: M, mucus; SM: smooth muscle; black arrows in inset: goblet cells; green arrows in inset: eosinophils. **f**: black arrows: intra-epithelial mast celsl, blue arrows: mast cells in submucosa, red arrows: mast cells among smooth muscle cells. Figure courtesy of GJ Berry, Stanford University, California and taken from Gally SJ et al. Nature 454: 445 (2008)

A Normal Airway



Galli SJ Nature 454: 445-454, 2008

An Airway from an Asthmatic Patient



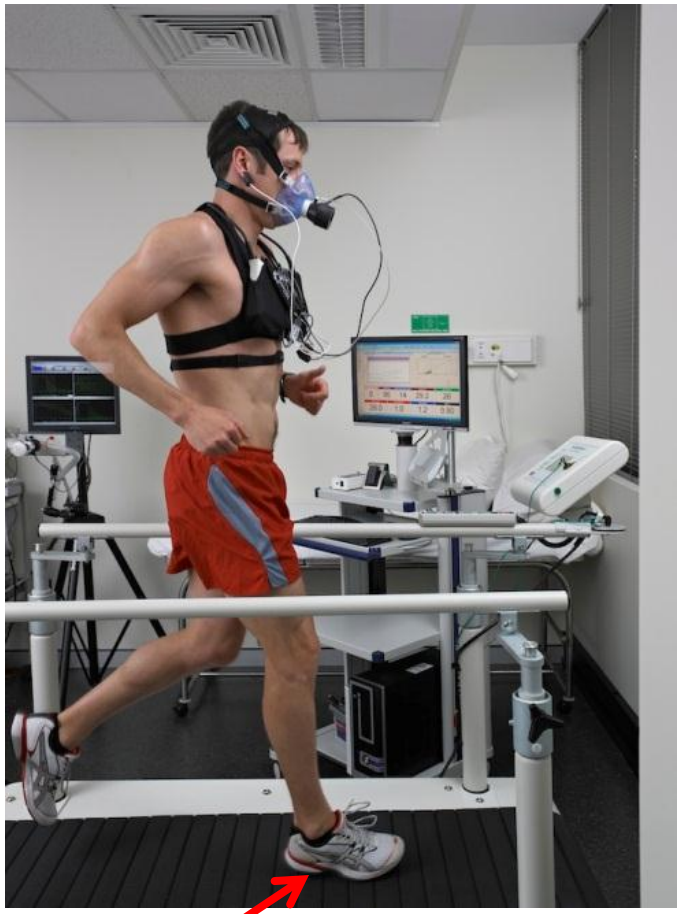
Galli SJ Nature 454: 445-454, 2008

How is asthma diagnosed?

- History, including family history, exposures, allergies…a careful history is key.
- Pulmonary function testing (“The pulmonologist’s EKG”)
- Allergy testing where indicated
- Provocative testing
  - Exercise testing
  - Methacholine or Cold Air Challenge

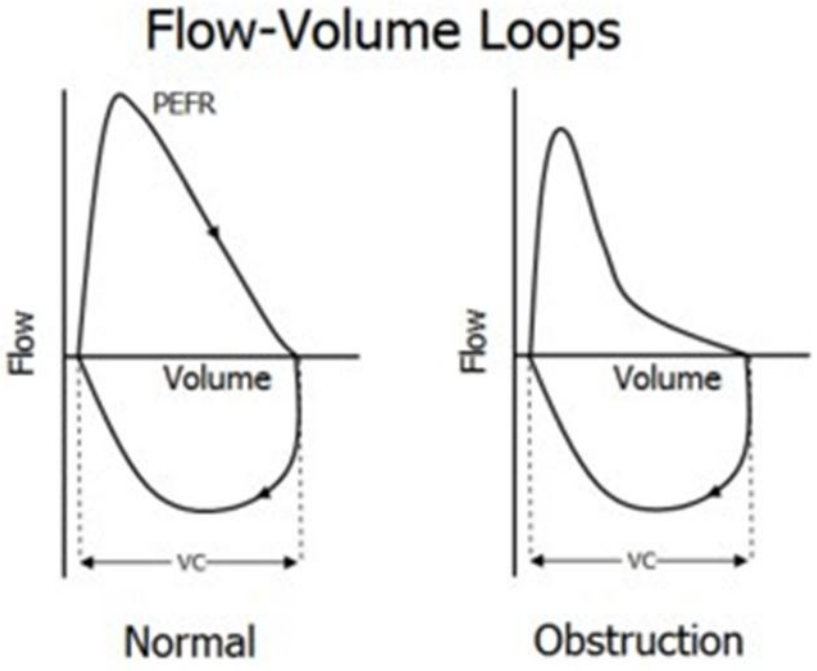
Spirometry

Exercise Testing



Underpronation?

Flow-volume loops



Exercise-Induced Bronchospasm

- Recognized for at least 2,000 years (!)
- Typically occurs after 5-15 minutes of exercise
  - Initially during exercise, the airways dilate, making breathing easier!
  - Exercise-induced symptoms tend to gradually increase
- More commonly occurs in cold, dry air
- Tends to worsen after exercise is completed or subject chooses to stop because of breathing difficulty
- Expiratory wheeze, shortness of breath
- May be prevented with bronchodilator (Albuterol) prior to exercise, or with the use of chronic inhaled corticosteroids. Montelukast (Singulair) or Zyflo also have some preventive effect.

Does EIB actually increase in athletes?

- Increased prevalence of “Exercise-induced asthma” or EIB in elite endurance athletes.
  - Larsson K BMJ 1993;307:1326–1329. (X-C skiers)
  - Helenius IJ Br J Sports Med 1998;32:125–129. (Runners, increased with atopy and cold air exposure)

Carlsen KH Allergy 63:387-403, 2008

Mechanism(s) of EIB

- Heat loss/airway cooling and fluid transfer across airway with exercise
  - McFadden ER Jr J Appl Physiol1985;58:564–570.
  - Gilbert IA. J Clin Invest 1992;90:699–704.
- Release of mediators of bronchospasm from Mast cells and other inflammatory cells.
  - Lee TH. J Allergy Clin Immunol 1994;73:634–639.

Diagnosis of EIB

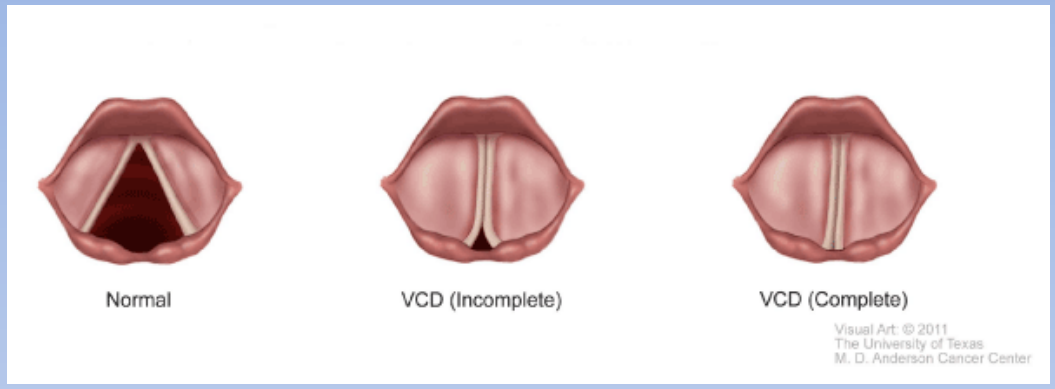
- History
- Exercise testing
- Provocative testing (Methacholine, cold air with or without hyperpnea)

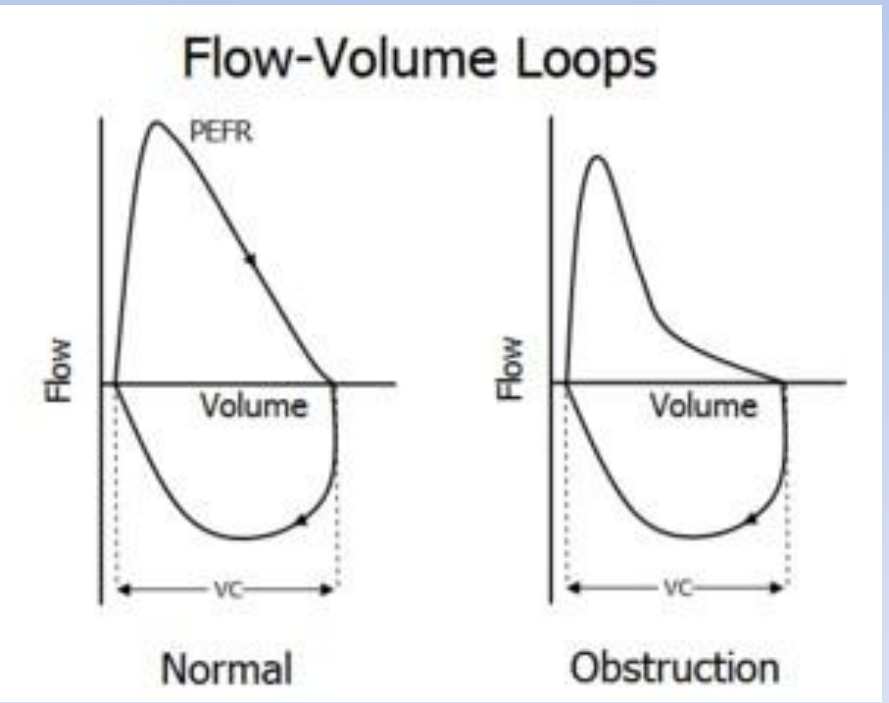
Treatment/Prevention of EIB

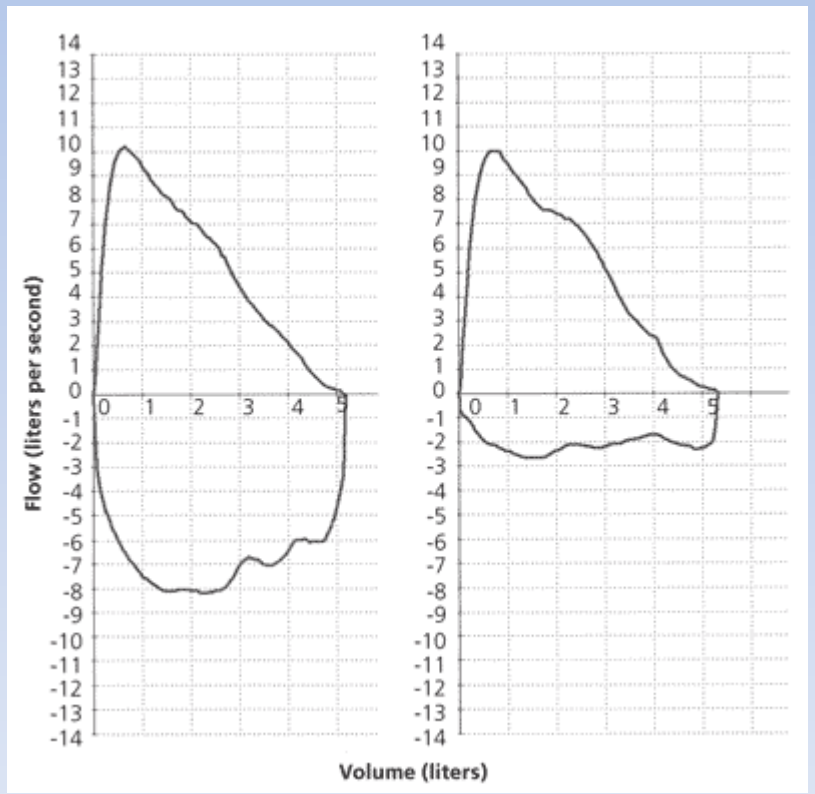
- Warm-ups
- Protection from cold air exposure with exercise (masks, etc.)
- Beta-2 agonist (e.g.Albuterol) prior to exercise
- Inhaled corticosteroids with or without long-acting Beta-2 agonist.

Vocal Cord Dysfunction

- Often masquerades as “Exercise-Induced Asthma”
  - McFadden ER Jr Am J Respir Crit Care Med 1996;153:942–947.
- Tends to occur rather suddenly, leading to difficulty with inspiration.
  - “Tight breathing” or “Airway blockage” often localized to the neck
- Usually rapidly (and suddenly) improves
- Bronchodilator may have little effect (other than “placebo effect”!)


Normal
VCD (Incomplete)
VCD (Complete)
Visual Art: © 2011
The University of Texas
M. D. Anderson Cancer Center


Flow-Volume Loops
PEFR
Flow
Volume
VC
Flow
Volume
VC
Normal
Obstruction


Flow (liters per second)
Volume (liters)

aafp.org

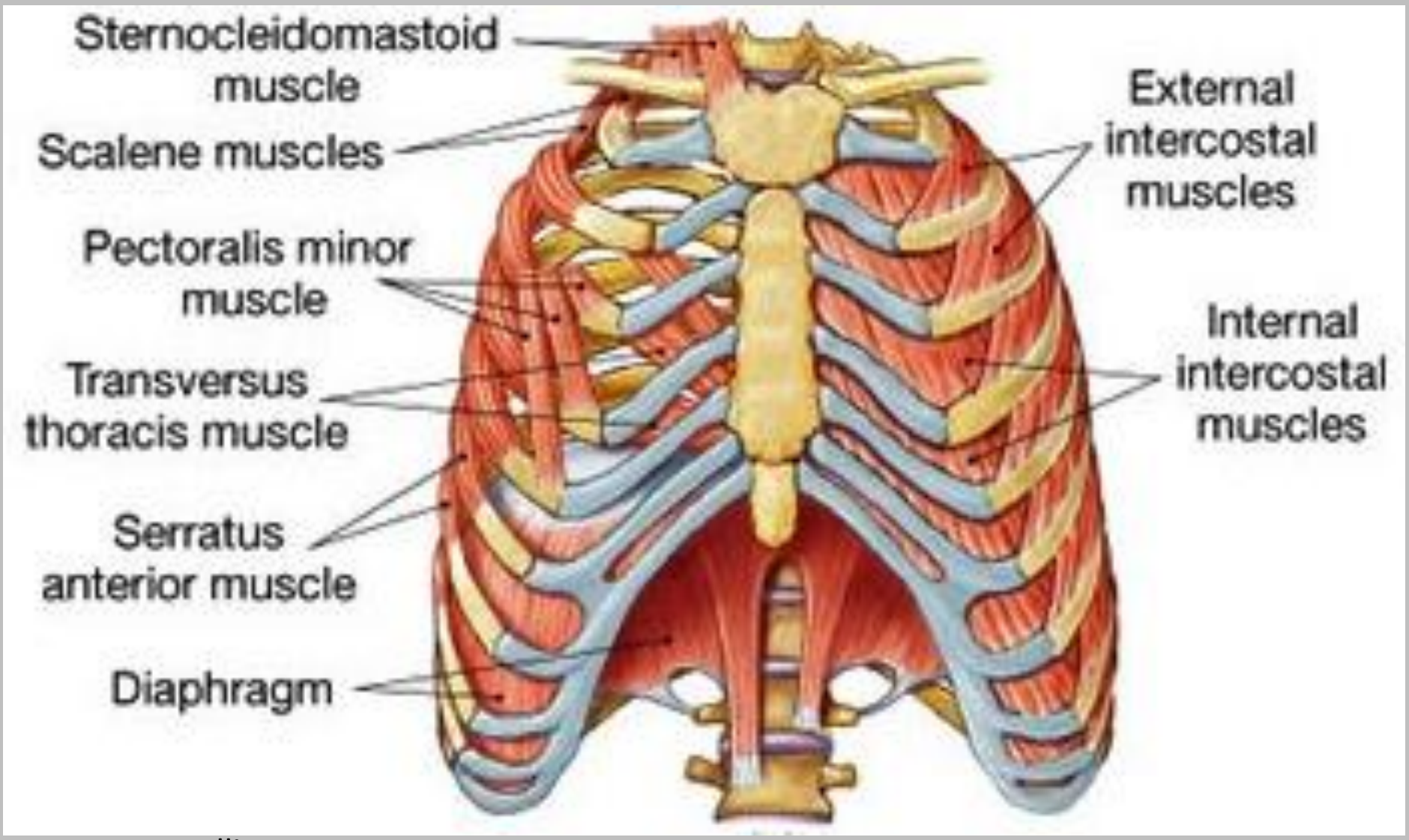
Airway problems in Ultramarathoners

- Airway irritants
  - Dust
  - Smoke (past history of forest fires along WS trail).
- Effects of hot, dry air in summer events.
  - Fluid loss
- Effects of cold air in winter events
  - Heat loss (especially strong trigger for EIB)

Respiratory Muscles

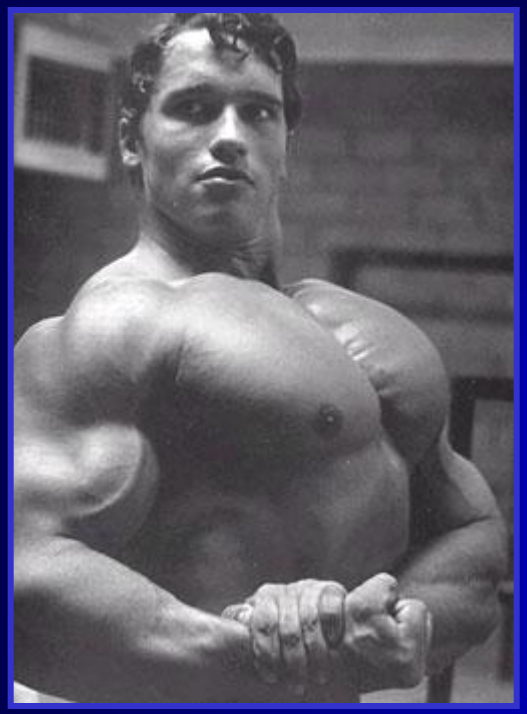
- Inspiratory
  - Diaphragm: quiet breathing
  - Alae nasi: nasal dilators
  - External intercostals: raise and expand the ribs
  - Scalenes: elevate upper ribs
  - Sternocleidomastoids: elevates the sternum
- Expiratory
  - Anterior abdominal wall
  - Internal intercostals

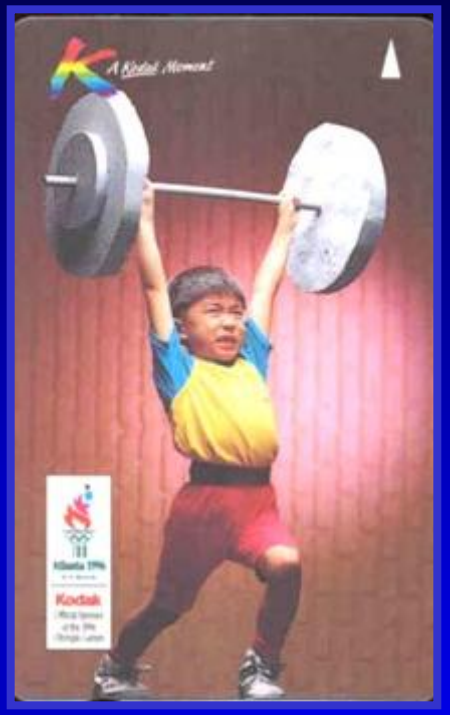
Muscles of Respiration



“How do the lungs ‘move’?”

- The lungs are completely passive, and rely on external forces, generated mainly by respiratory muscles, coupled with factors such as the elastic recoil of the lung and chest wall, in order to expand.
- Inhalation takes work.
- Expiration from lung volume higher than the “resting” volume of the lung is passive…
- Expiration requires work only as the lung volume is driven lower than the “resting” volume of the lung…or if respiratory rate and volume are increased





(Respiratory) Muscle Strength

"I'm trying to increase my lung capacity for huffing and puffing."

How can we measure the work (and strength) of muscles of respiration?

- It is difficult to separately measure the strength of the many muscle groups involved with respiration.
- Most measurements involve either non-invasive methods that measure “global” muscle strength or invasive methods that can isolate a single muscle (diaphragm most commonly).

(Respiratory) Muscle Strength

MIP/MEP

SNIP

Tw Pdi

ATS/ERS Statement on Respiratory Muscle Testing. AJRCCM 2002; 166:51-564

Respiratory Muscle Fatigue

- Respiratory muscle strength is usually measured by maximal negative pressure generation (i.e. inspiratory muscle strength).
- Strength not correlated with body mass index, height, weight, or maximum oxygen uptake.
- Following maximal running effort (shuttle run, 10-15 minutes), there is a decrease in inspiratory pressure generation.
- Percentage of pressure fall correlated i with initial strength.

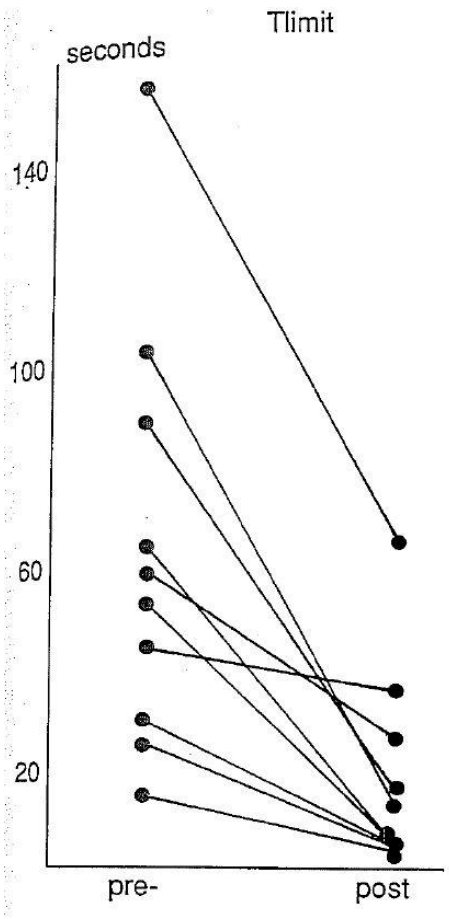
McConnell AK J Sports Med 13: 169-73, 1997

Respiratory Muscle Fatigue in Ultrarunners

- 10 runners (8 male, 2 female) studied pre- and 3 days post the “Downhill” running of the Comrades Marathon (87 km).
- MIP was used to measure strength
- For “endurance”: 75% of MIP held for 5 seconds of a 10 second “duty cycle”.
- The total time until subject unable to reach or sustain the target pressure determined the “endurance time”.

Ker JA Int J Sports Med 17: 493-496, 1996

- No difference in pre- and post-race MIP
- Significant drop in “endurance time”
- Inspiratory muscles do fatigue…



Mouth pressure with phrenic stimulation

- Measuring mouth pressure with stimulation of the phrenic nerves may be used as a surrogate marker for diaphragm strength.
- Use a mouthpiece with closed s
  pressure transducer instead of r
  transdiaphragm pressure with a
- This is called mouth twitch pres

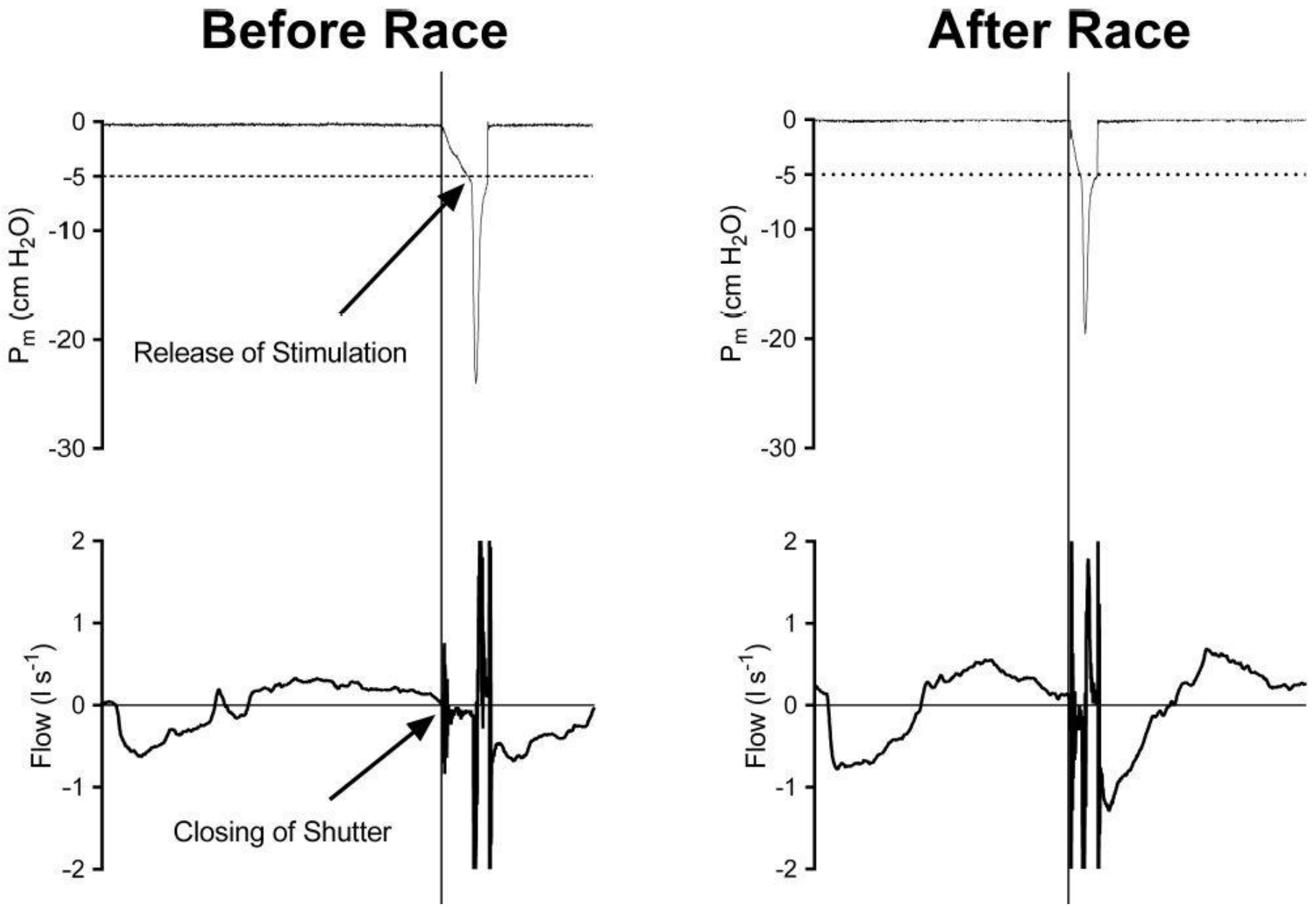
Maximum Voluntary Ventilation

- Another surrogate of respiratory muscle strength, measures the maximal amount of air that can be inspired and expired in 1 minute…although usually the test is done in 15 seconds (X4)!

Respiratory muscle strength in Ultramarathoners

- 22 ultra-trail runners (Mont Blanc) studied extensively before and after the Mont Blanc run (truncated from 167 to 110 km) in 2012.
- Pre race (1):
  - Exercise testing for maximum O2 uptake, and Lung function (with MVV)
- Pre race (2)
  - MIP and MEP
  - Mouth twitch (volitionally and with phrenic stimulation)
  - Lung function

Würthrich TU et. al. Med Sci Sports Exercise 47: 519-527, 2015



Würthrich TU et. al. Med Sci Sports Exercise 47: 519-527, 2015

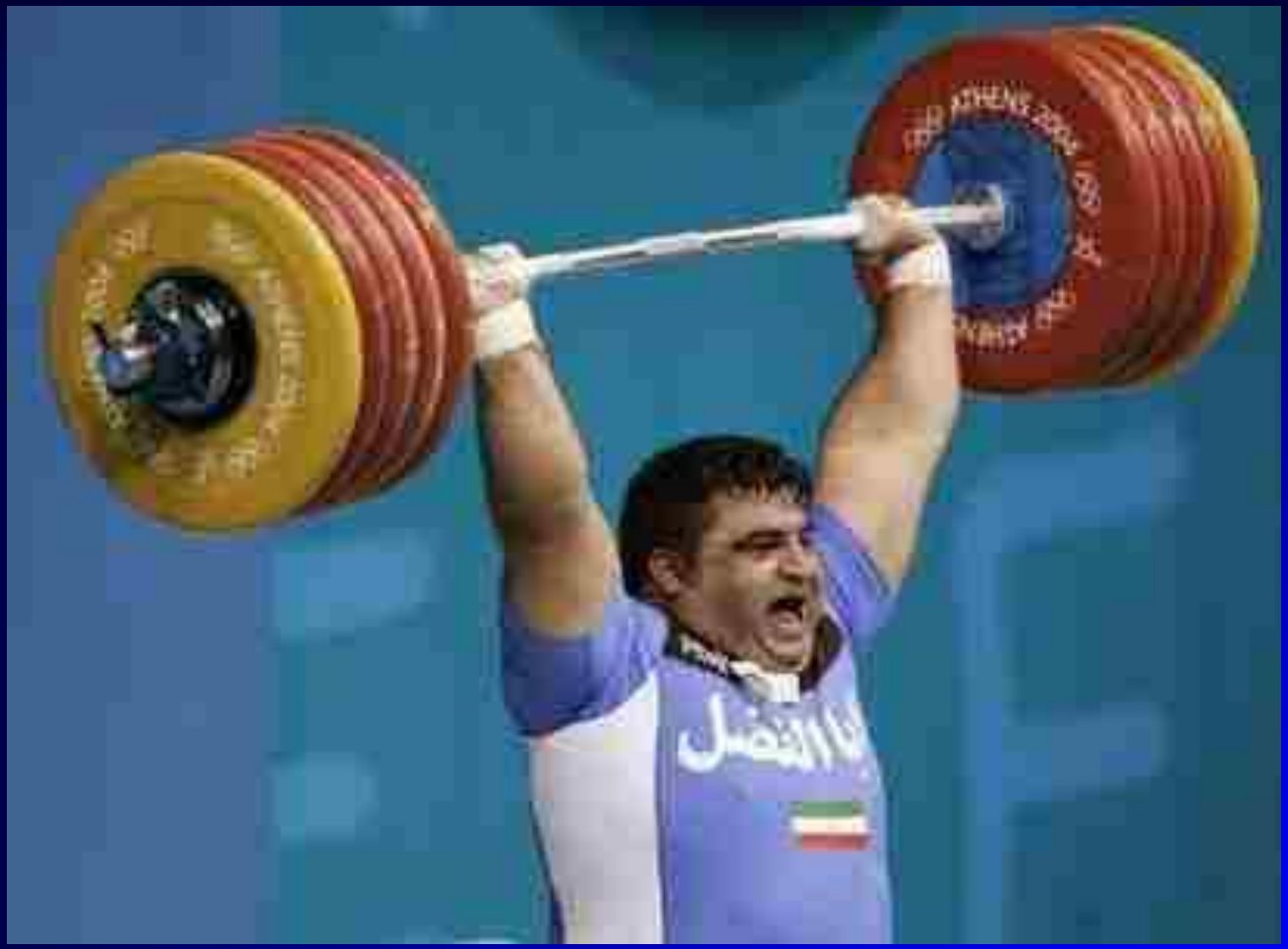
Conclusions of the Mt. Blanc study

- MIP and MEP both decreased (~15-20%) following the race
- Mouth twitch pressure (involuntary) was reduced by ~20%), suggesting peripheral muscles (not “central”=CNS_fatigue).
- MVV also significantly decreased.
- Precise reason(s) for this fatigue are not well understood.

Würthrich TU et. al. Med Sci Sports Exercise 47: 519-527, 2015

Questions Raised by Previous Studies

- Should we measure muscle strength before, during, and after a race?
- Is there a way to predict which runners might more easily develop respiratory muscle fatigue?
- Would such a study add to our understanding of muscle fatigue during ultrarunning events?



Could you do this all day?

STRENGTH *vs* ENDURANCE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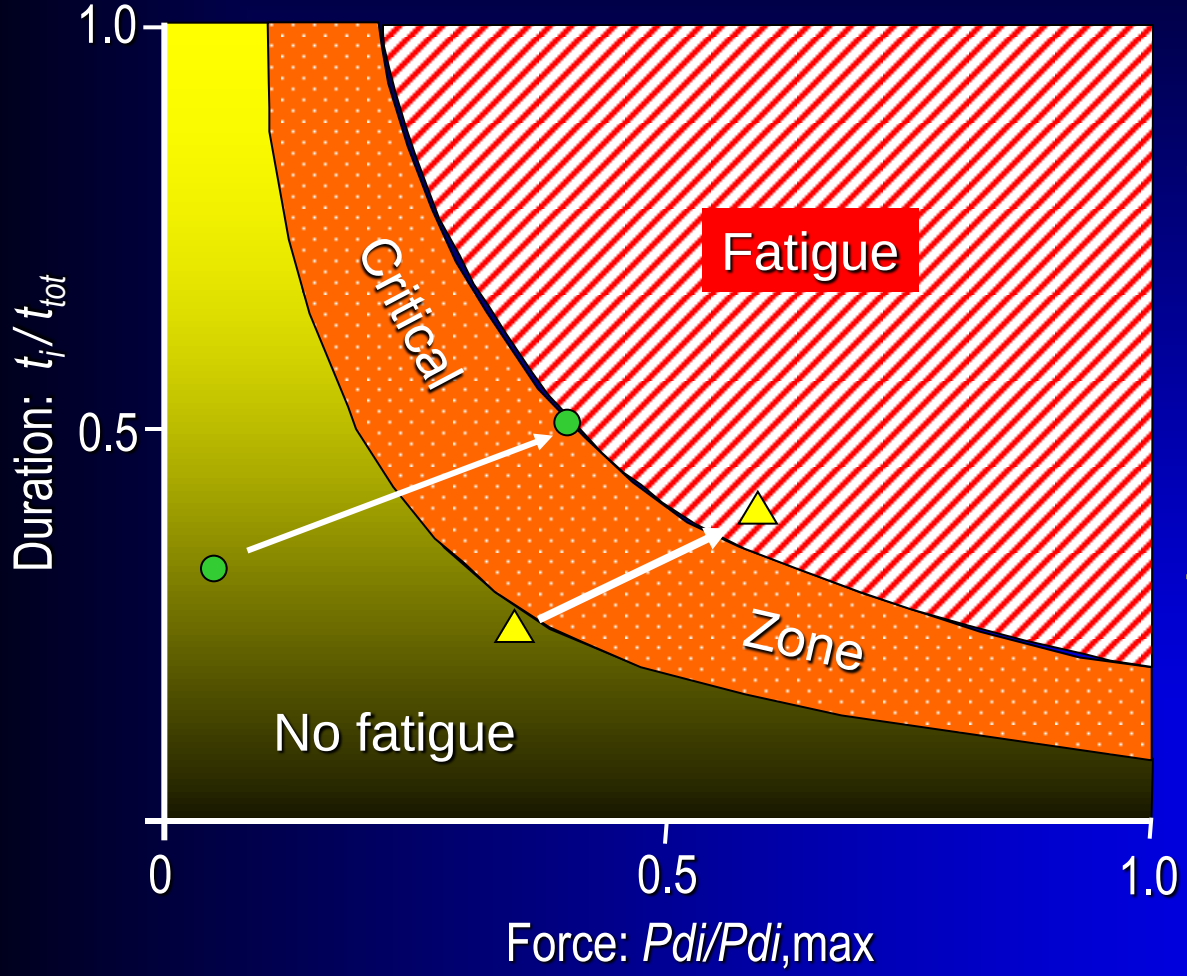
Tension-Time index (TTI) as a measure of muscle strength…and fatigue

- In general, TTI for muscle is defined as:
  - Average force developed divided by maximal force multiplied by the "duty cycle" (defined as contraction time divided by contraction plus relaxation time).
- For the diaphragm this would be:
  - P_{di}/P_{dimax} X T_i/T_{tot}
    - P_{di}= Mean transdiaphragm pressure
    - P_{dimax} = Maximal transdiaphragm pressure
    - T_i = Inspiratory Time
    - T_{tot}= Total Respiratory Cycle time.

Bellemare F et. al, J Appl Physiol 1982;53(5):1196-206

Tension Time Index of the Diaphragm



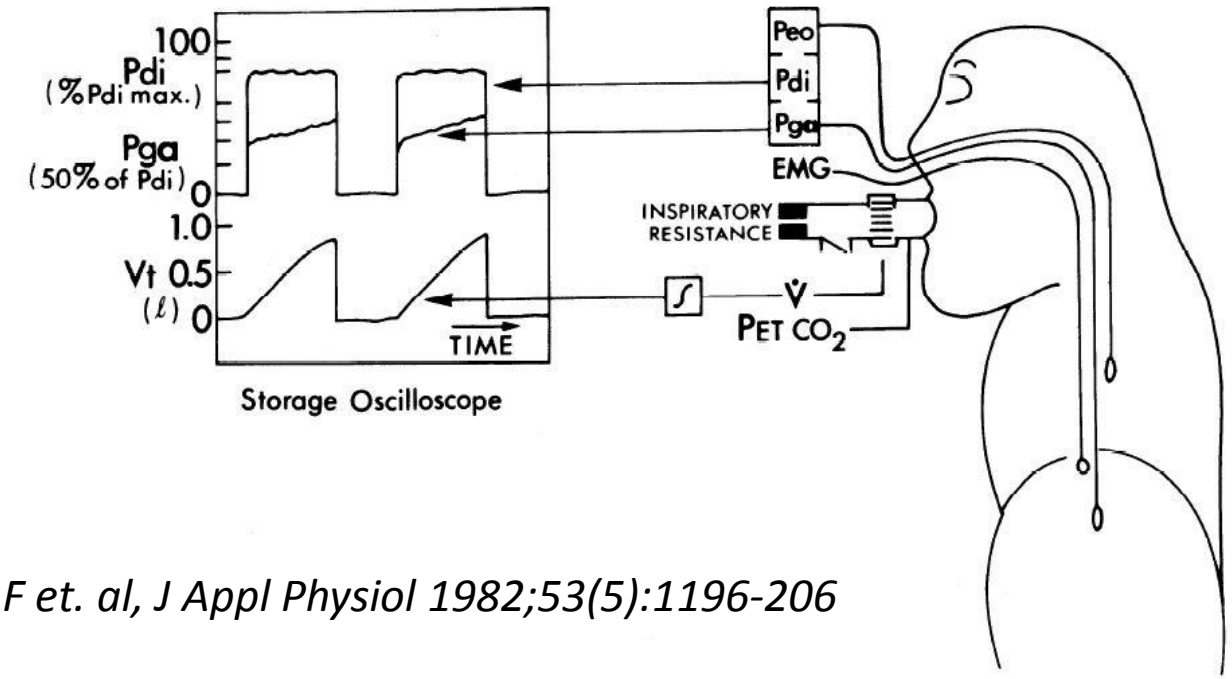
$$TTdi = (Pdi / Pdi_{max}) \cdot (T_i / T_{TOT})$$

$$T_{LIM} = 0.1\ (TTdi)^{-3.6}$$

Bellemare F and Grassino A. J. Appl. Physiol 1982; 53(5):1190-1195

Difficulties with TTI

- Placement of a nasal catheter.
- Lots of equipment.
- A willing participant!



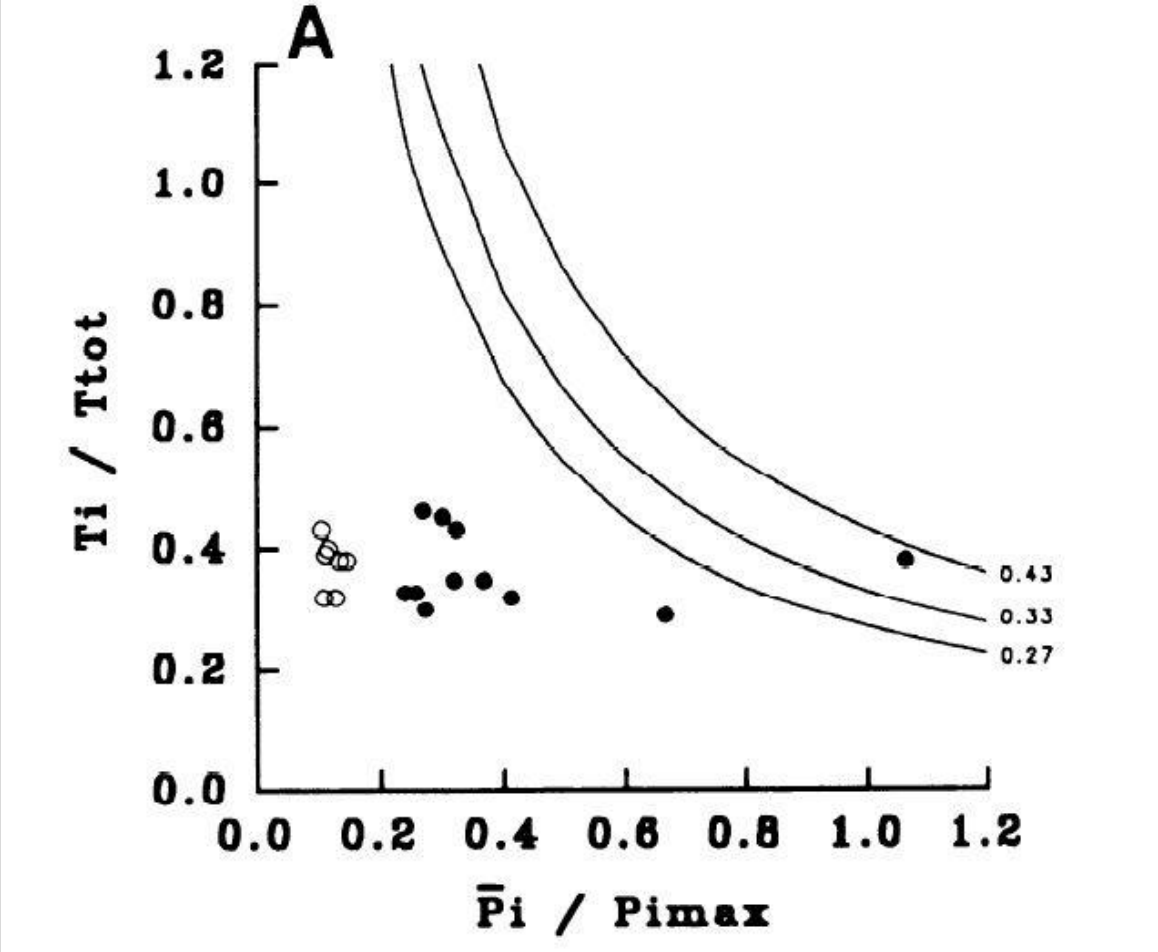
Bellemare F et. al, J Appl Physiol 1982;53(5):1196-206

TTmus as an alternative.

- A *non-invasive* technique based to measure P_I, based on P_{100}, has been described*
  - Calculated in a way analogous to the TTI
    - TTmus = (P_I/MIP) x (Ti/Ttot), where
      - » P_I mean inspiratory pressure
      - » MIP Maximal inspiratory pressure
      - » P_I and MIP are measured at the mouth
  - Likely reflects fatigue of *all* inspiratory muscles rather than just the diaphragm

* *Ramonatxo, J Appl Physiol. 1995; 78:646-653*

TTmus as an indicator of fatigue potential for respiratory muscles.



Ramonatxo, J Appl Physiol. 1995; 78:646-653

Advantages of TT_{mus}

- Non-invasive
- Less Equipment (but still some), and the equipment is movable.
- Relatively easy to do reproducibly.
- Could be used to investigate changes in respiratory muscle strength over time during an Ultrarunning event: Pre-race, 1-2 aid stations during race, and post-race.
- Predictability of muscle fatigue during race?