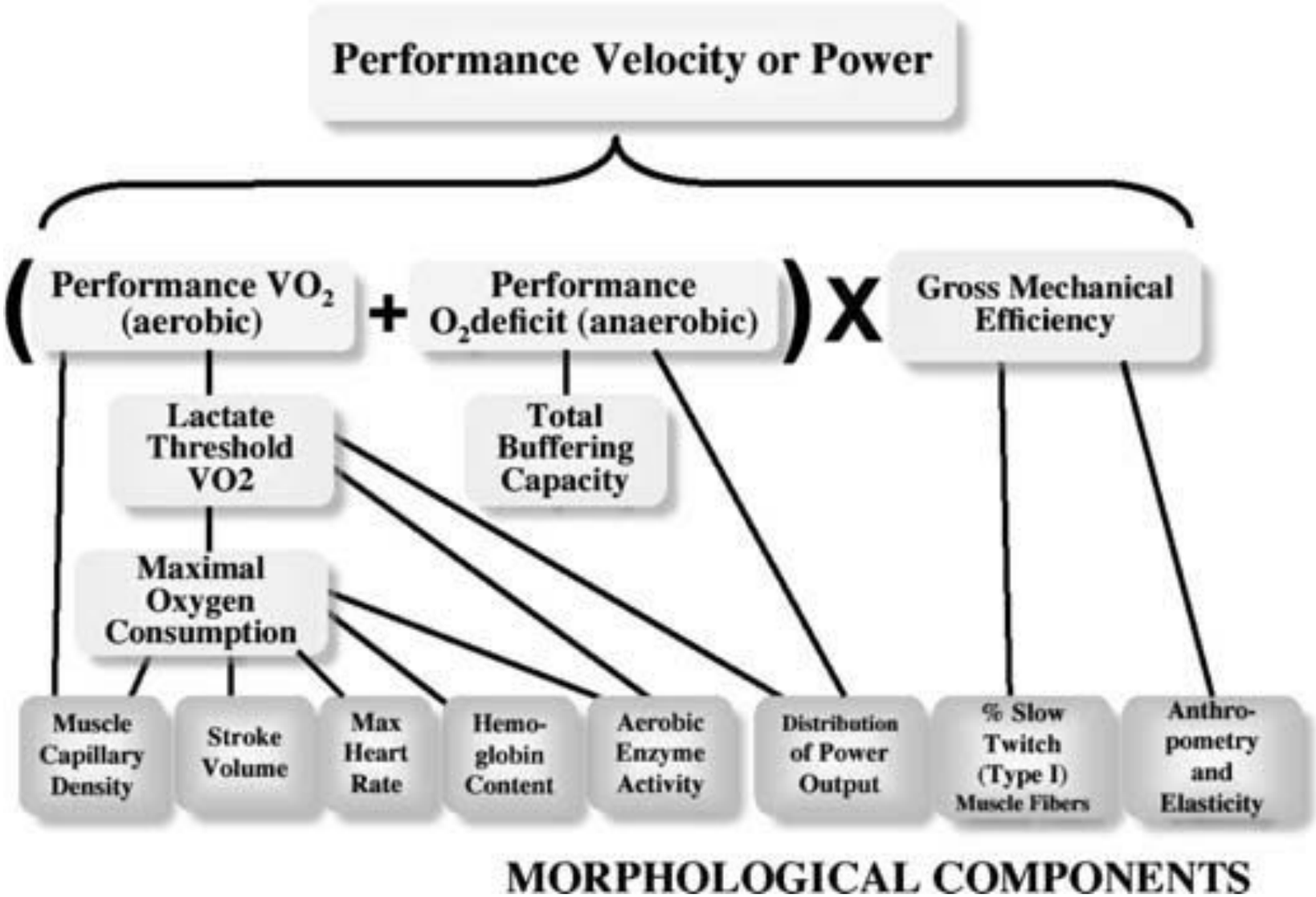
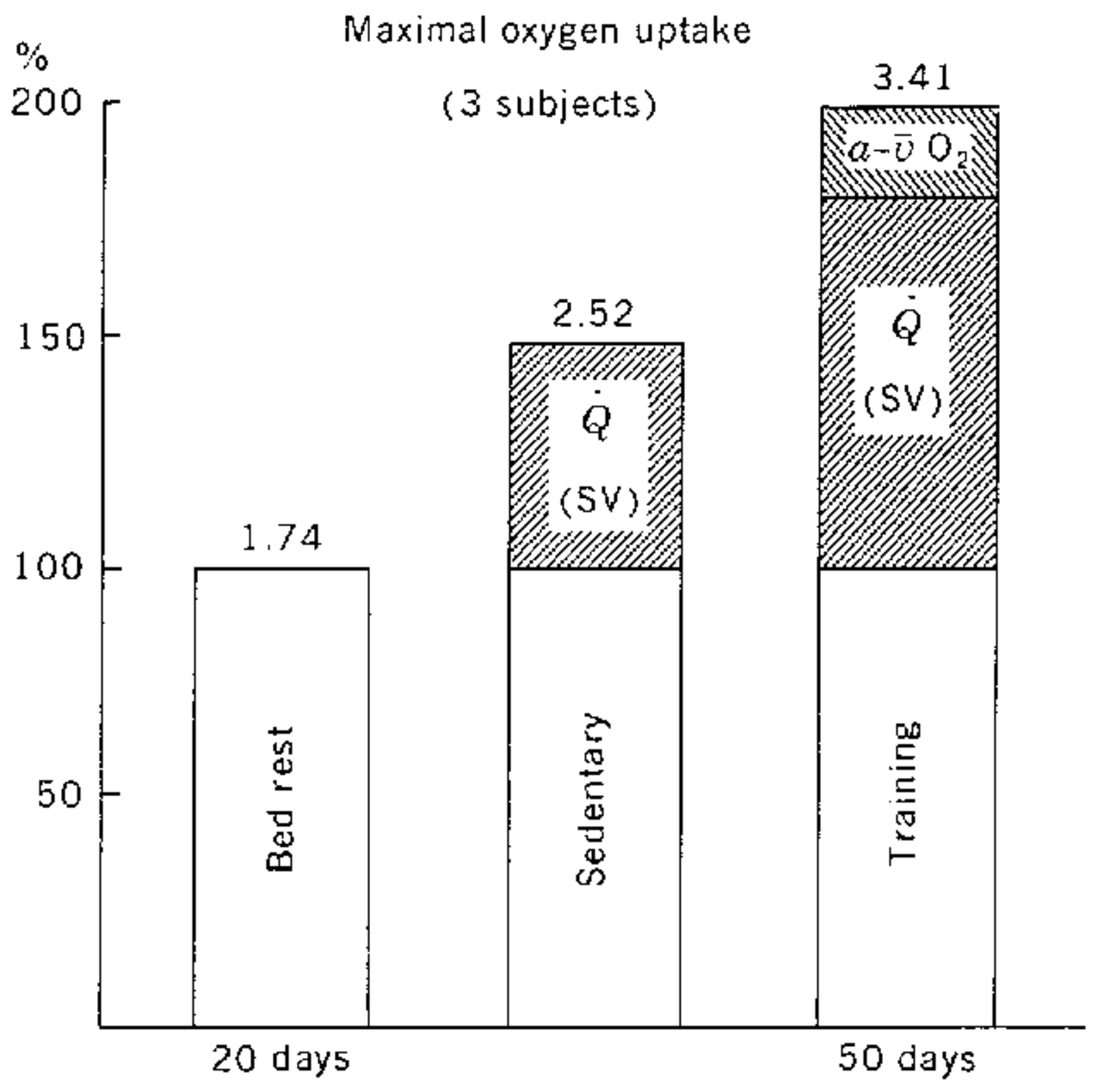
Main factors determining human endurance performance



Heart

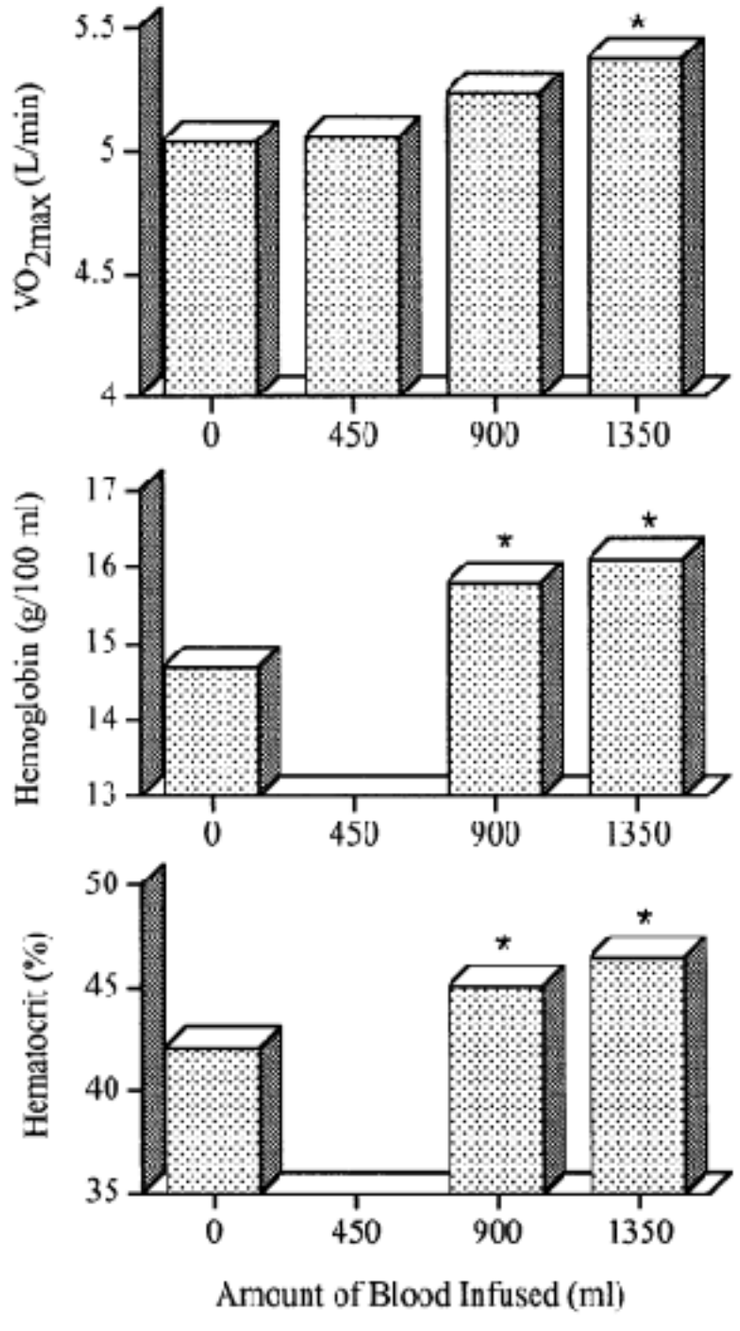
- Maximum heart rate constant
- Stroke volume increased by training
- Cardiac output = stroke volume * heart rate

—Lindhard(55)
Saltin et al, 1968, in Basset and Howley, 2000
Tesch(85) betablockers, reduction in max heart rate and resulting V02,max


Maximal oxygen uptake
(3 subjects)
%
200
150
100
50
1.74
2.52
3.41
$a-\bar{v}\,O_2$
$\dot{Q}$
(SV)
Bed rest
Sedentary
Training
20 days
50 days

Blood: Oxygen carrying capacity

- Increase blood volume by blood doping
- Higher level of VO2 max
- Is a limitation of VO2 max



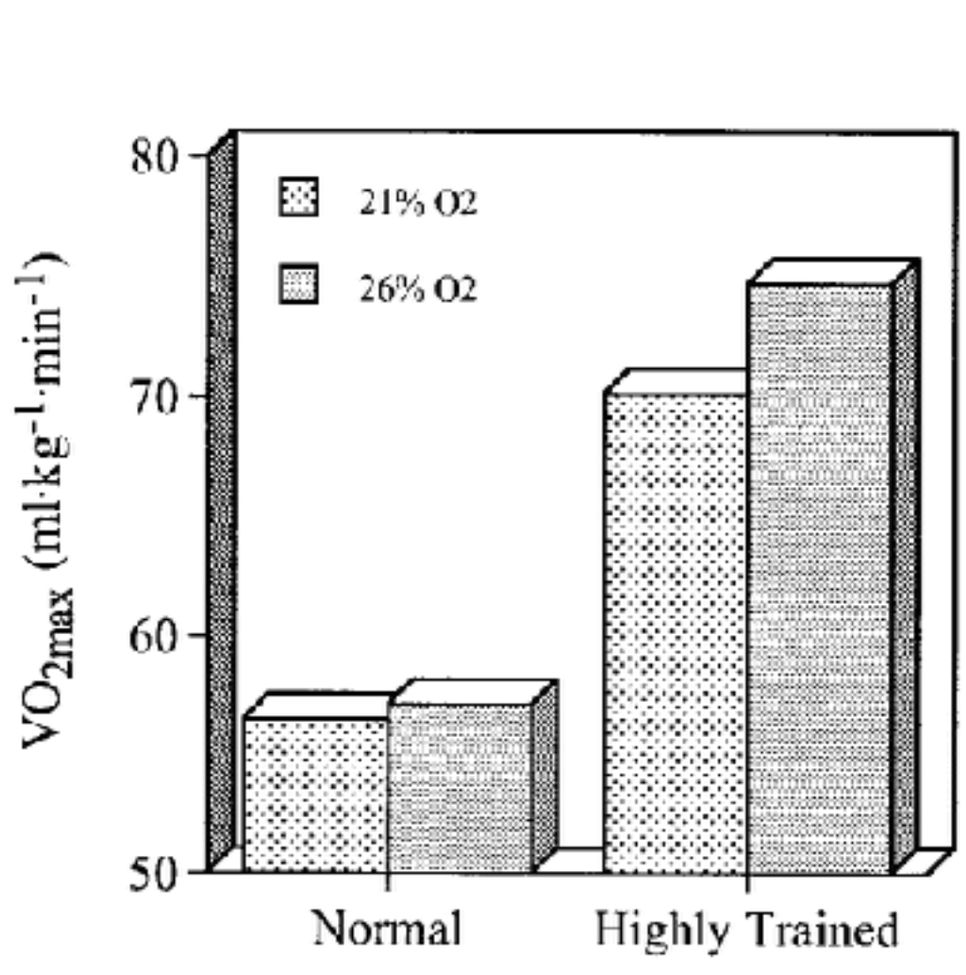
Gledhill(35,36), blood doping

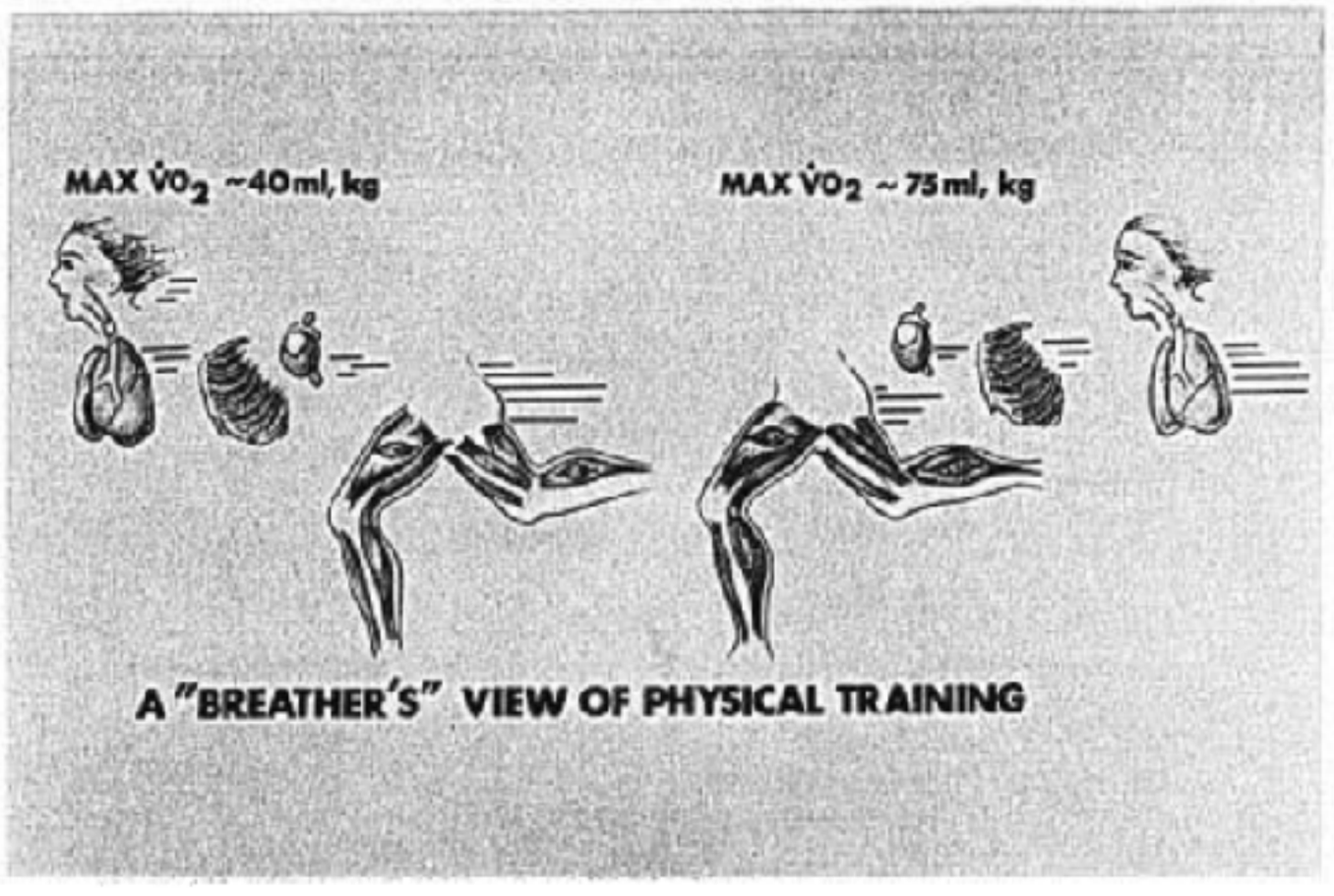
Skeletal muscle

- Oxygen extraction, mitochondria
  - 2.2 double mitochondria ≈ 20-40% VO2 max increase
  - Improve endurance performance
- Blood flow in muscles, increased by capillary density
  - Maintain transit time

Lungs

- Capacity to oxygenate blood in the time it passes through
- As the heart pumps faster, lungs has less time, and in athletes arterial desaturation of blood can occur. Dempsey and Henderson, 1984, in Basset and Howley, 2000
- Powers et al., 1989, hyperoxic air increases elite athlete VO2max, but not normal people.
- Lungs limit elite athletes VO2max, but not less trained people

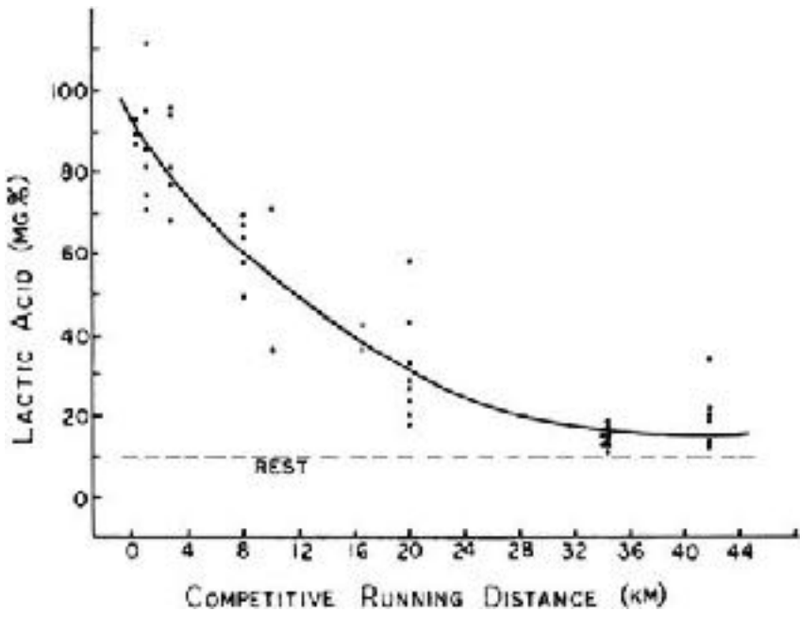


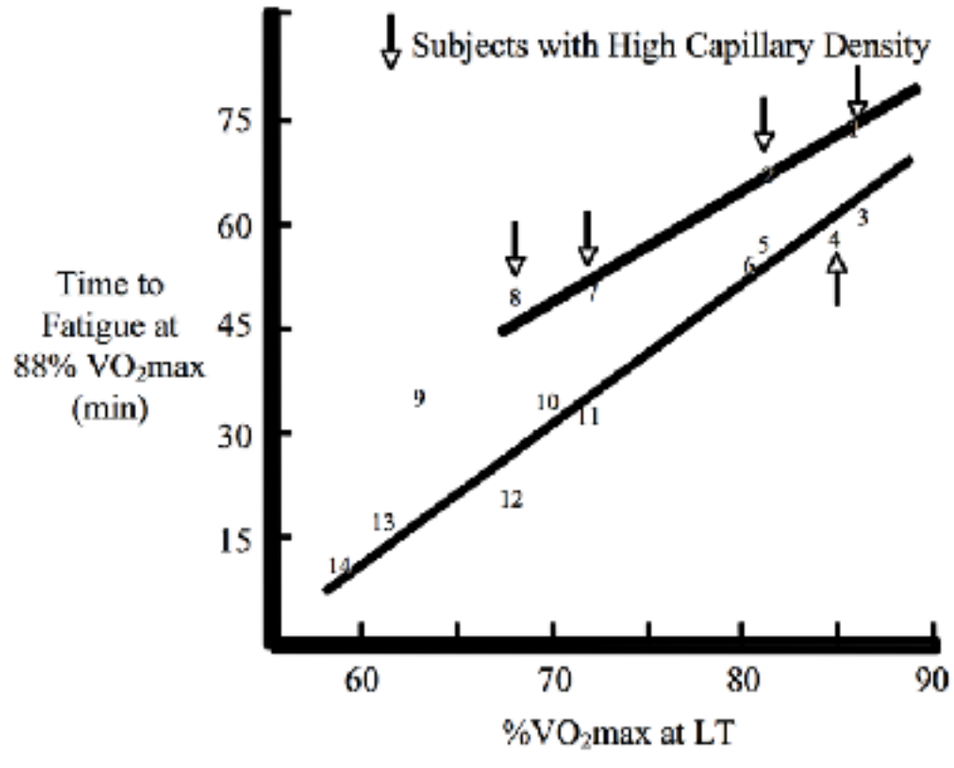


- **from Dempsey, 1986**

Working VO2, % VO2max

- Peripheral adaptations, Oxydative capacity, capillarisation in muscles
- quantity of muscle fibers recruited(coyle et at 1988, Joyner et al 2008) elite cyclists 30%
- More mitochondria gives less deviation from homeostasis,
- Evidence for LT, Coyle 1995, in Joyner et al, 2008, cyclists with same VO2max have different time to exhaustion





Economy/efficiency

- Big difference in speed and power between runners and cyclists with same % VO2max and
  VO2max (Joyner, 1991, in Joyner & Coyle, 2008), which explains that there must be another
  factor affecting human endurance performance
- Efficiency=how much speed/power (watts) can be generated for a given oxygen consumption?
- Oxygen cost at a given speed in endurance running can vary 30-40%
  (Joyner, 1991, in Joyner & Coyle, 2008)
- Oxygen cost at a given power output in endurance cyclist may vary 20-30%
  (Coyle, 1995, in Joyner & Coyle, 2008)
- Daniels&Daniels, 1992, in Basset & Howley, 2000 showed that running velocity varied between
  individuals with the same Vo2max
- Higher percentage of type 1 muscle fibers is one proposed mechanism in endurance trained cyclists
  (Coyle et al, 1992, in Joyner & Coyle, 2008)
- In cycling: lower force per contraction? Strength?
- Factors affecting running economy: fiber type and
- Is economy trainable, and how much? Two case reports showing running and cycling economy
  improves in elite athletes over the course of years

Unanswered questions

- Determinants of efficiency, especially for running
- How important are genetic markers for performance?
- «There are a number of studies showing that key elements of the response to training in sedentary persons is widely variable and has a genetic component» (Rankinen et al. 2006, in Joyner & Coyle, 2008, p. 42).
- Reports suggesting angiotensin converting enzyme (ACE) gene is over represented among elite endurance (Joyner & Coyle, 2008)
- «...to date there are no genetic markers identified in humans that have been clearly shown to be more frequent in elite endurance athletes» (Rankinen et al. 2000, in Joyner & Coyle, 2008, p. 42).