



Physiology Team

MEDICAL COLLEGE 433

Muscle adaptation to exercise

Color Index

Red = important

Purple = Addition

Orange = Explanation



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Objectives :

- **Strength, power, and endurance of muscles**
- **Effect of athletic training on muscles and muscle performance**
- **Muscle hypertrophy**
- **Fast-twitch and slow-twitch muscle fibers**
- **Respiration in exercise**
- **Oxygen consumption and pulmonary ventilation in exercise**
- **Effect of training on vo_2 max**
- **Cardiovascular system in exercise**
- **Work output, oxygen consumption, and cardiac output during exercise**
- **Effect of training on heart hypertrophy and on cardiac output**
- **Role of stroke volume and heart rate in increasing the cardiac output**
- **Body heat in exercise & heatstroke**

Strength, Power, And Endurance Of Muscles

	Strength	Power	Endurance
Definition	the amount of force a muscle can produce	amount of work that the muscle performs in a unit period of time (kilogram meters/ minute(kg-m/min)	Ability of muscles to sustain repeated contractions against a resistance for period of time.
Depend on	Depends on size of muscles a maximal contractile force between 3 -4 kg/cm² of a muscle cross-sectional area	strength , distance of contraction & number of contractions each minute	depends on glycogen stored in the muscle before exercise
Example	a muscle with cross-sectional area 150 cm ² cause maximal contractile strength of 525 kilograms applied to tendon of muscle	A muscle that can lift 1 kg weight to a distance of one meter in one minute, said to have a power of one kg-m/min	A person on high CHO diet stores more glycogen in muscles than a person on either high-fat or mixed diet
Note	Mechanical work of muscle = force applied by the muscle X distance over which force applied		endurance is greatly enhanced by high CHO diet

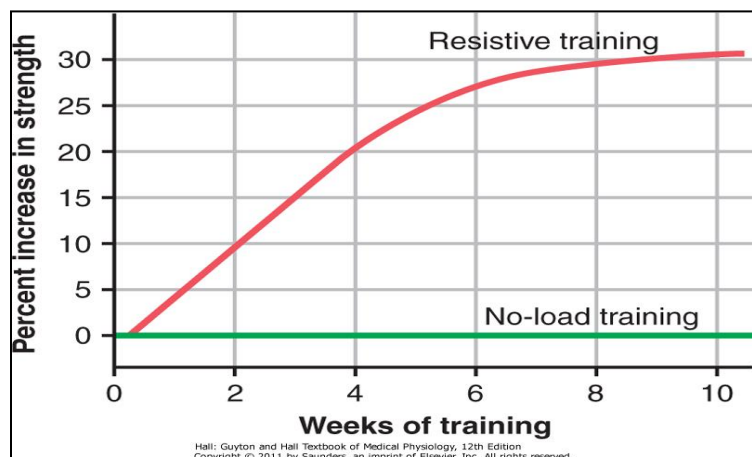
Effect of Training on Muscles and Muscle Performance

Without load

Muscle exercise for hours without load increase **little in strength**

With at 50% maximal contraction force

Muscle exercise at 50% maximal contraction force **develop strength rapidly** even if contract only a few minutes/day



6 maximal muscle contractions

X

3 sets in 3 days

X

one week

will lead to increase in muscle strength, without muscle fatigue.

Muscle Hypertrophy

What is muscle hypertrophy ?

Increase in bulk + mass + strength

How much muscles will hypertrophied after exercise ?

30- 60 %

Why muscles are hypertrophied ?

Due to **increase** diameter of the muscle fibers and **increase** number of fibers

What are the changes in body after hypertrophy ?

- ▶ Increase myofibrils
- ▶ 120 % in mitochondrial enzymes
- ▶ Increase ATP and phosphocreatine
- ▶ 50 % increased in stored glycogen
- ▶ 75 -100 % increased in stored triglyceride
- ▶ Increased anaerobic & aerobic metabolic capability specially oxidation rate increased by 45 %

Fast-Twitch and Slow-Twitch Muscle Fibers

- **Fast-twitch fibers:** forceful and rapid contraction (**deliver power for seconds to a minute**)

E.G gastrocnemius muscle as in jumping

- **Slow-twitch muscle:** for prolonged muscle activity (**provide endurance, prolonged strength of contraction minutes to hours.**)

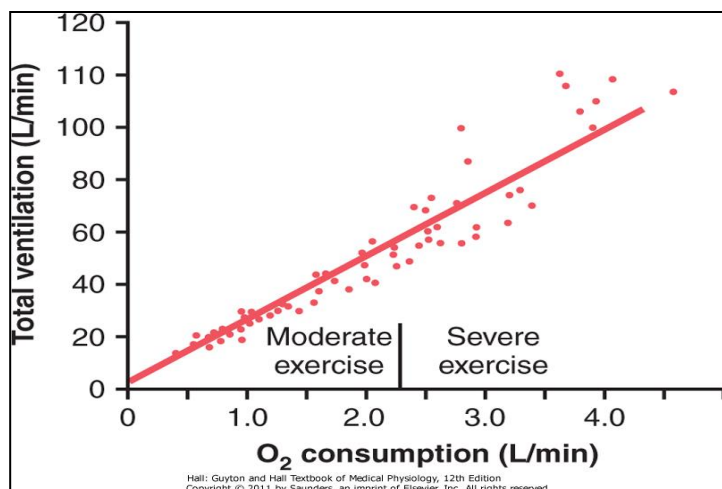
E.G leg muscle (soleus)

What is the differences between the fast-twitch and the slow-twitch fibers Read ?

- Fast:** large diameter, more active enzymes for phosphagen & glycogen-lactic acid system to release energy for rapid & short contractions
- Slow:** more mitochondria, more capillaries, more myoglobin to carry more O₂, more aerobic enzymes to generate aerobic energy for endurance.

Respiration In Exercise

- ❖ Oxygen Consumption is **VO₂** and Pulmonary Ventilation is **VE** in Exercise
- ❖ VO₂ at rest for a young man is about **250 ml/min**
- ❖ at Maximal efforts VO₂ and VE will increase about **20-fold** between the resting state and maximal intensity in well trained athletes.



Effect of Training on Vo₂ Max

What is Vo₂ Max ?

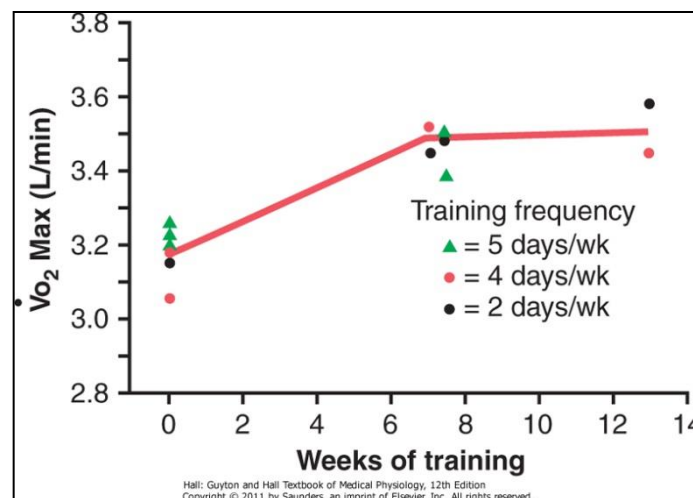
rate of o₂ usage under maximal aerobic metabolism

What are factors that Vo₂ depends on ?

increased only about **10 % by training**, Moreover other factors can increase it:-

- 1- Chest sizes in relation to body size
- 2- stronger respiratory muscles

As in marathoners Vo₂ Max increase **45%** greater than untrained.



Cardiovascular System in Exercise

Work Output, Oxygen Consumption, and Cardiac Output During Exercise:-

all these 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.

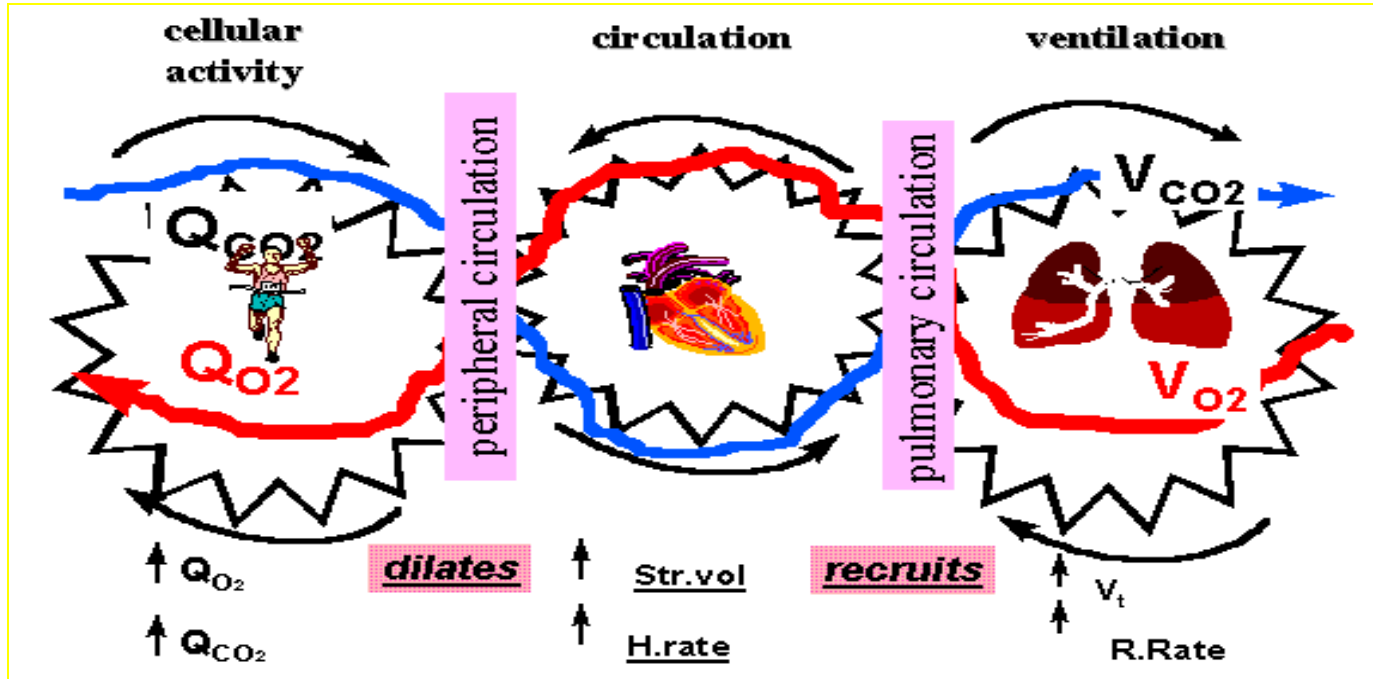
Effect of Training on Heart Hypertrophy and on Cardiac Output:

- Training increase C.O about 40 % greater than untrained persons
- heart chambers of marathoners enlarge about 40 percent in contrast to non trained
- Heart size of marathoner larger than normal person , heart enlarges to increase pumping capacity in endurance types of training

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

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



Stroke Volume increase to maximum till Cardiac Output increase only halfway to its maximum ,then Cardiac Output increase by increasing the Heart Rate

Body Heat In Exercise

Almost all the energy released by the body's metabolism converted into body heat.

Muscle work use only 20 - 25 %.

remainder converted into heat energy to overcome:

- (1) resistance to the movement of the muscles and joints,
- (2) friction of the blood flowing through the blood vessels, and
- (3) other effects

Heatstroke

- ▶ During endurance training body temperature rises 98.6° to 102° or 103°F (37° to 40°C)
Also hot and humid conditions body temperature rise to 106° to 108°F (41° to 42°C)
- ▶ **Consequently**, temperature destroy tissue cells mainly **(brain cells)** and symptoms appear as :
Body weakness, exhaustion, headache, dizziness, nausea (disgust), sweating, confusion, uncontrolled gait, collapse, and unconsciousness. And may lead to death
- ▶ **Temp can not fall if he stop exercise as temp regulatory mechanisms fail & increased rate of intracellular chemical reactions produces more heat.**

Treatment :

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

Summary :

1. Muscle strength depends on the size of the muscle.
2. Muscle endurance depends on glycogen stored in the muscle before exercise
3. Muscle exercise for hours without load increase little in strength
4. muscles hypertrophied, Due to the increasing in the diameter of the muscle fibers.
5. VO_2 at rest for a young man is about 250 ml/min.
6. Athletes have a lower heart rate at rest & their heart pumps more blood with a lower heart rate
7. the heart rate increase a greater proportion of the increase in cardiac output than does the increase in stroke volume.

Multiple Choice Questions

1- Which of the following depend on muscle cross sectional?

- A) Power
- B) Endurance
- C) Strength
- D) Cardiac Output

2- amount of work that the muscle performs in a unit period of time is?

- A) Strength
- B) Power
- C) Endurance
- D) Mechanical work

3- How much muscles will hypertrophied after exercise ?

- A) 10-20 %
- B) 30-60 %
- C) 20-40 %
- D) 15-25 %

4- at Maximal efforts VO₂ and VE will increase about ?

- A) 20-folds
- B) 30-folds
- C) 40-folds
- D) 50-folds

5- Stroke Volume at rest for marathoner is?

- A) 75 ml
- B) 162 ml
- C) 75 ml
- D) 105 ml

6- Muscle work use only ____ of energy?

- A) 15-20 %
- B) 20-25 %
- C) 25-30 %
- D) 30-35 %

1-C 2-B 3-B 4-A 5-D 6-B