Eat Smart, Train Smart - Part II
Physiological Testing for Cycling

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Overview

- Maximal aerobic capacity – Max VO2
- LT or AT (VT)
- Why test?
- What does it tell us?
- How do we use the information?
- Lance Armstrong physiology
- Body composition – facts and fallacies
- Evaluating the tools

Pre-test: Who wins?

- Jim has a high VO_2 max but a moderate LT
- John has a moderate VO_2 max but a ridiculously high LT
- Being the same size and weight, who would likely find himself victorious in a head to head race up L’Alpe d’Huez?

Max VO_2 = Aerobic Capacity

The amount of oxygen that can be taken in and utilized during activities performed continuously. Maximum oxygen utilization is termed "VO_2max". This is trainable (*e.g. heart, lungs, blood vessels and muscles*).

SYNONYMS: maximal oxygen uptake, maximal aerobic capacity, maximal functional capacity, max METS (MMETS).

Max VO2 testing:

How does it work?

- staged
- progressive
- voluntary exhaustion
- plateau in 02 consumed
- repeatable

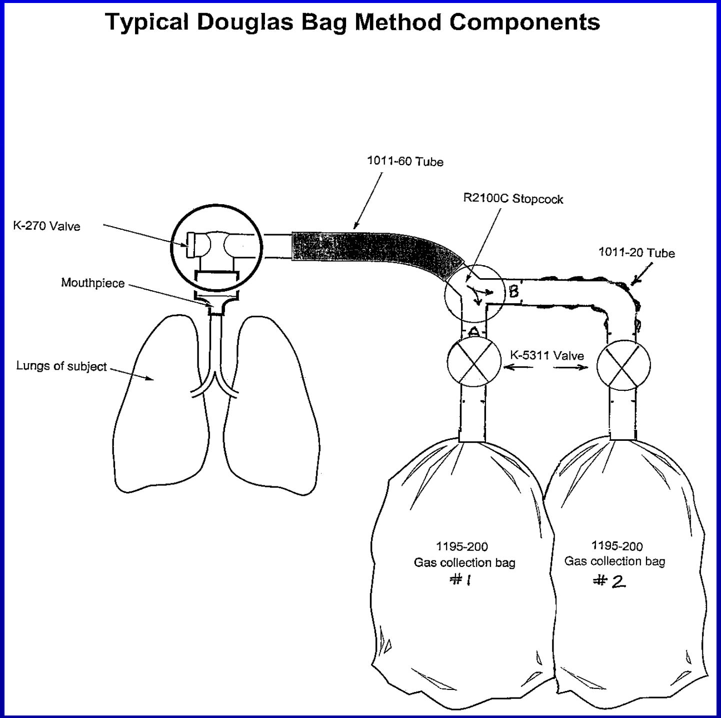
It is a performance test
not a diagnostic test

Max VO2 testing:

What is going on here?

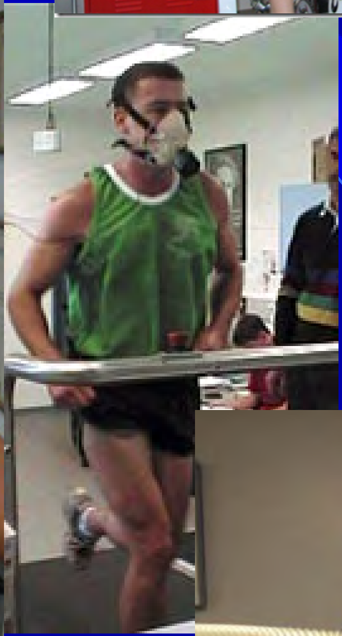
Max VO2 testing:

Technology advances



Max VO2 testing:

Headgear



Max VO2 testing:

Flow advances

Why Test?

1. Education for the individual and coach
2. Sport specific training programs
3. Used to assess <u>progress</u> within a training program
4. It will not predict success
5. Individual 5 zone heart rate training profile

Effective Testing

1. Tests are valid and reliable
2. Uses sport-specific protocols
3. Controlled lab environment
4. Goal: Train smarter not harder

AEROBIC

"with oxygen"

Easy
Steady state
Feeling good

ANAEROBIC

"without oxygen"

Hard
The Burn
Rubber legs
Lactic Acid

Factors affecting VO2max

There are four primary factors that can affect VO2max:

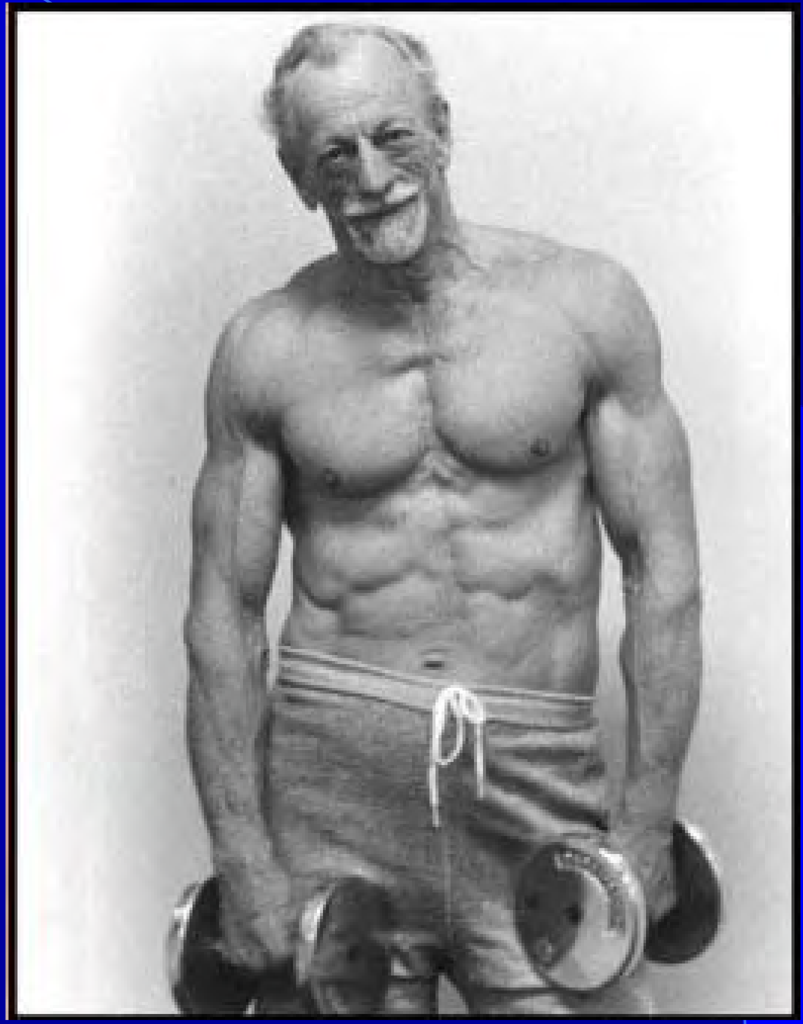
- altitude
- age
- gender
- genetics

Altitude

- An increase in altitude results in a decrease in air density
- Decreases the partial pressure of oxygen in the air
- Therefore, you can expect a 5-7 % loss in VO2max from sea level to 5,000 ft
- 10% loss for every 3300 ft above that

Age

- Peak physiological function occurs at about 30 years of age
- VO2max decreases approximately 30 percent between the ages of 20 and 65
- Greatest decline after age 40
- However, decreases in VO2max can be extremely variable and can (at least partially) be offset by training



Gender

- Females have lower VO2max values than males (15 percent to 20 percent less)
- Differences in body composition, hemoglobin content in the blood, and heart size
- Females, on average, have a higher percentage of body fat, lower content of hemoglobin in their blood, and have a smaller adaptation of heart size in response to endurance and resistance training
- It is important to note that these differences are "in general" - there are always exceptions

Genetics

- Approximately 80 percent of an individual's VO2max is genetically determined
- Depending on your current training level, VO2max may be enhanced through progressive endurance training
- Untrained individuals have the potential to increase their VO2max by 15-20 percent
- Well-trained athletes are unlikely to realize an increase in VO2max of greater than 3-5 percent

Absolute and relative VO2max values of untrained, moderately trained, and elite aerobic individuals

Females

Training status	Untrained	Trained	Elite
Absolute VO2 (l/min)	<3.0	3.0-	>3.0
Relative VO2 ml/kg/min	26-42	40-60	55+

Costill, D.L. and Wilmore, J.H. (1994).Cardiorespiratory Function and Performance. Physiology of Sport and Exercise.Champaign, IL: Human Kinetics.

Absolute and relative VO2max values of untrained, moderately trained, and elite aerobic individuals

Males

Training status	Untrained	Trained	Elite
Absolute VO2 (l/min)	<3.0	3.5-	>4.0
Relative VO2 ml/kg/min	36-52	50-70	60+

Costill, D.L. and Wilmore, J.H. (1994).Cardiorespiratory Function and Performance. Physiology of Sport and Exercise.Champaign, IL: Human Kinetics.

Highest Max VO2 ever?

- Male = 94 ml/kg/min
- Female = 77 ml/kg/min
- Both were cross country skiers

Astrand P-O and Rodahl K. (1986) *The Textbook of Work Physiology: Physiological Bases of Exercise (3rd ed.).* New York: McGraw-Hill

Is VO2 the ultimate predictor of performance?

- If you've been training hard for the past year and your VO2max is in the 50's, don't expect a VO2 of 70 ml/kg/min
- The good news is that your lactate threshold is highly trainable, and elevating your LT will improve performance
- Since many elite athletes share comparable VO2max values, lactate threshold is often a better measure of endurance performance

Lactate Threshold?

- Lactate is a by-product of anaerobic metabolism
- Despite common misconception, is produced across all exercise intensities
- In fact, even when you stand up from sitting in a chair, lactate acid is produced

Lactate Threshold

- The key in sport is the balance between the rate of lactate production and lactate absorption
- During light and moderate-intensity exercise, the blood concentration of lactate remains low
- The body is able to absorb lactate faster than the muscle cells are producing it

Lactate Threshold

- As intensity increases lactate removal fails to keep up with the rate of lactate production
- This point is referred to as the lactate threshold (LT)
- The beginning of the end of high intensity exercise
- Excessive blood lactate interferes with muscle contraction
- Power output drops, suffering increases and you are forced to slow down

Factors that affect the rate of lactate accumulation

- **Exercise intensity -** The harder you work, the more lactate your active muscles produce
- **Diet -** Low glycogen stores increases lactate
- **Training status -** Proper training develops four primary mechanisms to slow the rate of lactate accumulation
  1. Higher mitochondrial density allows for greater lactate resynthesis
  2. Superior fatty acid oxidation prevents lactate production at submaximal exercise intensities
  3. Your body will preferably burn fat over glycogen and this will preserve your glycogen as a fuel source for continued exercise
  4. Greater capillary density improves both oxygen delivery to and lactate removal from the active muscles

Factors that affect the rate of lactate accumulation

- **Muscle fiber type -** Slow twitch (Type I) muscle fibers produce less lactate at a given workload than fast twitch (Type II) muscle fibers. Although there is a big genetic component, proper training can influence the proportion of slow vs. fast twitch muscle fibers
- **Distribution of workload -** A large muscle mass working at a moderate intensity will produce less excess lactate that a small muscle mass working at a high intensity

Where do you stand?

- Untrained individuals usually reach LT at about 60 percent of their VO2MAX
- Moderately trained athletes reach LT at 65-80 percent VO2MAX
- Elite endurance athletes have a very high LT relative to their VO2MAX . They are able to ride at 85-95 percent VO2MAX (they make a living riding bikes)

Quiz result

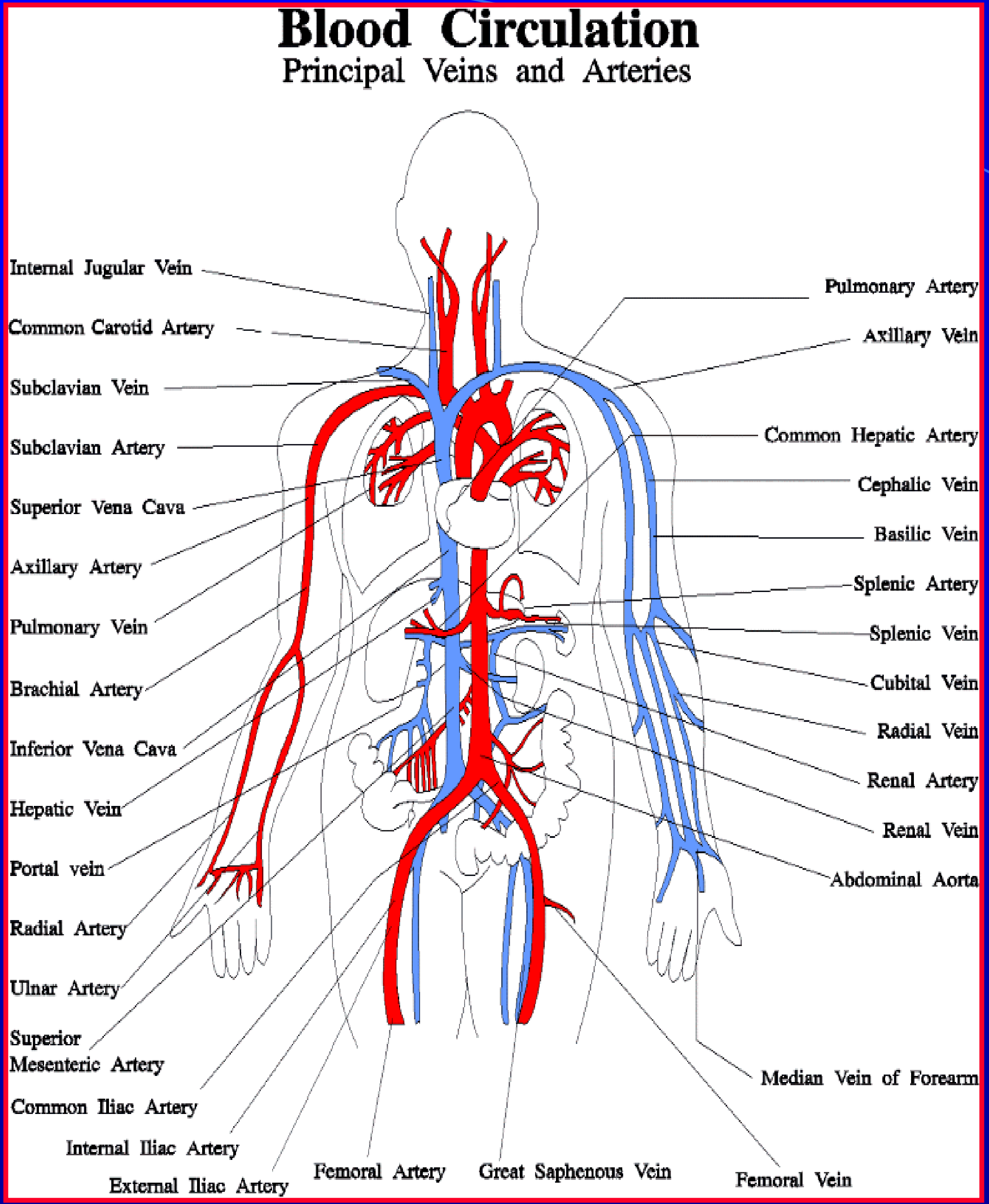
- Remember our two cyclists Jim and John?
- Jim had a high VO2max but a moderate LT, and John had a moderate VO2max but a ridiculously high LT
- Being the same size and weight, John would likely find himself victorious in a head to head race up L'Alpe d'Huez.

How do we improve aerobic fitness? Central vs. Peripheral

- Central (heart and lungs) focus on the core and delivery mechanism

  "Presentation theory"
- Peripheral (O2 extraction and lactate removal at the muscle level)

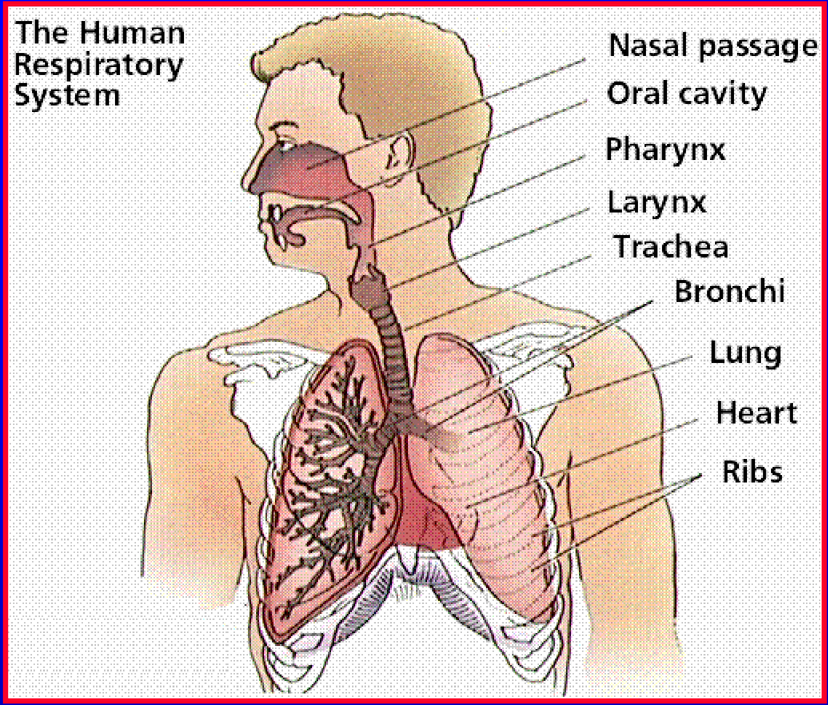
  "Utilization theory"



Circulatory System

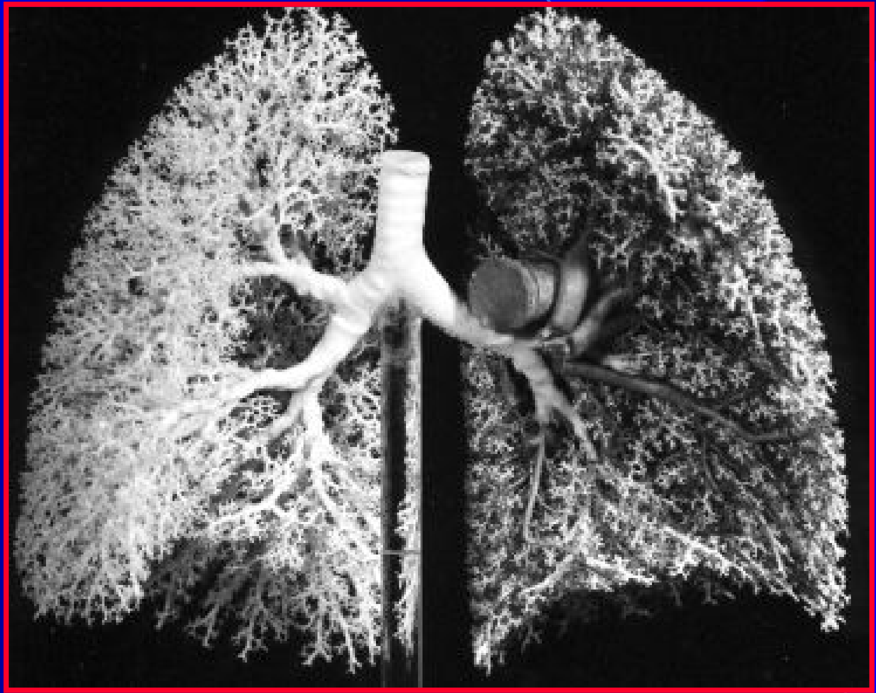
1. Three varieties of blood vessels:
   a) **Arteries** – blood away from the heart; deliver oxygen rich blood
   b) **Veins** – blood to the heart; carry waste-rich blood back to the heart
   c) **Capillaries** – connect arteries and veins; site where oxygen is exchanged for carbon dioxide
   d) Lots of "plumbing":
      I. **Children** – 60,000 miles
      II. **Adults** – 100,00 miles
2. Heart – the pump
3. Red blood cells carry O2 from the lungs to all the cells of the body

Respiratory System



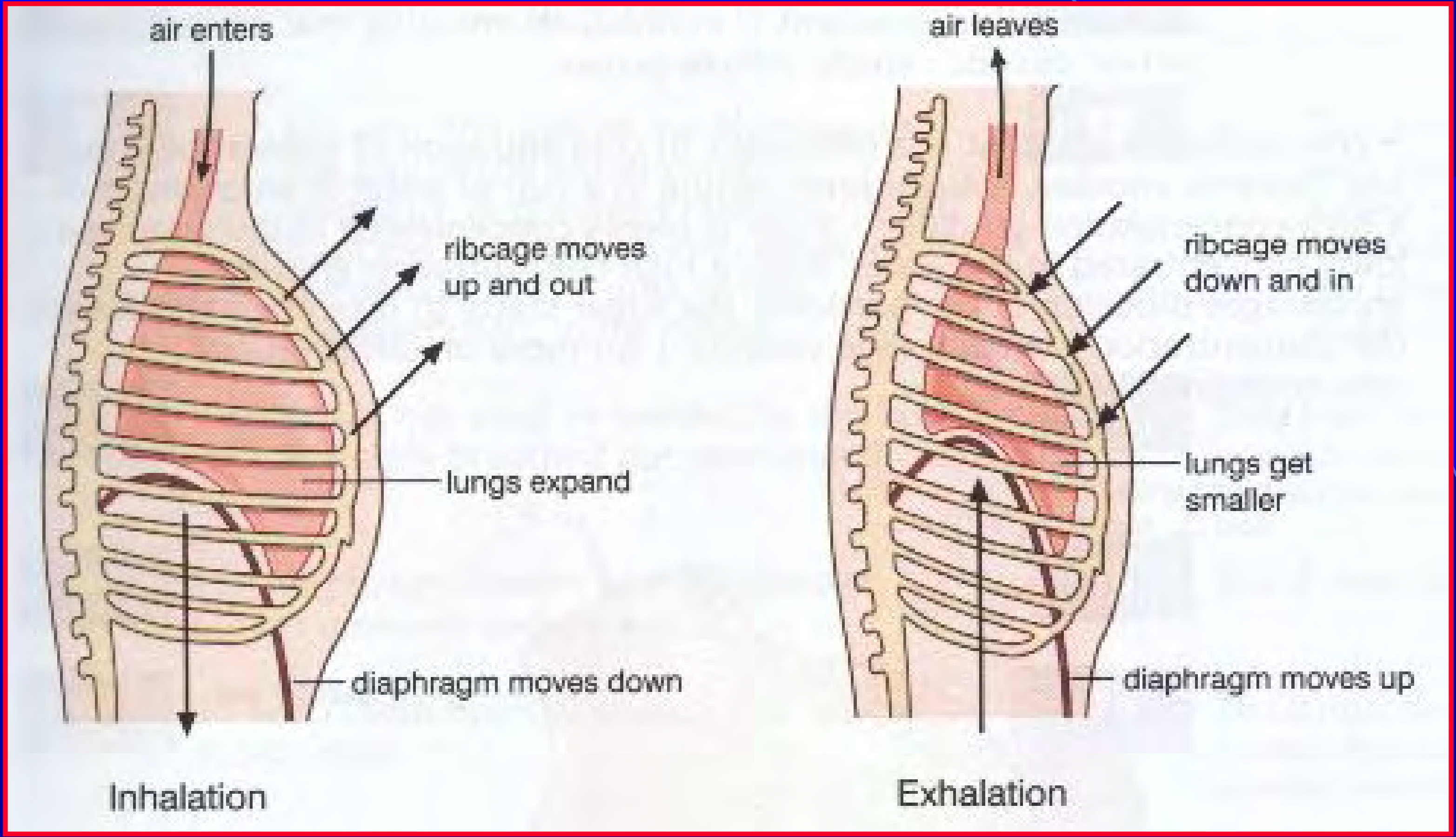
Each day, we breathe about 20,000 times, and by the time we're 70 years old, we will have taken at least 600 million breaths.

Respiration is the exchange of oxygen from the environment and carbon dioxide from the body's cells.



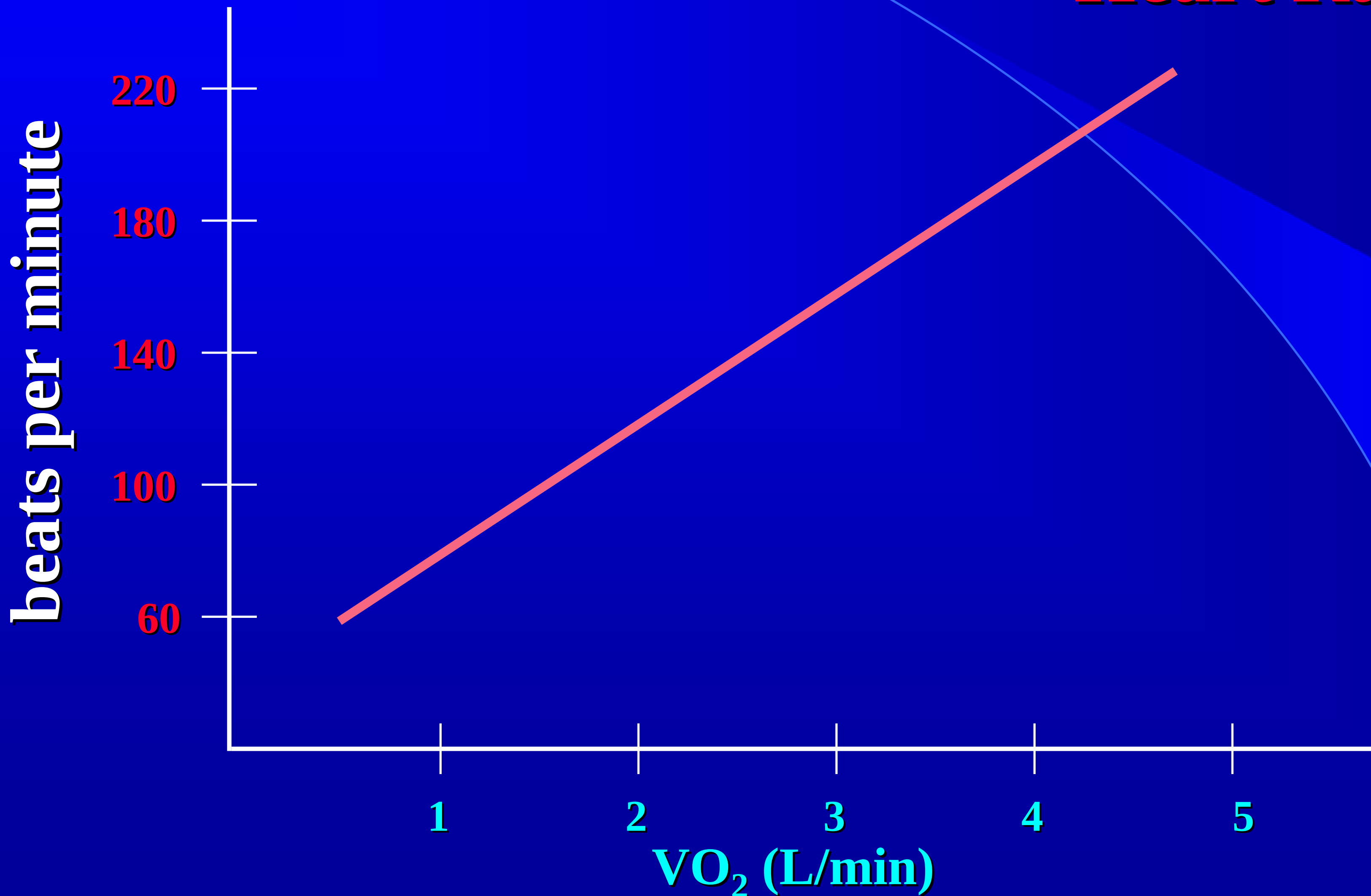
Your lungs contain almost 1500 miles of airways and over 300 million alveoli.

Every minute you breathe in *__6 liters__ at rest and up to __250 liters__ at maximal exercise*



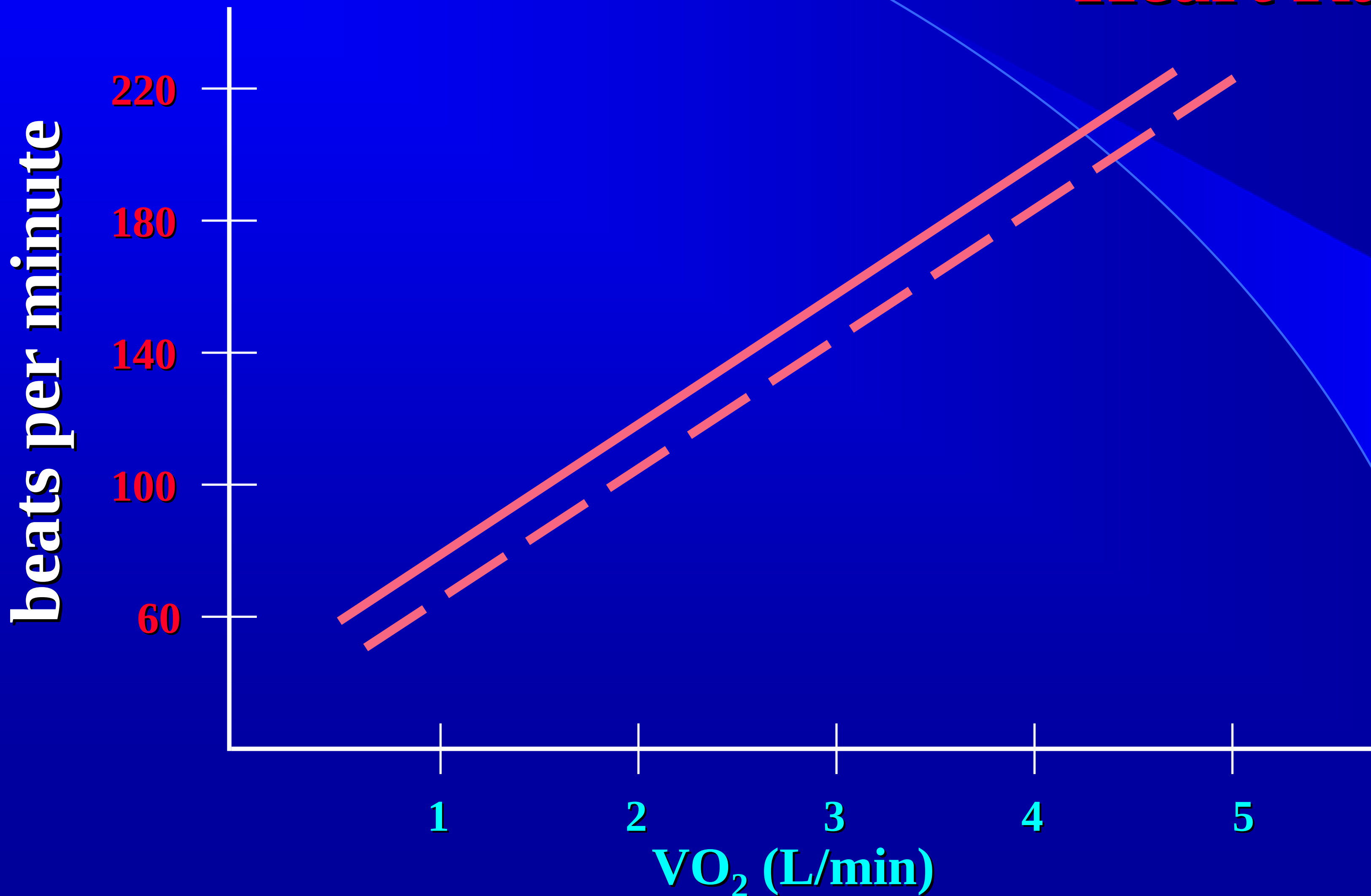
Chronic Responses to AEROBIC Exercise

Heart Rate



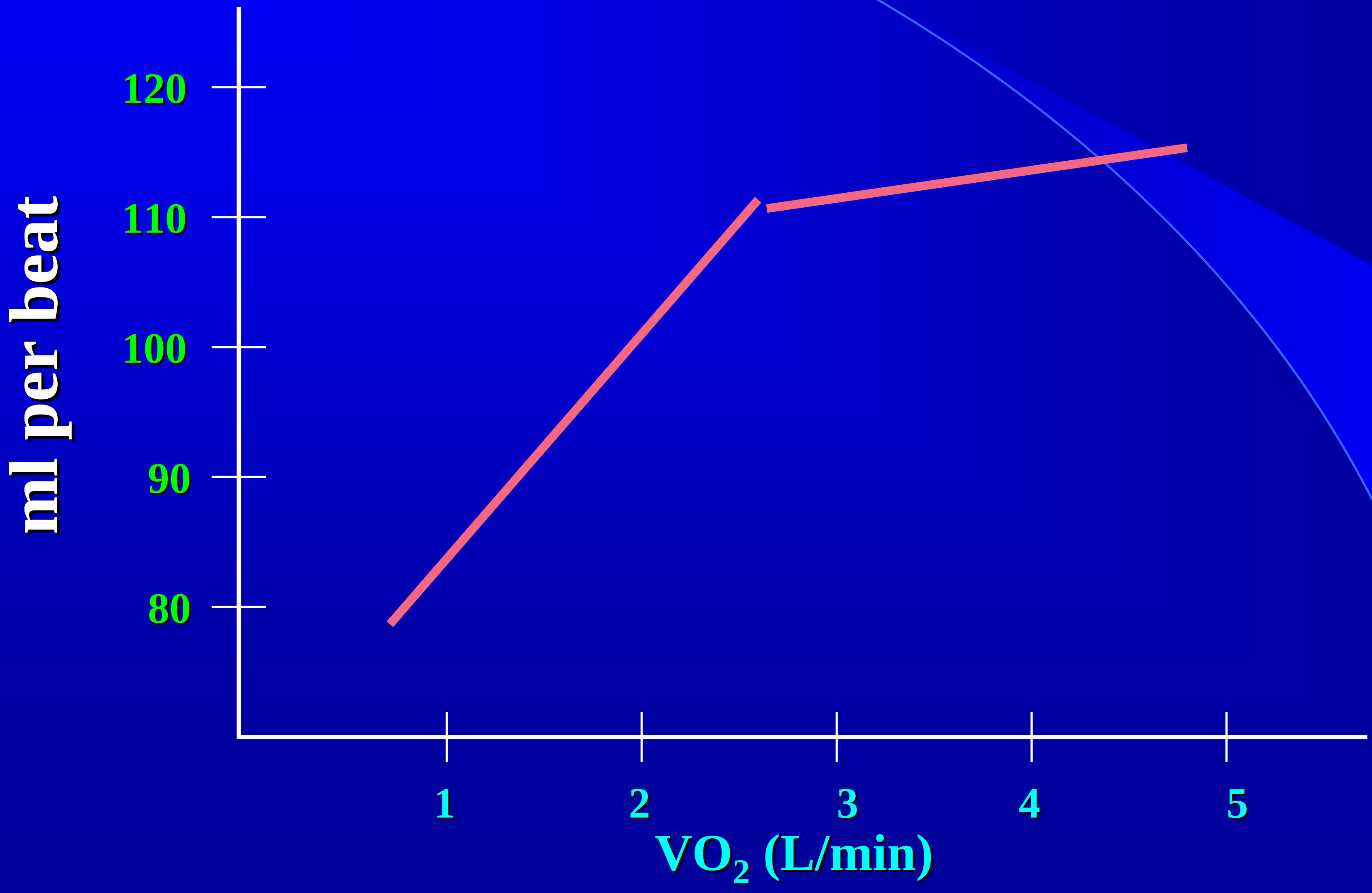
Chronic Responses to AEROBIC Exercise

Heart Rate



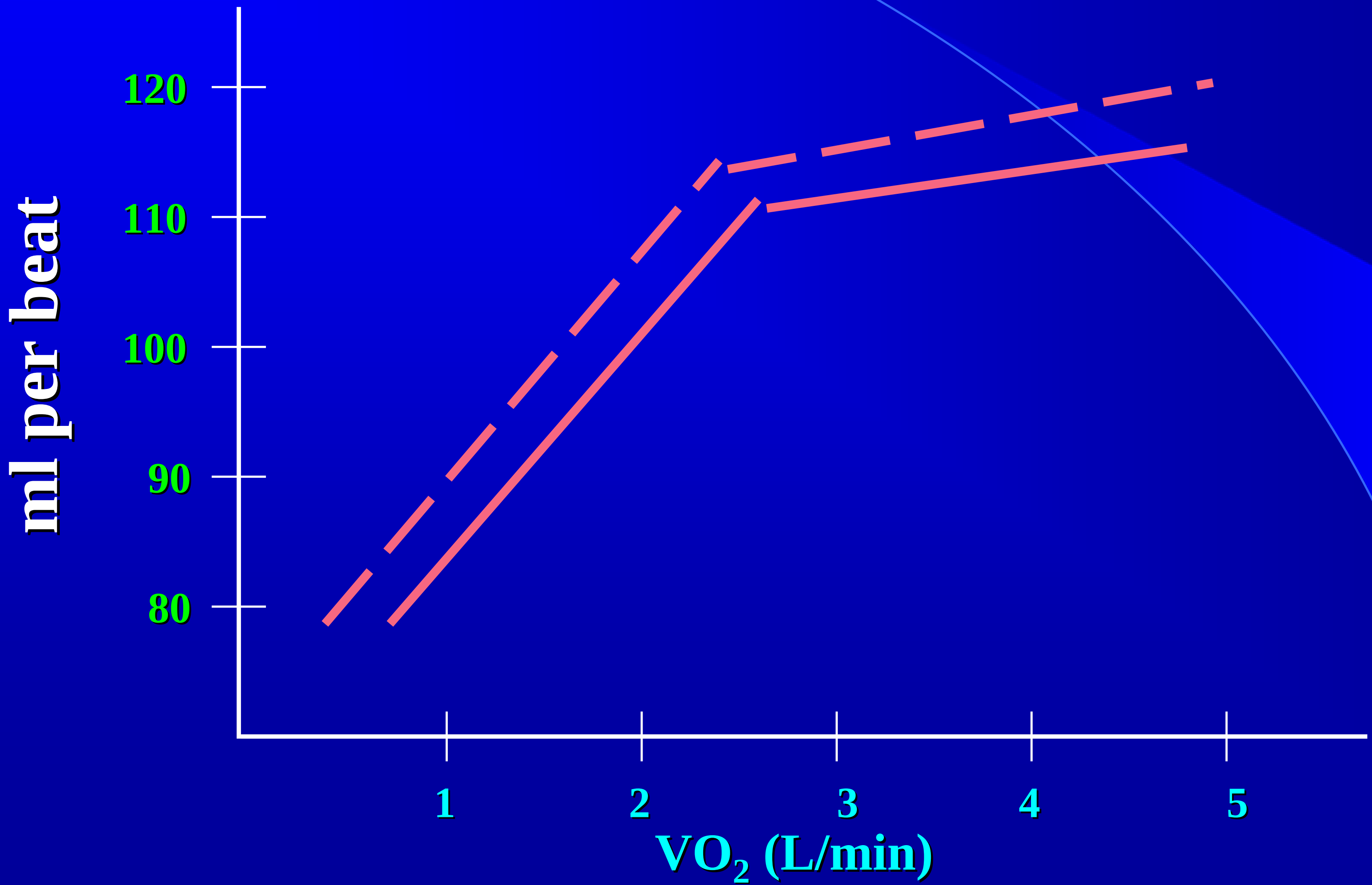
Chronic Responses to AEROBIC Exercise

Stroke Volume



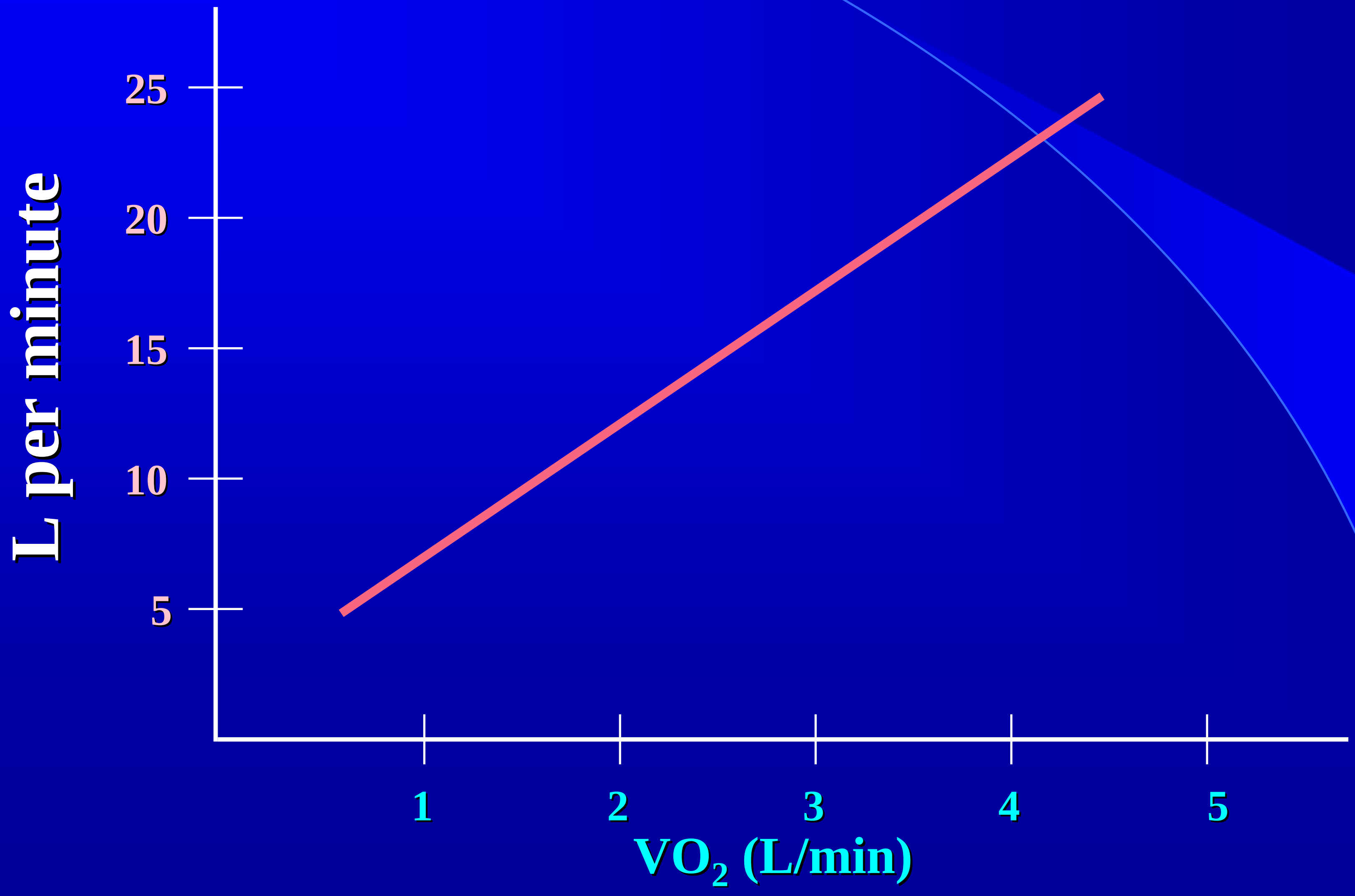
Chronic Responses to AEROBIC Exercise

Stroke Volume



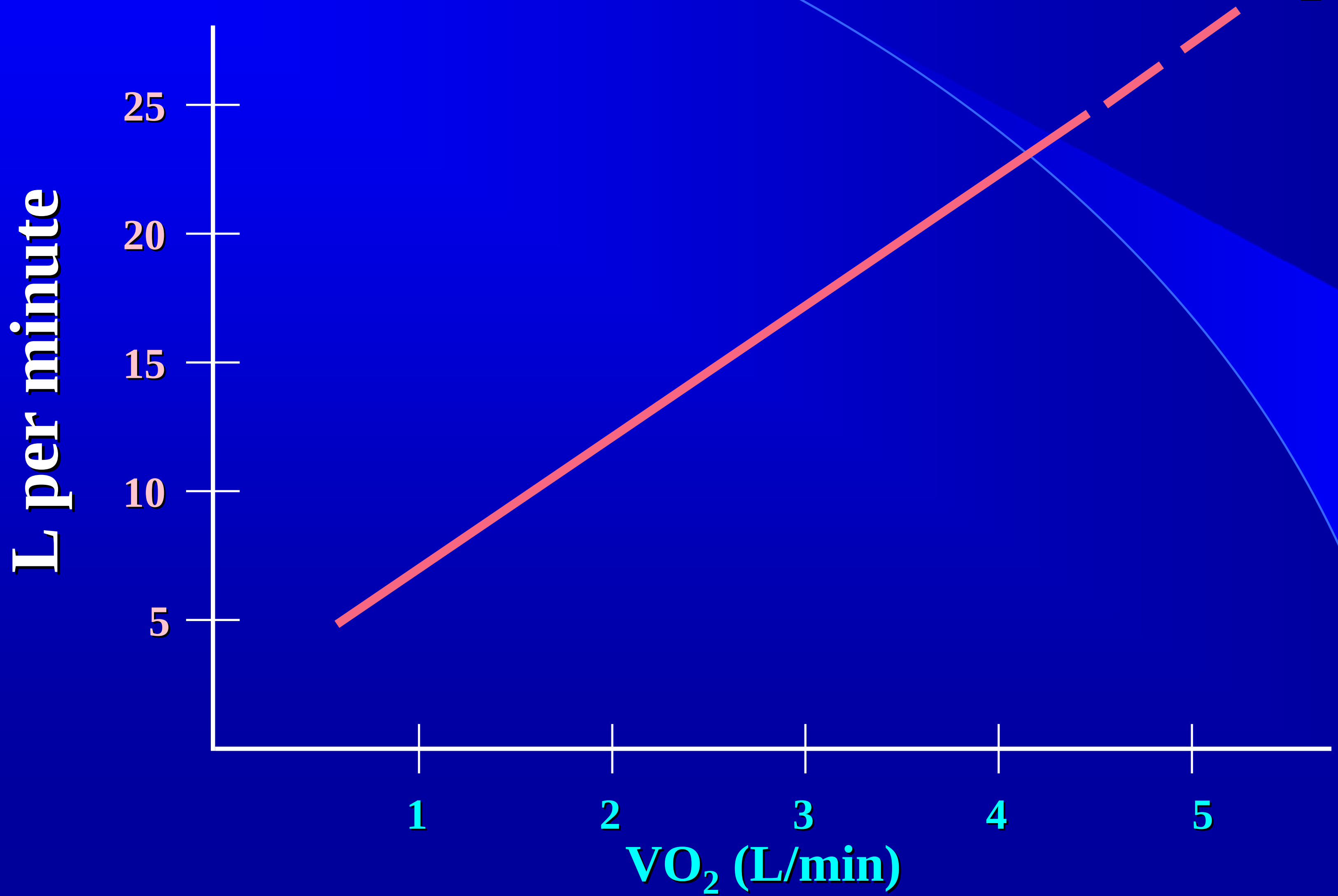
Chronic Responses to AEROBIC Exercise

Cardiac Output



Chronic Responses to AEROBIC Exercise

Cardiac Output



Name	Jane Doe
Date of Max test	2/11/2009
Measured Max HR	189
Measured Max VO2	59.2
Estimated AT HR	174-176

Training Zone	Heart Rate (Sharkey)	VO2 (Sleamaker & Browning)	Description
Zone 1 (Aerobic) 60-70% MHR 55-65% VO2 MAX	113.4 to 131.3	32.264 to 38.48	**Over-Distance / Active Recovery** This is a low intensity training zone for warm-ups, cool-downs and the easy portion of long workouts. You are primarily burning body fat for energy. The zone establishes the cardiovascular base, thus building endurance for longer events. The zone promotes improved cardiovascular O2 transport efficiency, increased stroke volume and increased O2 absorption through increased capillary and mitochondrial density. The zone is commonly used for active recovery following intense exercise.
Zone 2 (Aerobic) 70-80% MHR 66-75% VO2 MAX	132.3 to 150.2	39.072 to 44.4	**Aerobic / Endurance Training** Training in this zone will continue to develop your cardiovascular system. The body's ability to transport oxygen to, and carbon dioxide away from, the working muscles (i.e. endurance) will be improved. This is a moderate intensity zone often described as a steady state or calorie burning zone because you can exercise in this zone comfortably for long periods of time.
Zone 3 (Aerobic/Anaerobic) 80-90% MHR 76-80% VO2 MAX	151.2 to 169.1	44.992 to 47.36	**Lactic Acid Tolerance / Tempo / Race Pace Training** Training in this zone increases lactic acid tolerance and improves the anaerobic threshold. Your individual anaerobic threshold - sometimes referred to the point of deflection (POD) is found here. The amount of fat being utilized as the energy source is greatly reduced and stored muscle glycogen is predominantly used. One of the by-products of burning this glycogen is lactic acid. Lactic acid production is not sufficient to immediately degrade performance until POD is reached. However, there is a point at which the body can no longer remove the lactic acid from the working muscles quickly enough. This happens at an individual heart rate and is accompanied by a rapid rise in heart rate, breathing and eventual slowing of your pace (this is your anaerobic threshold or POD). Through the correct training it is possible to delay the POD and increase your ability to tolerate lactic acid longer (pushing the POD higher). Conditioned athletes will spend most of their time in this zone during a race or time trial of 30-60 minute duration.
Zone 4 (Anaerobic) 90-95% MHR 91-90% VO2MAX	170.1 to 178.55	47.952 to 53.28	**Threshold / Interval Training** This high intensity zone is used for speed work and interval training. Training in this zone increases the body's tolerance of high levels of lactic acid. Because you can only maintain this effort for a few minutes, intervals are the most common workout. During interval training, intensity is maintained for a short period, followed by active recovery allowing the body time to flush out the lactate and then repeat the exposure. Training is this zone is also used for specific sport performance. Caution is warranted and the zone should be used carefully with full rest periods between high intensity workouts to avoid over-training, over-use and injury.
Zone 5 (Anaerobic) > 95% MHR 91-100% VO2 MAX	179.55 to 189	53.872 to 59.2	**Maximum Effort / Red Line** These are extremely short, maximum efforts, sprints or bursts of intensity. This is the highest-intensity training zone and is used only for very difficult interval type training or at the end of performance pieces. Care must be used when training in this extreme zone to avoid over-training or injury. Training in this zone will only be possible for short periods of time. It effectively trains your fast twitch muscle fibers and helps to develop speed.

You completed a MAX VO2 test. Max VO2 is short for maximal volume of oxygen. It is the gold standard measure of cardiovascular fitness, measuring how efficiently your body takes in, transports and utilizes oxygen. While some performance testing involves a sub-maximal test (the test is ended before reaching maximal effort and VO2 max is actually "projected" based on an "age-predicted" max heart rate) you were able to work through the top of zone 5. You were tested to voluntary exhaustion or what is affectionately termed... MAX! Congratulations!

NOTE: Performance testing and conditioning are not an exact science. Daily variation based on medications, environmental conditions, fueling, fluid replacement and fatigue will effect heart rate response to exercise. Therefore, use this as a general guide only to vary your workouts and maximize your gains.

Lance Armstrong Physiology

Lance Armstrong

"Improved muscular efficiency displayed as Tour de France champion matures"

Edward F. Coyle
Human Performance Laboratory, Department of Kinesiology and Health Education, The University of Texas at Austin, Austin, Texas

J Appl Physiol **98: 2191-2196, 2005**

Lance Armstrong

data collected:

- 1992-1997
- Age 21- 28
- 1999 – 2005 Tour de France Grand Champion

Age	21.1	21.4	22.0	25.9	28.2
Date:	Nov 92	Jan 93	Sept 93	Aug 97	Nov 99
Training stage	Preseason	Preseason	Racing	Reduced	Preseason
Body weight, lbs	174	168	165	175	176
Lean body weight, lbs	155	154		155	158
Body fat, %	10.7	8.8		11.7	
Max VO2, l/min	5.56	5.82	6.10	5.29	5.7
Max VO2, ml/kg/min	70.5	76.1	81.2	66.6	71.5

Lance Armstrong

- Cycling cadence increased progressively during this 5-year period from 85-95 rpm to about 105-110 rpm (during time trial races of 30-60 minute)
- Maximal blood lactate concentration was remarkably low in the trained state

Lance Armstrong

Conclusions

- During the months leading up to each of his Tour de France victories, he reduced body weight and body fat by 4–7 kg (i.e., 7%).
- Improvements in muscular efficiency and reduced body fat contributed equally to a remarkable 18% improvement in his steady-state power per kilogram body weight when cycling at a given O2 (e.g., 5 l/min).

Lance Armstrong – Body Composition


UWBADGERS.COM
The Official Website of University of Wisconsin Athletics




SENCOR



IRONMAN Wisconsin
MADISON TRIATHLON
9:04:26


Body Composition

- Athletes are pushing their physiological limits
- Too little body fat may be as dangerous as excess body fat

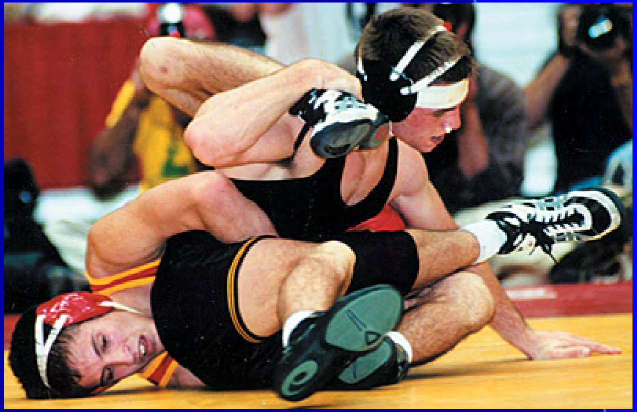
Body composition measurement is not an exact science!

We can only *estimate* body composition

- to literally measure body fat we would have to extract lipids from all body tissues
- weigh the collected mass and express it as a percentage of total body weight
- the result would be extremely accurate
- however, the patient would not survive the extraction process

Wrestling MW requirements

- Wisconsin Interscholastic Athletic Association (1989)
- NCAA (1998)
- National Federation of High School Athletic Assoc (2006)
- 250,000 HS wrestlers



Will leaner make me faster?   Jump higher?

Overview

- What are the limitations of BMI?
- Why measure body fat?
- Advances in body composition
- Evaluating the new technologies

BMI Review

- Body Mass Index (BMI) = Wt/Ht^2
- Because measurement of body fat is "difficult", BMI is calculated instead
- Assumed to be a "good" substitute for body fat in most people

$$BMI = \frac{Wt\ (kg)}{Ht\ (m)^2} = \frac{Wt\ (lb) \times 703}{Ht\ (in)^2}$$

http://www.nhlbisupport.com/bmi/bmicalc.htm

BMI in adults

BMI	Status
<25	lower risk*
25-29.9	overweight
30+	obese

* Lower rates of diabetes, heart disease, high blood pressure and overall mortality

BMI limitations

- It **<u>overestimates</u>** body fat in athletes and those with a muscular build
- It **<u>underestimates</u>** body fat in older persons and others who have lost lean mass

Arnold (Mr. Olympia)

6’2” 260 lbs BMI = 33.4

BMI in adults

BMI	Status
<25	lower risk
25-29.9	overweight
30+	obese
33.4	Arnold

Evaluating the technology in body composition assessment

- How do these devices work?
- Are they cost effective?
- Are they valid?
- Are they reliable?

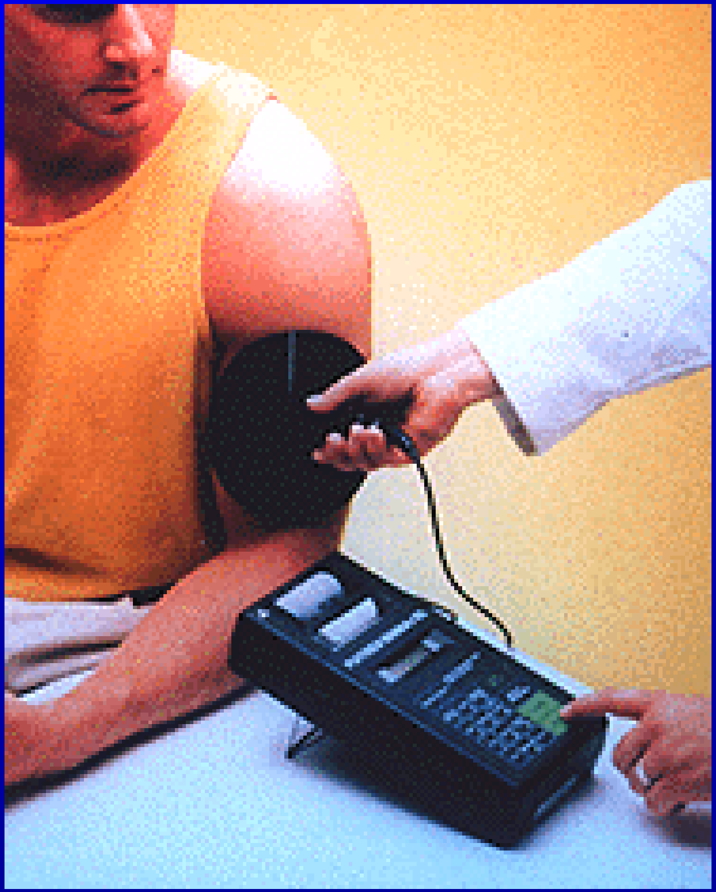
Tanita

Tanita

Pros:
quick, cost effective, minimal technician training

Cons:
Sensitive to hydration status
Standardization - time of day, activity, fluids
Athlete mode, calibration standards
Precision questioned

NIR



NIR

Pros:
quick, cost effective, minimal technician training

Cons:
Is bicep best indicator? single vs. multi site, little data supporting use, accuracy and precision questioned

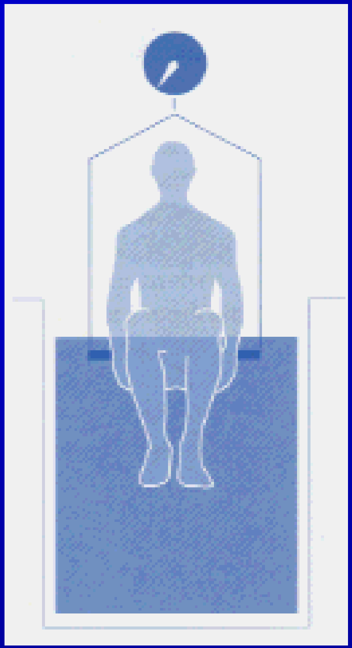
Skinfolds

Skinfolds

Pros:
Safe, cost effective, widely available, minimal discomfort

Cons:
Trained measurer required
Calibrated caliper
Appropriate equation
Ethnic differences

Densitometry



Densitometry

Pros:

Historic “gold standard”

Cons:

Submersion in water

Subject participation - maximal exhalations

Measurement of residual lung volume required

Trained technicians, coaching

Equipment cost

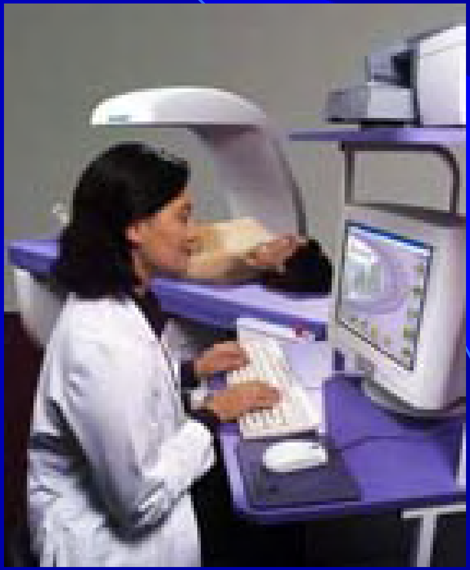
Bod Pod

Bod Pod

Pros:
Convenient, minimal subject discomfort

Cons:
Measurement of thoracic gas volume required
HVAC room requirements
Standardize clothing, swim cap and Speedo suit
Body temperature, muscular body build, body hair
Equipment cost

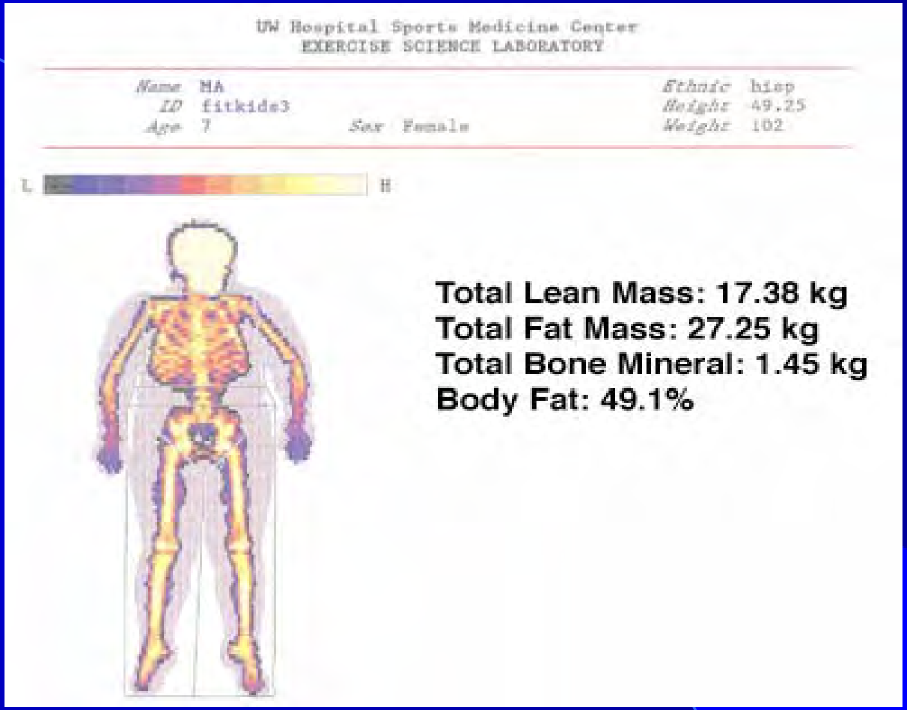
DXA



DXA

Pros:
3 compartment model (bone, muscle and fat)
Providing regional fat (fat distribution)

Cons:
X-ray (low dose)
Subject must remain motionless
Removal of metal
Pregnancy screening
Trained technicians, calibration standards
Equipment cost



DXA measurement of body composition

What is our criterion method?

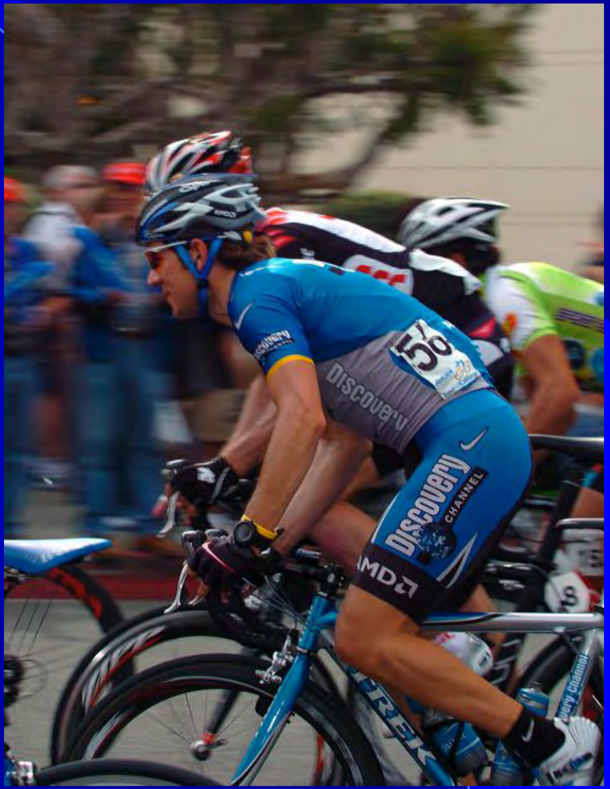
Historical "gold standard"

- Hydrostatic weighing – 2 component model (fat and fat-free body)
- However, this approach not the most accurate because of the physical changes taking place during: 1) growth and maturation, 2) physical conditioning and 3) aging
- These include changes in hydration, bone mineralization and density of the fat-free-mass

What is our criterion method?

Modern "gold standard":

- DXA – dual energy x-ray absorptiometry
- 3 compartment model – bone, muscle and fat
- evaluate the body as a whole and regional distribution of body fat
- evaluate custom regions of interest



More Information?

Sports Medicine
Exercise Science Laboratory

Dan Nagle - 890-8567

Randy Clark - 265-3798

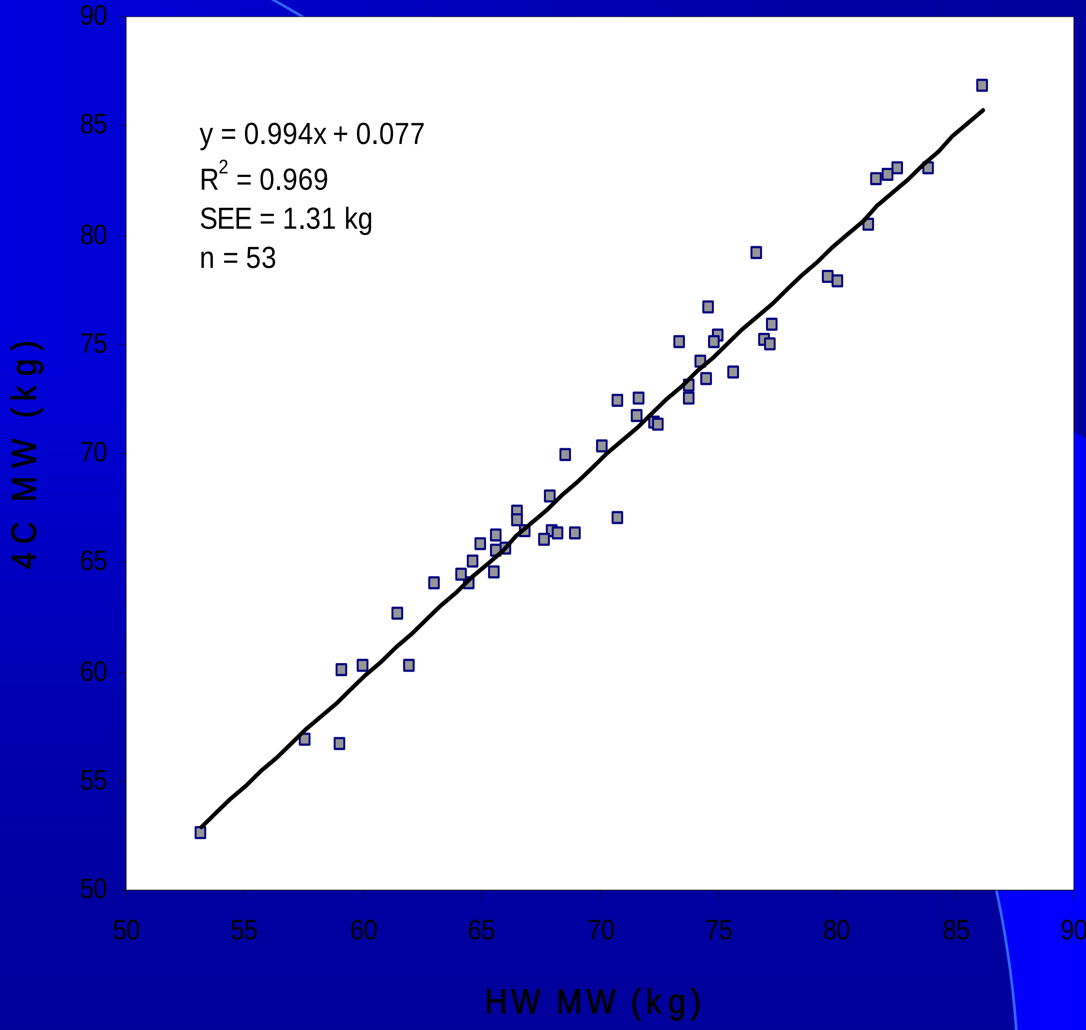
uwsportsmedicine.org

Thank you and questions

Resource slides

Accuracy

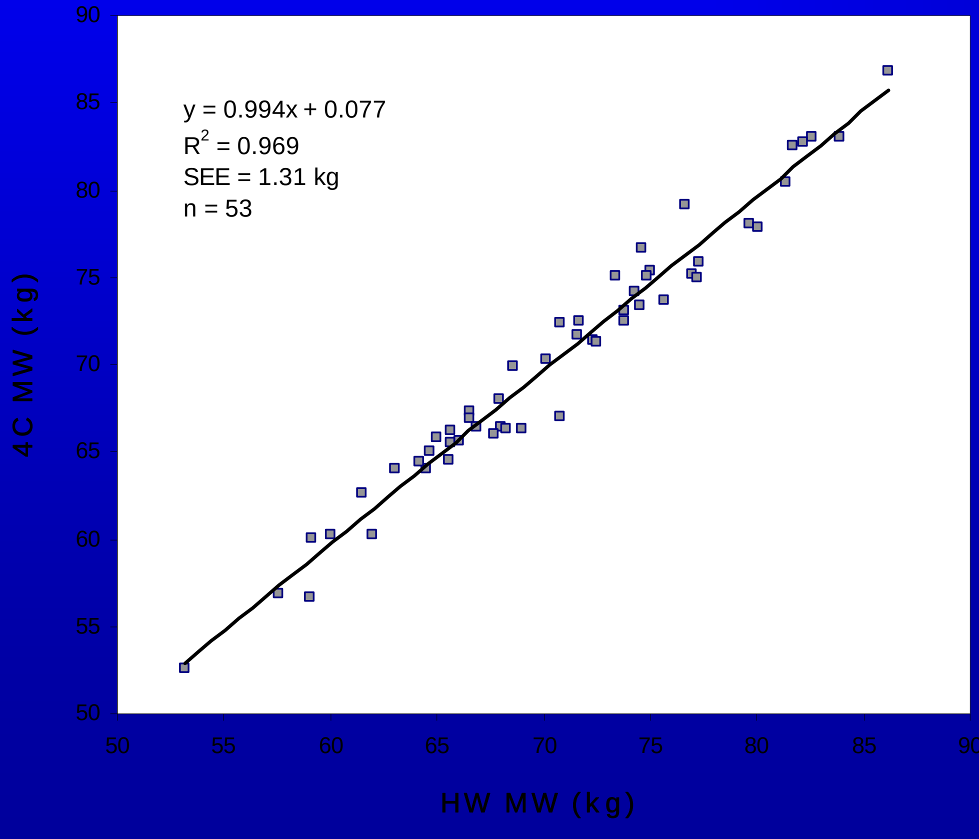
- Accuracy – regression between the two methods is not significantly different than the line of identity (intercept = 0, slope = 1.0)

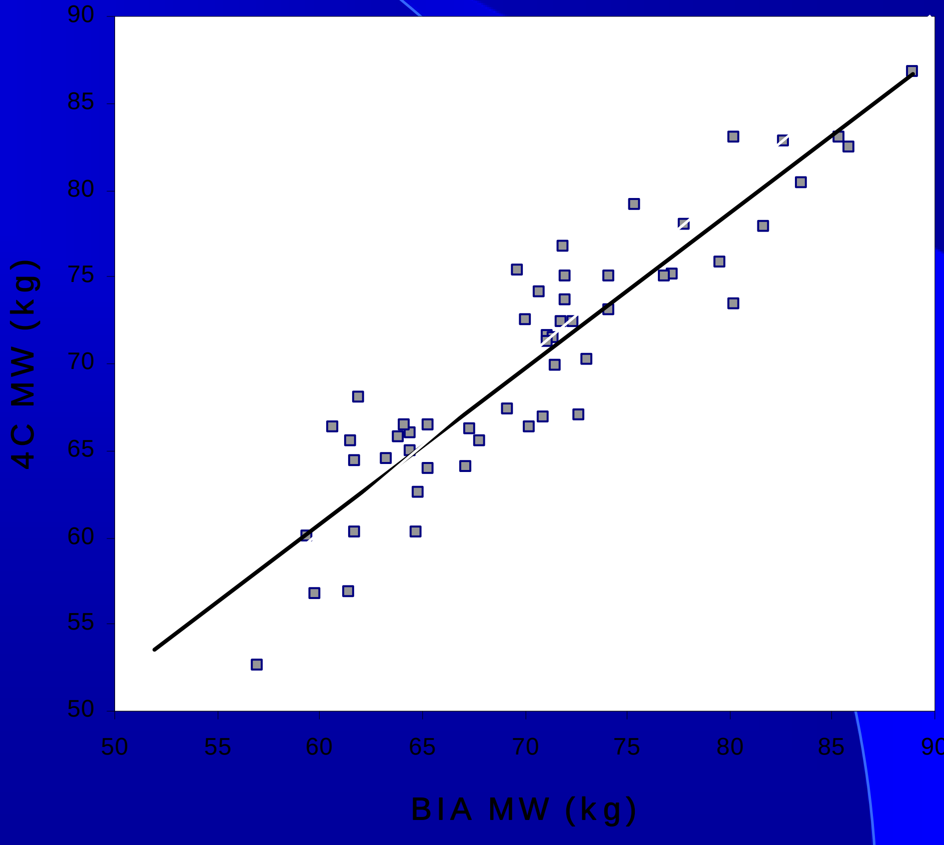


Accuracy

Evaluate scatter plots

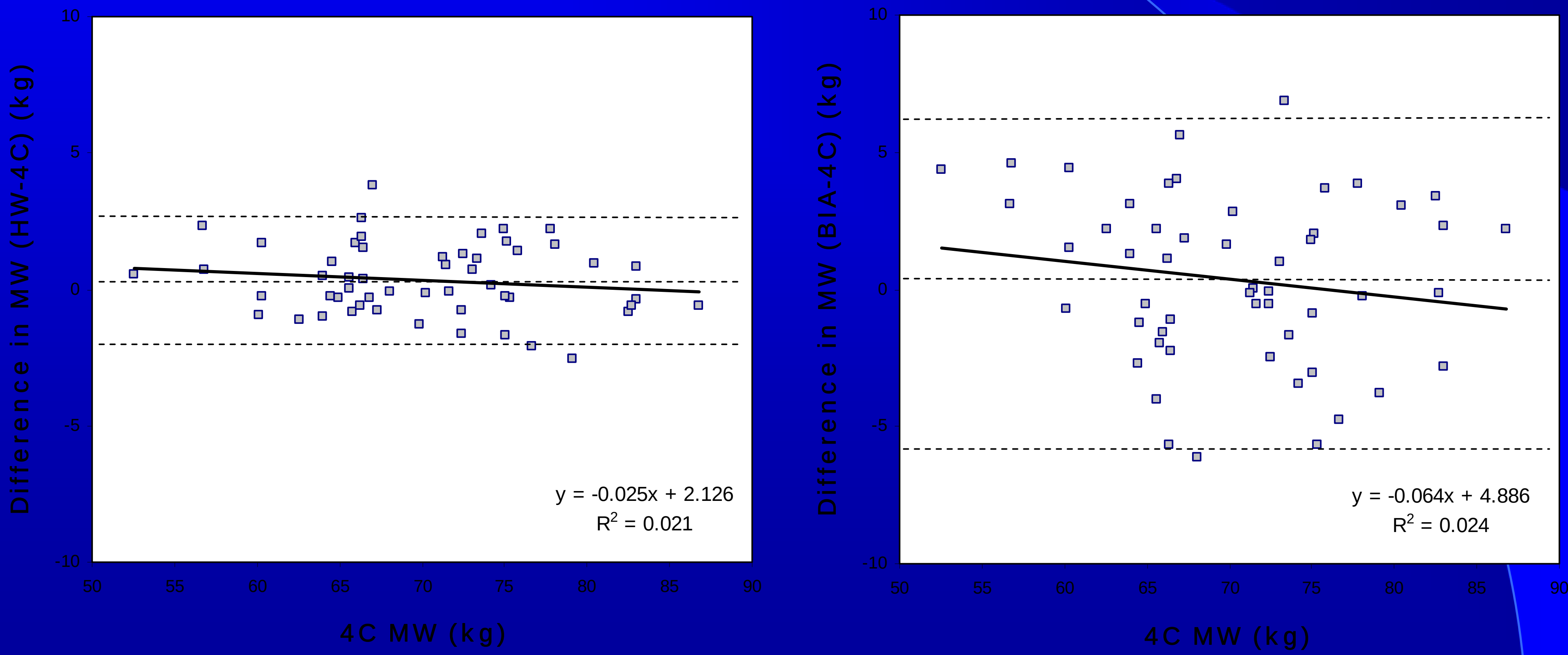
SEE and PE values





Precision

How does the method perform for individual subjects?



Systematic Bias

- Bias - Does the method vary across the body weight range or percent body fat range?