Muscle adaptation to exercise

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Objective

- Define **strength, power**, and **endurance** of muscles.
- Analyze the effect of athletic **training** on muscle structure and muscle performance.
- Explain the different forms of muscle **remodeling** E.g
  - *-muscle hypertrophy and muscle atrophy.*
  - *-Adjustment of Muscle Length*
  - *-Hyperplasia of Muscle Fibers.*
  - - Muscle atrophy caused by denervation
- Contrast **Fast**-twitch and **Slow**-twitch muscle fibers.
- Describe the changes in **body fluids and salts** in exercise.
- Explain the **body heat** changes in exercise and the heatstroke.
- Mention the effects of **drugs** on athletes.
- Demonstrate how body **fitness** improves life

Strength, Power, and Endurance of Muscles

Muscles strength: 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^2 of the cross section of the muscle e.g. The cross-sectional area of quadriceps in a world class weight lifter is 150 cm^2 causes maximal contractile strength of 525 kilograms. e.g weight lifting, digging, etc..

Mechanical work performed by a muscle (W): is the amount of force applied by the muscle multiplied by the distance over which the force is applied.

Work output= The force applied by the muscle (L) x The distance over which the force is applied (D)

W= L x D it is expressed in (kg-m).

Cont… Strength, Power, and Endurance of Muscles

- **Muscles Power:** Is 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

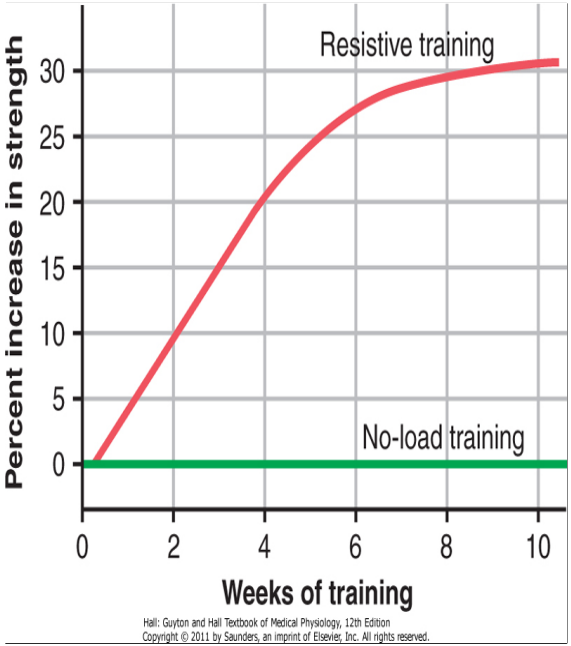
Maximal Resistance Training:

- 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 % **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 30% increase in muscle strength and muscle mass (hypertrophy), in the first 6-8 wks 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

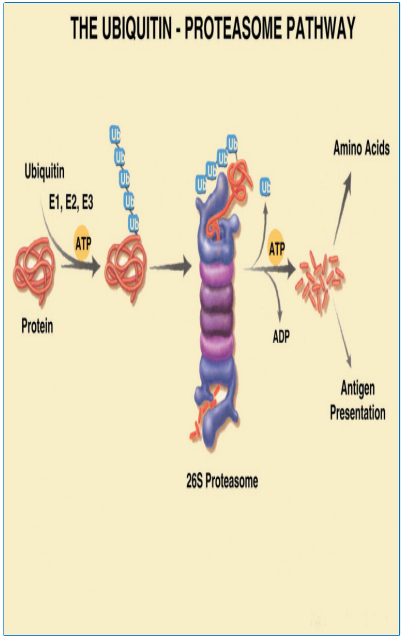
- Is the increase of the total mass of a muscle.
- The size of muscles is determined to a great extent by heredity and level of testosterone secretion. So men has considerably larger muscles than women.
- Hypertrophy occurs to a much greater extent when the muscle **is loaded** during the contractile process.
- With training muscles hypertrophied 30-60 % due to increased **diameter** of the muscle fibers with **some** increase in number of fibers by longitudinal splitting of enlarged fibers (***fiber hyperplasia***).
- 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%

Adjustment of Muscle Length

- Another type of hypertrophy occurs when muscles are stretched to greater than normal length.
- This stretching causes new sarcomeres to be added at the ends of the muscle fibers, where they attach to the tendons.
- New sarcomeres can be added as rapidly as several per minute in newly developing muscle.
- Conversely, when a muscle continually remains shortened to less than its normal length, sarcomeres at the ends of the muscle fibers can actually disappear.
- It is by these processes that muscles are continually remodeled so they have the appropriate length for proper muscle contraction.

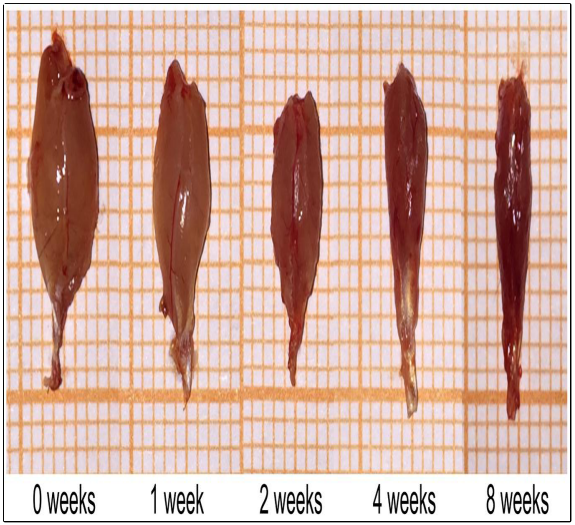
Muscle Atrophy

- When a muscle remains unused for many weeks, the rate of degradation of the contractile proteins is more rapid than the rate of replacement (muscle atrophy occurs).
- The pathway of the protein degradation in a muscle undergoing atrophy is the *ATP-dependent ubiquitin-proteasome pathway*.
- Proteasomes are large protein complexes that degrade damaged or unneeded proteins by *proteolysis* (breakdown of peptide bonds).
- Ubiquitin is a regulatory protein that labels which cells will be targeted for proteasomal degradation.



Muscle Denervation Causes Rapid Atrophy

- When a muscle loses its nerve supply, it no longer receives the contractile signals that are required to maintain normal muscle size.
- The atrophy begins almost immediately. After about 2 months, degenerative changes also begin to appear in the muscle fibers.
- If the nerve supply to the muscle grows back rapidly, full return of function can occur in as little as 3 months



Fast-Twitch and Slow-Twitch Muscle Fibers

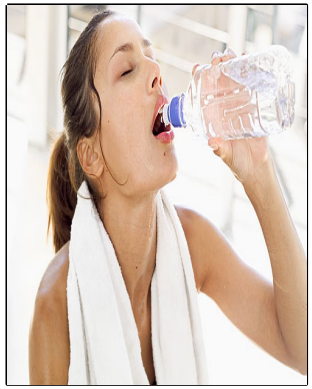
- In the humans, all muscles have varying percentages of *fast-twitch* and *slow-twitch muscle fibers.*
- **Fast-twitch fibers:** Achieves maximal power in very short periods of time. Adapted for forceful and rapid contraction. e.g. gastrocnemius muscle capable of forceful and rapid contraction of the type used in 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 leg used to a greater extent for prolonged lower leg muscle activity.. (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 14 th E Unit XV chapter 85 page 1090)**

Body fluids and salts in exercise

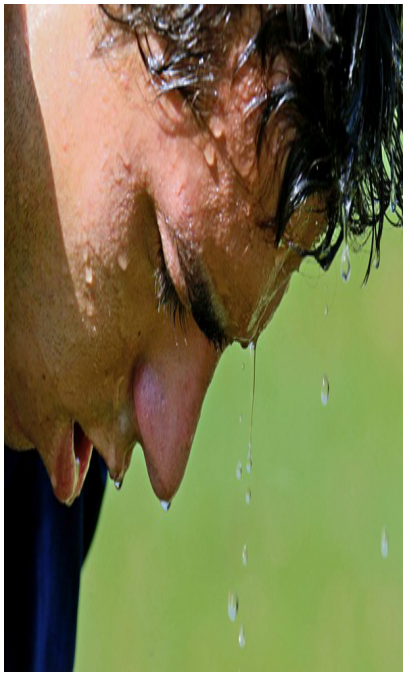
- Exercise for 1 hour during endurance athletic event causes ***5-10 pounds of weight loss*** in hot humid atmosphere due to ***sweat loss***.
- Loss of enough sweat ***reduces performance*** 5-10% and may lead to cramps, nausea & serious effects.
- So it ***should be replaced by Sodium*** tablets and supplemental fluids containing ***potassium*** in the form of fruit juice is required to athletes.



- ***Acclimatization*** to exercise by gradual increase over 1-2 weeks instead of maximal exposure is needed.
- The acclimatization decreases the salt lost in the sweat by increased aldosterone secretion by the adrenal cortex.
- The aldosterone increase reabsorption of sodium chloride from the sweat before it is secreted .
- Once the athlete is acclimatized, he rarely need salt supplements during athletic events.

Body Heat In Exercise

- Almost all the energy released by the body's metabolism of nutrients is eventually converted into body heat.
- This applies to muscle contraction for the following reasons:



First, the maximal efficiency for conversion of nutrient energy into muscle work, is only 20% to 25%. the remainder of the nutrient energy is converted into heat during the course of the intracellular chemical reactions.

Second, almost all the energy that does go into creating muscle work still becomes body heat because most of this 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, and

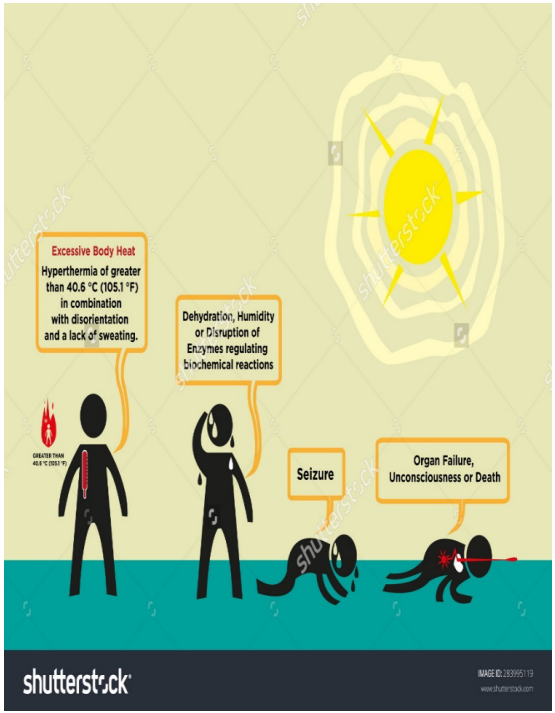
(3) other, similar effects, all of which convert the muscle contractile energy into heat.

The sweating mechanism help to eliminate this heat. Guyton & Hall 14 th E Unit XV chapter 85 page 1082

Heatstroke

- During endurance training body temperature often rises from 37° to 40°C)
- In hot and humid conditions that prevent sweating, or with excess clothing, body temperature may rise up to 41° to 42°C). An intolerable and even lethal condition called *heatstroke.*
- High temperature is destructive to tissue cells mainly **(brain cells)** .

Symptoms: Body weakness, exhaustion, headache, dizziness, nausea, 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.

Drugs and athletes

- ***Caffeine*** increase athletes performance.
- **Male sex hormone (Androgens) & other anabolic steroids** increase athletes performance but they ↑ the risk of heart attacks due to hypertension, ↑ LDL and ↓ HDL.
- Male sex hormones ↓ testicular functions & ↓ natural testosterone secretion ***in males***.
- ***Women*** develop facial hair, stoppage of menses, ruddy skin and bass voice if they take androgens.
- ***Amphetamine & cocaine*** improve performance but ***overuse*** *reduce performance* they are *psychic stimuli*.
  -the action of these drugs in addition to epinephrine and norepinephrine (hormones of adrenal medulla) secreted during exercise leading to *death by ventricular fibrillation*. Read Guyton & Hall: Textbook of Medical Physiology 14th Ed. page; 1083

Body fitness improves life

- Studies shows that body fitness, exercise &weight control have additional benefit of prolonged life expectancy (between 50-70).

Reasons:-

1-It reduces *CVD, heart attacks, brain stroke* and *kidney* disease due to low blood pressure, low blood cholesterol, low LDL, and high HDL.

2-It reduces *insulin resistance* and type 2 diabetes.

3-Improved fitness reduces *the risk* of breast, prostate, and colon ***cancers*** and reduces obesity.


Thank you !