Muscle adaptation to exercise

Collage of medicine
Physiology Dep.
DR Abdulrahman Alhowikan

Objective

- Define strength, power, and endurance of muscles.
- Analyze the effect of athletic training on muscle structure and muscle performance.
- Discuss the mechanism of muscle hypertrophy.
- Contrast Fast-twitch and slow-twitch muscle fibers.
- Explain the respiratory changes in exercise (Oxygen consumption, pulmonary ventilation and VO_2 max).
- Identify the cardiovascular changes in exercise (Work output, oxygen consumption, and cardiac output , heart hypertrophy).
- Interpret the role of stroke volume and heart rate in increasing the cardiac output.
- Explain the body heat in exercise & the heatstroke.

Strength, Power, and Endurance of Muscles

- Muscles Strength: Refers to the amount of force a muscle can produce.
- Size of muscles influences the maximal contractile force, Normally 3 -4 kg/cm^2
- e.g. a cross-sectional area 150 cm^2 cause maximal contractile strength of 525 kilograms
- Mechanical work of muscle = force applied by the muscle X distance

Strength, Power, And Endurance Of Muscles

- **Muscles Power :** amount of work that the muscle performs in period of time (kg-m/min)

	kg-m/min
First 8 to 10 seconds	7000
Next 1 minute	4000
Next 30 minutes	1700

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Strength, Power, And Endurance Of Muscles

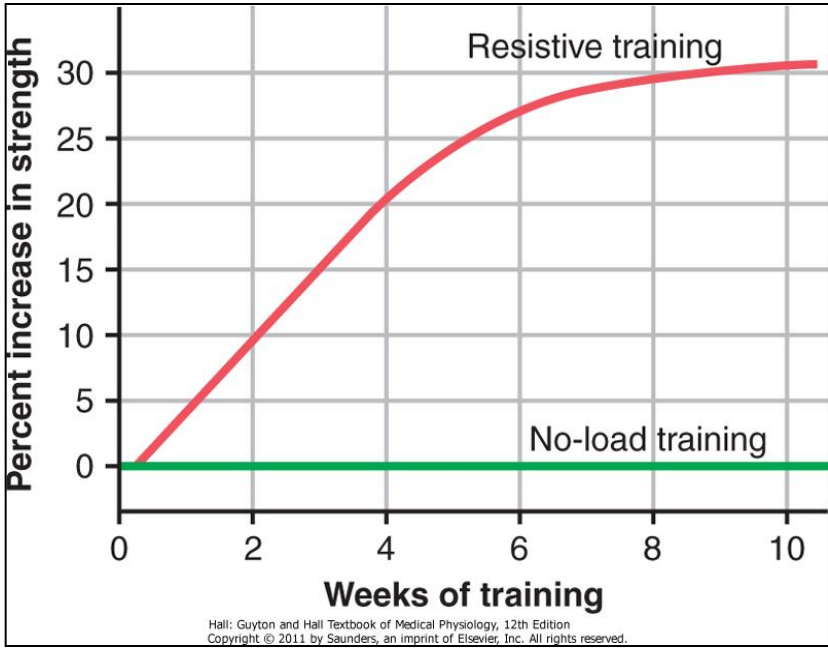
- Muscles Endurance: Ability of muscles to sustain repeated contractions against a resistance for period of time.
- It depends on glycogen stored in the muscle.
- Dynamic endurance: is defined as a muscle's ability to contract and relax repeatedly.
- Static endurance: is a muscles ability to remain contracted for a long period.

Effect of Training on Muscles and Muscle Performance

- Maximal Resistance Training:
- 6 maximal muscle contractions X sets 3 days X one week ↑ increase in muscle strength, without muscle fatigue.

However !!!!

- Muscles function under no load little ↑ in strength



Approximate effect of optimal resistive exercise training on increase in muscle strength over a training period of 10 weeks.

Muscle Hypertrophy

- With training muscles hypertrophied 30- 60 %
- Due to ↑ diameter of the muscle fibers with some increase ↑ in number of fibers.
- Changes in the hypertrophied muscle fiber:
- ↑ myofibrils
- ↑ 120 % in mitochondrial enzymes(tricarboxylic acid)
- ↑ ATP and phosphocreatine
- 50 % ↑ in stored glycogen
- 75 -100 % ↑ in stored triglyceride.
- ↑ Both the aerobic & anaerobic metabolisms
- The efficiency of the oxidative metabolic system increases by 45 %.

Fast-Twitch and Slow-Twitch Muscle Fibers

- **Fast-twitch fibers**: for forceful and rapid contraction.

e.g. gastrocnemius muscle used for jumping.

- **Slow-twitch muscle**: for prolonged muscle activity

e.g. soleus muscle in the lower leg muscle for standing.

fast-twitch fibers achieves maximal power in very short periods of time.

slow-twitch fibers organized for endurance, especially for generation of aerobic energy. provide endurance, prolonged strength of contraction minutes to hours.

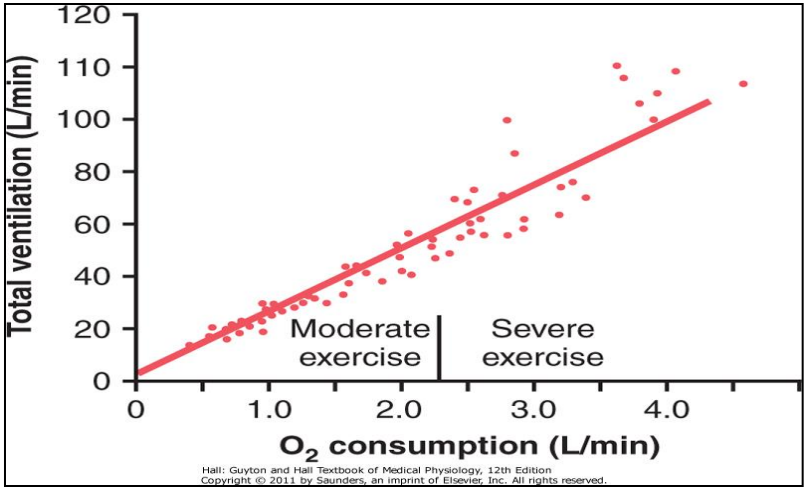
* **differences between** the fast-twitch and the slow-twitch fibers Read Guyton & Hall: Textbook of Medical Physiology 12E Unite XV chapter 84 page 1036)

Respiration In Exercise

- **Oxygen Consumption VO_2 and Pulmonary Ventilation VE in Exercise**
- VO_2 at rest is about 250 ml/min , However !!! at Maximal efforts

	ml/min
Untrained average male	3600
Athletically trained average male	4000
Male marathon runner	5100

VO_2 and V_E increase about 20-fold between the resting state and maximal intensity

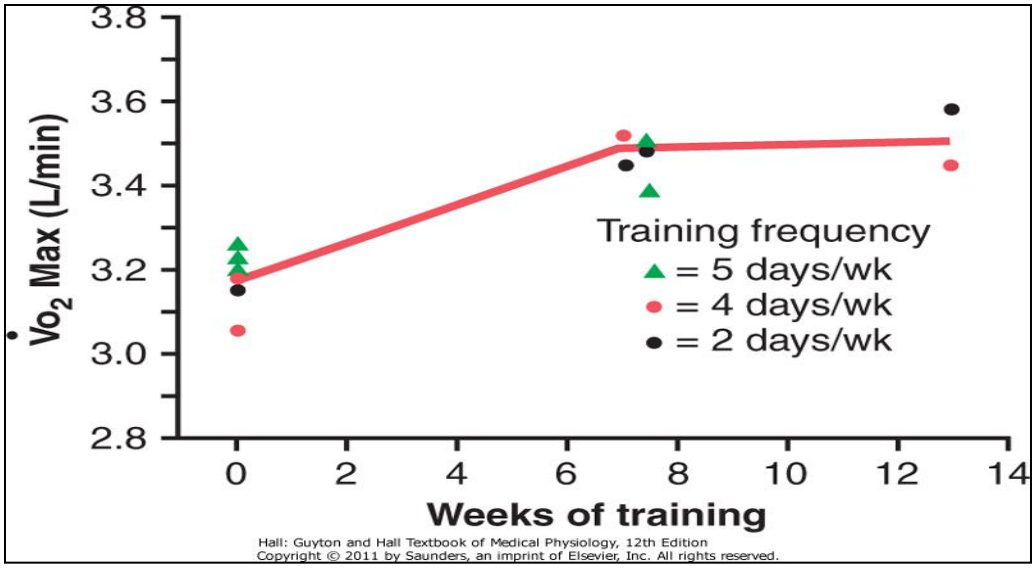


F Effect of exercise on oxygen consumption and ventilatory rate. (Redrawn from Gray JS: Pulmonary Ventilation and Its Physiological Regulation. Springfield, Ill: Charles C Thomas, 1950.)

Effect of Training on VO_2 Max

- In below study VO_{2Max} increased only about 10 percent by training, Moreover other factors !!!
- Chest sizes in relation to body size
- Increase respiratory muscles
- For more information check

Guyton & Hall12E
Unite XV chapter 84 page 1037-38



Increase in Vo2 Max over a period of 7 to 13 weeks of athletic training. (Redrawn from Fox EL: Sports Physiology. Philadelphia: Saunders College Publishing, 1979.)

Cardiovascular System in Exercise

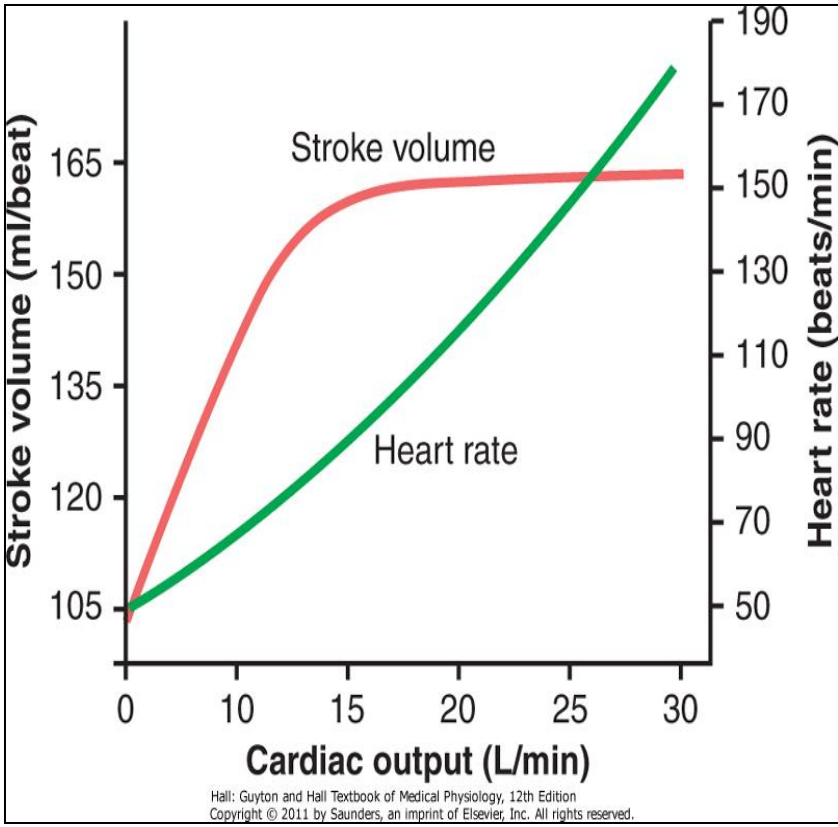
- **Work Output, Oxygen Consumption, and Cardiac Output During Exercise**
- All are directly related to one another, muscle work output increases oxygen consumption, and increased oxygen consumption in turn dilates the muscle blood vessels, thus increasing venous return and cardiac output C.O .
- **Effect of Training on Heart Hypertrophy and on Cardiac Output:**
- Training increase C.O about 40 % greater than untrained persons So,
- heart chambers of marathoners enlarge about 40 percent in contrast to non trained
- Heart size of marathoner larger than normal person

Comparison of Cardiac Function Between Marathoner and Nonathlete

	Stroke Volume (ml)	Heart Rate (beats/min)
Resting		
Nonathlete	75	75
Marathoner	105	50
Maximum		
Nonathlete	110	195
Marathoner	162	185

Cardiovascular System in Exercise cont…

- The **cardiac output** increases from its resting level of about 5.5 L/min to 30 L/min.
- The **stroke volume** increases from 105 to 162 milliliters, an increase of about 50 percent
- Whereas the **heart rate** increases from 50 to 185 beats/min, an increase of 270 percent.
- The heart rate increase a greater proportion of the increase in cardiac output than does the increase in stroke volume **why ?????**



Approximate stroke volume output and heart rate at different levels of cardiac output in a marathon athlete.

Role of Stroke Volume and Heart Rate in Increasing the Cardiac Output

Cardiovascular Response To Exercise

Complete: Any Questions

Heart Rate
(↑ before exercise)

Heart Rate
↑ during exercise
(similar to VO_2)

a-vO_2 difference
(↑ extraction)

Stroke Volume
4 factors

Blood Pressure
- ↑ Systolic
- ↔Diastolic

Blood Flow to Muscle
Rest = 20%
Maximal Exercise = 85 - 90%
How?

Body Heat In Exercise

- Almost all the energy released by the body's metabolism converted into body heat.
- Working muscle use only 20 - 25 %.
- Remainder converted into heat as result of :
- (1) resistance to the movement of the muscles and joints.
- (2) friction of the blood flowing through the blood vessels, and
- (3) muscle contractile converted into heat.
- What will happen if sweating mechanism cannot eliminate the heat ???? see

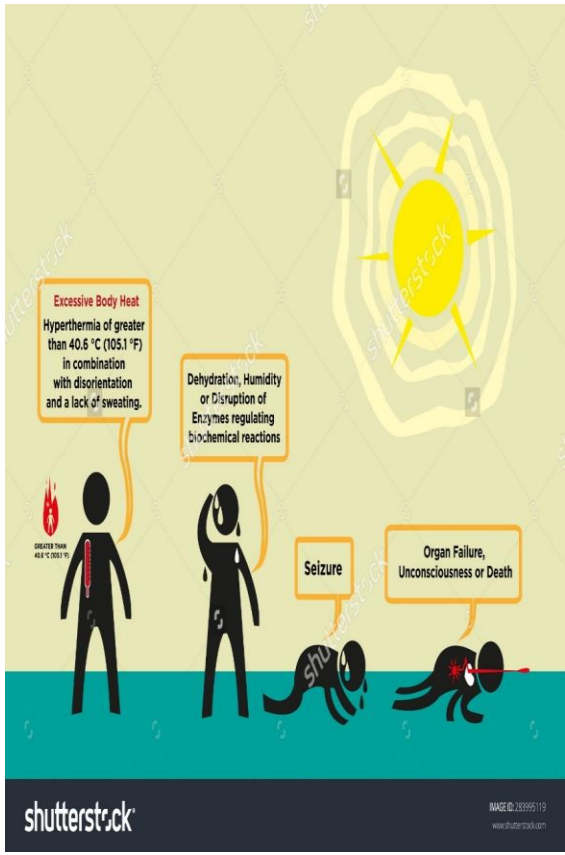
- Guyton & Hall12E Unite XV chapter 84
- page 1039-40

Heatstroke

- During endurance training body temperature rises

98.6° to 102° or 103°F (37° to 40°C)

- hot and humid conditions body temperature rise to 106° to 108°F (41° to 42°C)
- High temperature is destructive (-ev)to tissue cells mainly **(brain cells)**
- Symptoms: Body weakness, exhaustion, headache, dizziness, nausea (disgust), sweating, confusion, uncontrolled gait, collapse, and unconsciousness and may lead to death



Treatment of heatstroke

The most practical way :

- Remove all clothing
- Maintain a spray of cool water on all surfaces of the body or continually sponge the body.
- Blow air over the body with a fan.
- Physicians prefer total immersion of the body in water containing a mush of crushed ice if available.


Thank you !

Reference book

Guyton & Hall: Textbook of Medical Physiology 12E

Thank you