

# Muscle adaptation to exercise

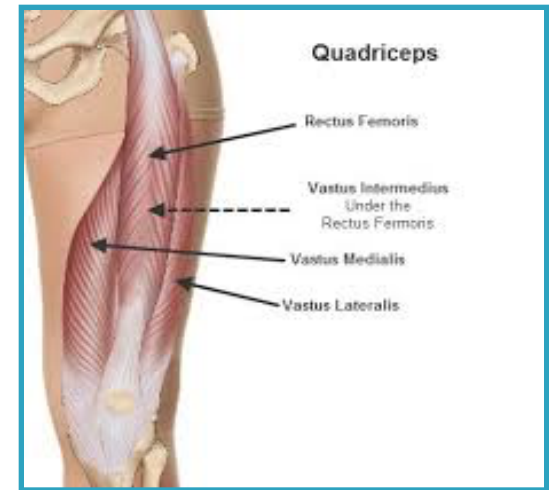


# Objective

- ▶ 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  $\text{VO}_2$  max).
- ▶ Identify the cardiovascular changes in exercise (Work output, cardiac output, heart hypertrophy).
- ▶ Interpret the role of stroke volume and heart rate in increasing the cardiac output.
- ▶ Explain the body heat in exercise and the heatstroke.

# Strength, Power, and Endurance of Muscles

- ▶ **Muscles strength:** Refers to the amount of force (push or pull) a muscle can produce against resistance in a single maximal effort.
- ▶ Size of the muscle influences the maximal contractile force. Normally 3-4 kg/cm<sup>2</sup> of the cross section of the muscle e.g. The cross-sectional area of quadriceps in a world class weight lifter is 150cm<sup>2</sup> causes maximal contractile strength of 525 kilograms.  
e.g weight lifting, digging,
- ▶ **Mechanical work of muscle (W):**  
= The force applied by the muscle (L) x The distance over which the force is applied (D) it is expressed in (kg-m).  
$$W = L \times D$$



## Cont... Strength, Power, and Endurance of Muscles

- ▶ **Muscles Power:** The amount of work the muscle performs in a period of time. It is expressed in (kg-m/min).

The maximal power achievable by all muscles in the body of a highly trained athlete working together is approximately the following:

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



## Cont... Strength, Power, and Endurance of Muscles

- ▶ **Muscle's Endurance:** The ability of the muscle to sustain repeated contractions against a resistance for a period of time.
- ▶ It depends on the **glycogen** stored in the muscle before the exercise. Therefore, endurance is enhanced by a high-carbohydrate diet.
- ▶ **Static endurance:** is the muscle's ability to remain contracted for a long period.
- ▶ **Dynamic endurance:** is defined as the muscle's ability to contract and relax repeatedly.



# Effect of Training on Muscle structure and Muscle Performance

## ▶ **Maximal Resistance Training:**

Muscles that function under **no load**, even if they are exercised for hours on end, increase little in strength. At the other extreme, muscles that contract at more than **50 per cent** maximal force of contraction will develop strength rapidly even if the contractions are performed only a few times each day e.g 6 maximal muscle contractions /3 times daily/3 days/ a week give approximately optimal increase in muscle strength, without producing chronic muscle fatigue.

▶ **However** Multiple weeks of increased muscles function under no load will cause little increase in strength.



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

# Muscle Hypertrophy

- ▶ Is the increase of the total mass of a muscle . Hypertrophy occurs to a much greater extent when the muscle is loaded during the contractile process.
- ▶ With training muscles hypertrophied 30-60 % due to increased **diameter of the muscle fibers** with some increase **in number** of fibers.
- ▶ **Changes in the hypertrophied muscle fiber:**
  - ▶ ↑ the actin and myosin filaments numbers.
  - ▶ 120 % ↑ in mitochondrial enzymes.
  - ▶ ↑ ATP and phosphocreatine, 50% ↑ in stored glycogen.
  - ▶ 75 -100 % ↑ in stored triglycerides.
  - ▶ ↑ Increased 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:** Achieves maximal power in very **short periods** of time. Adapted for forceful and rapid contraction. e.g. gastrocnemius muscle used for jumping. (**anaerobic metabolism**)

**Slow-twitch fibers:** Provide endurance, **prolonged** strength of contraction minutes to hours. Is organized for generation of aerobic energy. e.g. of **Slow-twitch muscle adapted** for prolonged muscle activity is soleus muscle in the lower leg used for standing. (**aerobic metabolism**)

**In summary,** fast-twitch fibers can deliver **extreme** amounts of power for a **few seconds to a minute** or so. Conversely, **slow-twitch fibers** provide endurance, delivering **prolonged strength** of contraction over **many minutes to hours**.

\* **differences between the fast-twitch and the slow-twitch fibers** Read **Guyton & Hall: Textbook of Medical Physiology 13E Unit XV chapter 85 page 1090)**

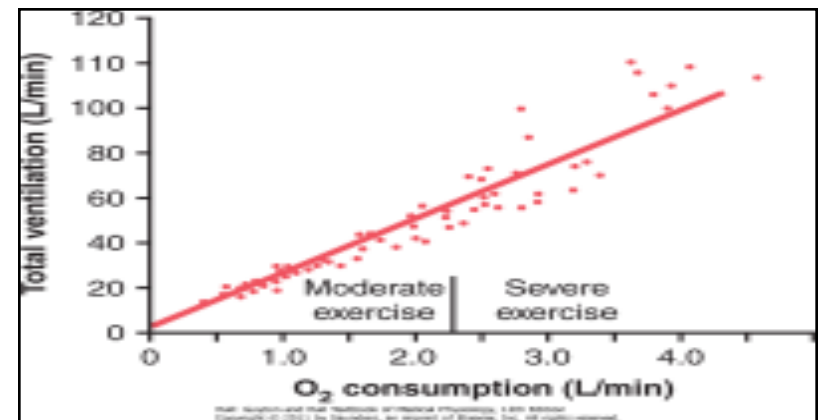


# Respiration In Exercise

- ▶ **Oxygen Consumption (VO<sub>2</sub>) and Pulmonary Ventilation (VE) in Exercise**
- ▶ **VO<sub>2</sub>** at rest is about 250 ml/min. **However** at Maximal efforts can be as follows:

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

**VO<sub>2</sub>** and **VE** increase about 20-fold between the resting state and maximal intensity



Effect of exercise on oxygen consumption and ventilatory rate.)

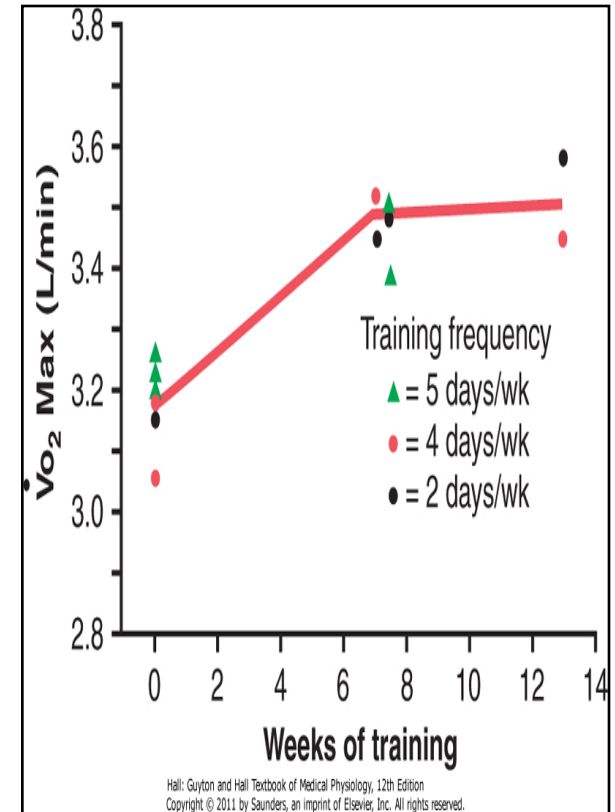
# Effect of Training on VO<sub>2</sub> Max

- ▶ **VO<sub>2</sub> Max:** The rate of oxygen usage under maximal aerobic metabolism is VO<sub>2</sub> Max.
- ▶ In the below study VO<sub>2</sub> Max increased only about 10% by training.

## other factors that increase the VO<sub>2</sub> Max

- chest sizes in relation to body size
- the power of respiratory muscles contraction

**Guyton & Hall 12E Unit XV chapter 85 page 1090–91**



**Increase in Vo<sub>2</sub> Max over a period of 7 to 13 weeks of athletic training.**

# Cardiovascular System in Exercise

- ▶ Work Output, Oxygen Consumption, and Cardiac Output (C.O.P) during exercise are directly related to one another.
- ▶ Increased Muscle work will ↑ oxygen consumption → dilates the muscle blood vessels, thus ↑ venous return and C.O.P .
- ▶ **Effect of Training on Heart Hypertrophy and C.O.P:**
- ▶ Training increases C.O.P about 40 % than in untrained persons.
- ▶ Heart chambers of marathoners enlarge (dilate) about 40% in contrast to non trained.
- ▶ Heart size of the marathoner is larger than normal person.
- ▶ [Guyton & Hall: Textbook of Medical Physiology 13E: 1092-94](#)

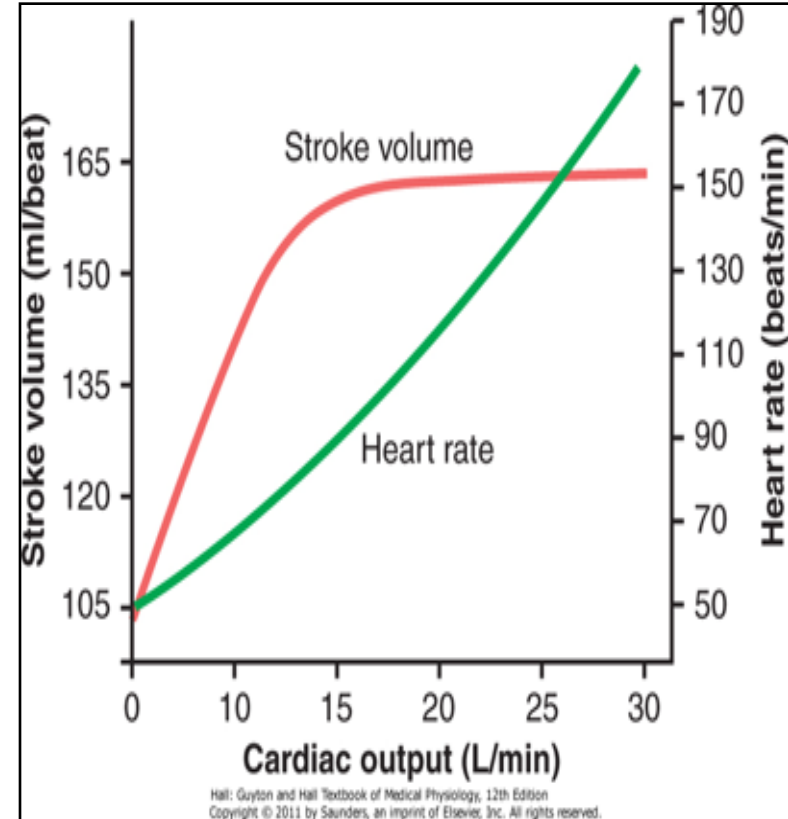


Comparison of Cardiac Function Between Marathoner and Nonathlete

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

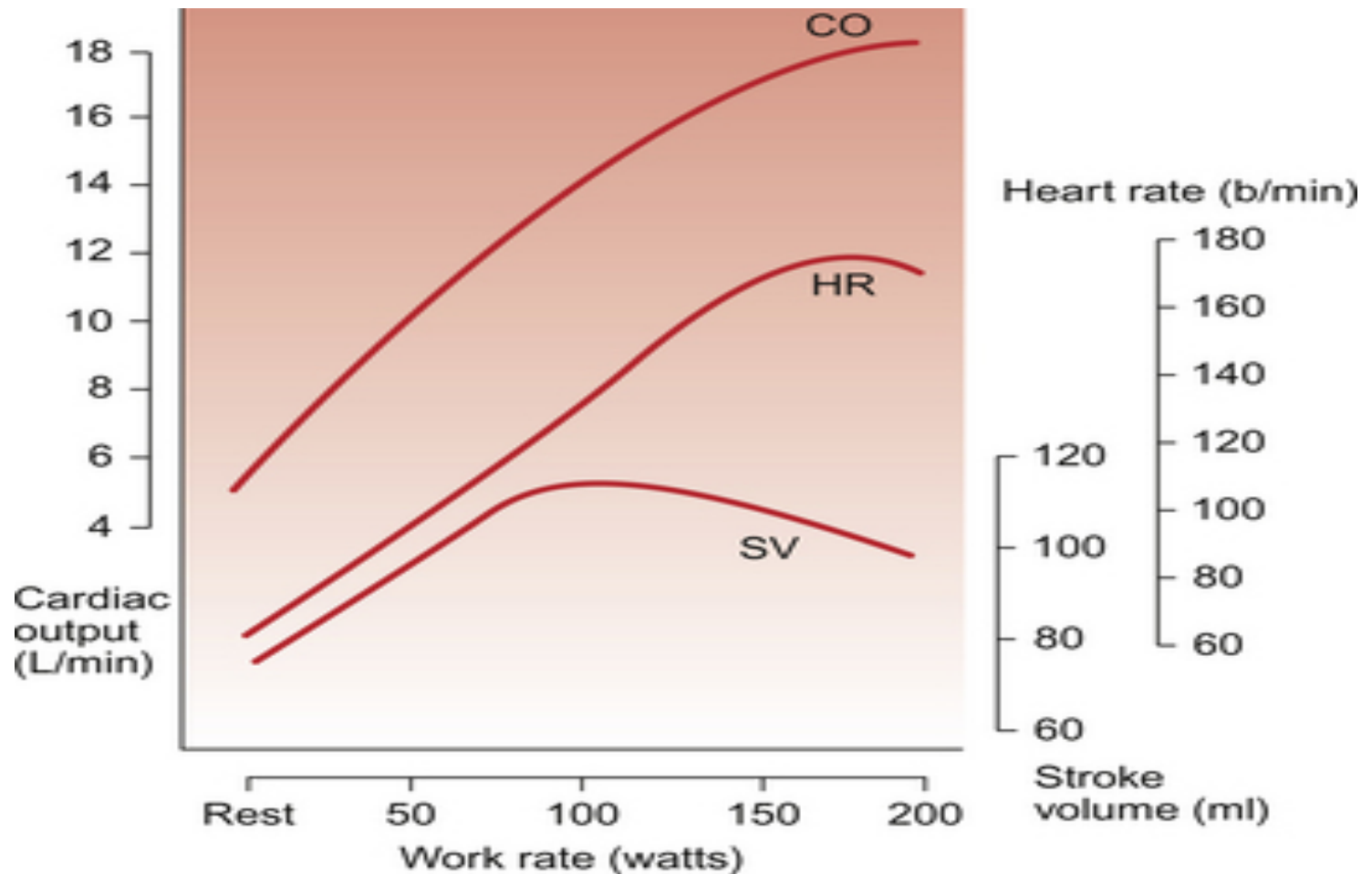
## Cardiovascular System in Exercise cont...

- In Marathon runner 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%.
- Whereas the **heart rate** increases from 50 to 185 beats/min, an increase of 270 %.
- The heart rate increase a greater proportion of the increase in cardiac output than does the increase in the stroke volume.



**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



## Body Heat In Exercise

Almost all the energy released by the body's metabolism of nutrients is converted into **body heat**.

Working muscle use only 20-25 %.

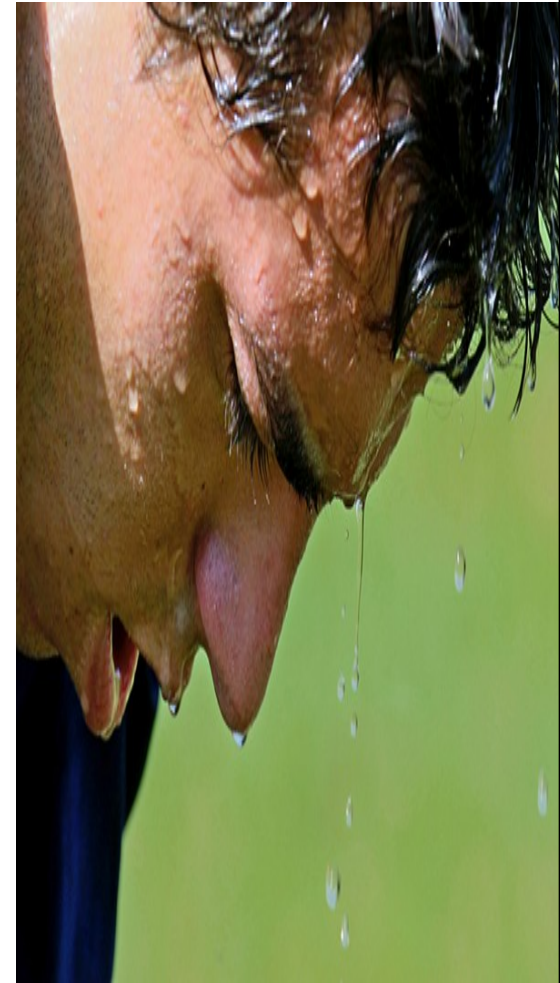
A small portion of the energy is used for

- (1) overcoming viscous resistance to the movement of the muscles and joints,
- (2) overcoming the friction of the blood flowing through the blood vessels,
- (3) other, similar effects—all of which convert the muscle contractile energy into heat.

almost all the energy that does go into creating muscle work still becomes body heat

**What will happen if sweating mechanism cannot eliminate the heat? see**

Guyton & Hall 13E Unit XV chapter 85  
page 1094



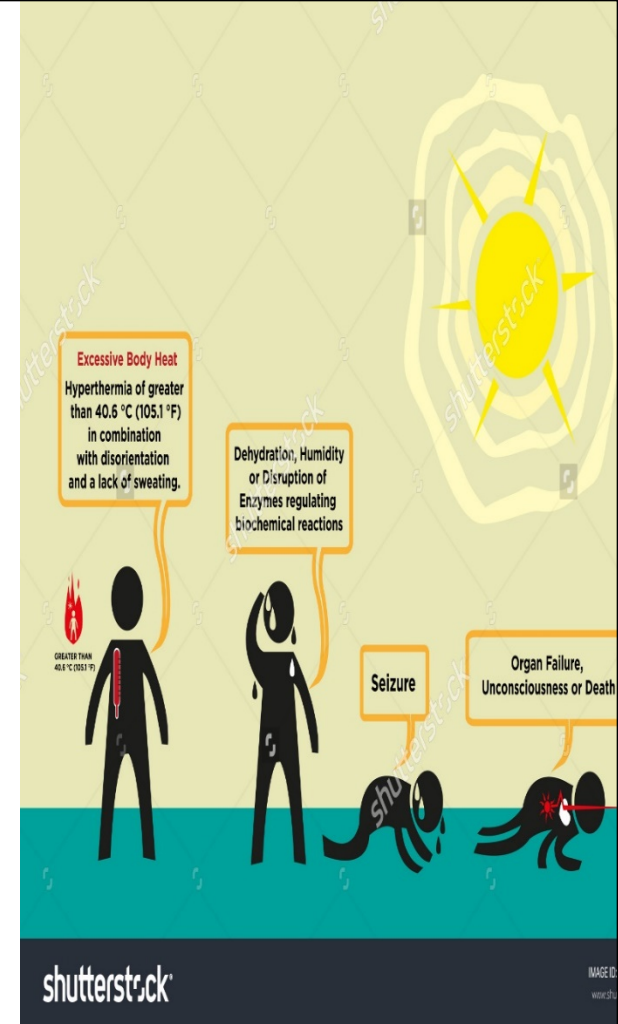
# Heatstroke

During endurance training body temperature rises **from 37° to 40°C)**

In hot and humid conditions body temperature rise up to **41° to 42°C)**

**High** temperature is destructive 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 !