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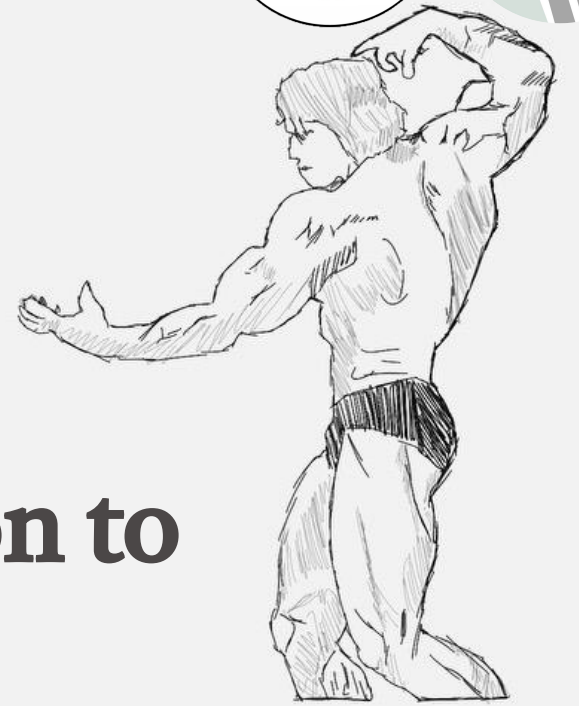
Muscle Adaptation to Exercise



Color Index:
-Main Text -Important -Notes
-Boy Slides -Girl Slides -Extra

Ty to Hasan Alsugahyir for sketch (MED445 inshallah) <3

Objectives

01 Define strength, power, and endurance of muscles.

02 Analyze the effect of athletic training on muscle structure and muscle performance.

03 Explain the different forms of muscle remodeling.

- Muscle hypertrophy and muscle atrophy.
- Adjustment of Muscle Length.
- Hyperplasia of Muscle Fibers.
- Muscle atrophy caused by denervation.

04 Contrast Fast-twitch and Slow-twitch muscle fibers.

05 Describe the changes in body fluids and salts in exercise.

06 Explain the body heat changes in exercise and the heatstroke.

07 Mention the effects of drugs on athletes.

08 Demonstrate how body fitness improves life.

Muscle Strength

- **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.
  - **Normal maximal contractile force:** 3 - 4 kg/cm^2 of the cross section of the muscle.
  - The size of the muscle can be increased by: weight lifting - digging.
  - A man who is well supplied with testosterone or who has enlarged his muscles through an exercise training program will have increased muscle strength.
    - Example:

Larger muscle size → stronger muscle.

Cross-sectional area of quadriceps in a world class weight lifter: 150 cm^2 (larger than normal) → maximal contractile strength: 525 kg (by multiplying 150 x 3.5).

- **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 muscle (L) x distance over which force is applied (D)
  W = L x D
  Unit: (kg-m)

Muscle Power

- **Muscle power:** the amount of work the muscle performs in a period of time.
- **Unit: (kg-m/min)**
- The maximal power achievable by all muscles in the body of a highly trained athlete working together is approximately the following:

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

Notice that power **decreases** over time (inverse relationship)

Muscle Endurance

- **Muscle endurance:** the ability of the muscle to sustain repeated contractions against a resistance for a period of time.
- Depends on the glycogen stored in the muscle before the exercise → endurance is enhanced by a high-carbohydrate diet.
- Types of endurance:

Types of Endurance

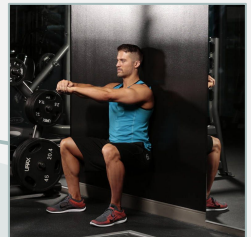
Static Endurance

Muscle's ability to remain contracted for a long period.

Dynamic Endurance

Muscle's ability to contract and relax repeatedly.

مثال: سكوات ثابت



Effect of Training on Muscle Structure & 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 extreme, Muscles that contract at more than 50% maximal force of contraction (even if contractions were performed few times each day) → develop strength rapidly.

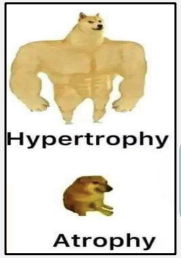
Example:

- 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 → little increase in strength.

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

Med439: Fatigue that occurs after training is due to the expiration of the amount of glycogen stored in the muscles.

Muscle Hypertrophy



VIDEO

- **Muscle hypertrophy:** 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.
- Occurs to a much greater extent when muscle is loaded during the contractile process.
- With training, muscles hypertrophied 30-60% due to:

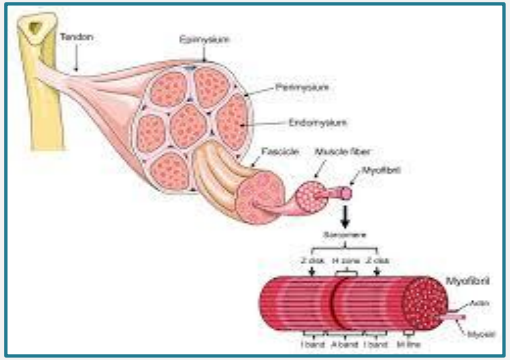
1. Increased diameter of the muscle fibers.
2. Some Increase in number of fibers.
   by longitudinal splitting of enlarged fibers (fiber hyperplasia).

Changes in the hypertrophies muscle fiber:

- ↑ actin & myosin filaments numbers
- 120%↑ in mitochondrial enzymes.
- ↑ ATP & phosphocreatine المجهود زاد -> تحتاج طاقة أكثر
- ↑stored glycogen by 50%
  & ↑ in stored triglycerides by 75-100%.
- ↑ aerobic & anaerobic metabolisms
- The efficiency of oxidative metabolic system increases by 45%

Adjustment of Muscle Length

- Another type of hypertrophy occurs when muscles are stretched to greater than normal length.
- 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.
- by these processes that muscles are continually remodeled so they have the appropriate length for proper muscle contraction.



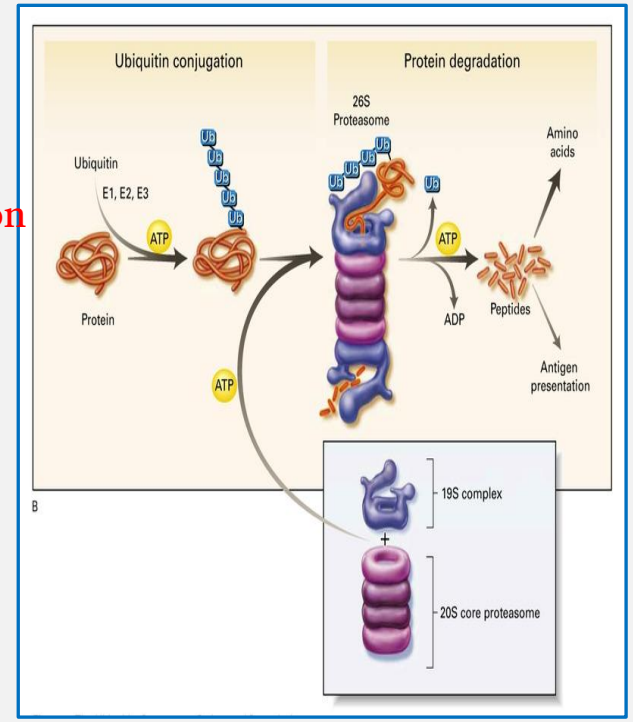
Muscle Atrophy

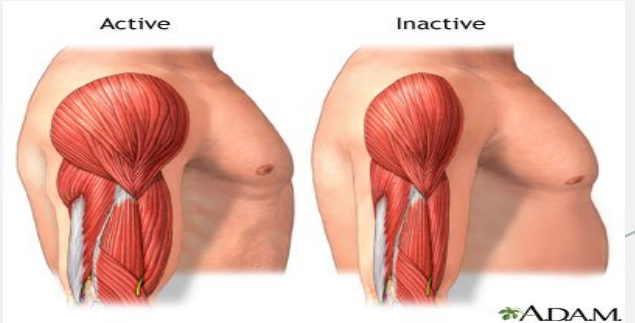
When a muscle remains unused for many weeks, the rate of degradation of the contractile proteins is more rapid than the rate of replacement (muscle atrophy occurs).

The pathway of the protein degradation in a muscle going through atrophy is the ATP-dependent ubiquitin-proteasome pathway

- Proteasomes: large protein complexes that degrade unneeded/ damaged proteins by proteolysis (it breaks down the protein's peptide bonds)

- Ubiquitin: regulatory protein that labels which cells will be targeted for proteasomal degradation



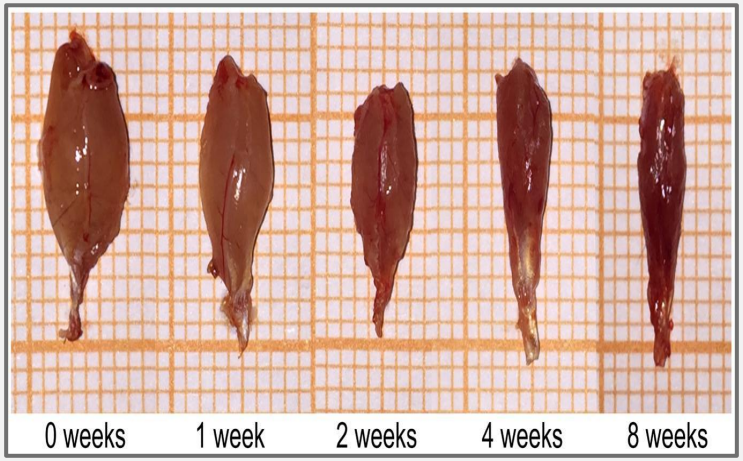


Muscle Denervation Causes Rapid Atrophy

When a muscle loses its nerve supply, it no longer receives contractile signals required to maintain normal muscle size.

Atrophy begins **immediately**, and after **2 months**, degenerative changes appear in the muscle fibers.

- If the nerve supply returns, full function can return in **3 months.**



Fast-Twitch & Slow-Twitch Muscle Fibers

In the human being, all muscles have varying percentages of fast-twitch and slow-twitch muscle fibers. Some people have considerably more fast-twitch than slow-twitch fibers, others have more slow-twitch fibers → determine the athletic capabilities of different individuals.

	Slow-twitch fibers (red / type I)	Fast-twitch fibers (white / type II)
Function	"Organized for generation of aerobic energy" Provide endurance, prolonged strength of contraction minutes to hours.	"Adapted for forceful & rapid contraction" Achieves maximal power in very short periods of time.
Example	Soleus muscle (lower leg) in standing (aerobic metabolism)	Gastrocnemius muscle in jumping and weight lifting (anaerobic metabolism)
Summary	Provide endurance, delivering prolonged strength of contraction over many min to hours.	Deliver extreme amounts of power for a few seconds to a minute

Fast-Twitch & Slow-Twitch Muscle Fibers

VIDEO

Slow-twitch fibers (red / type I)	Fast-twitch fibers (white / type II)
- Smaller in diameter - Enzymes (of phosphagen & glycogen-lactic acid systems) are less active - More mitochondria - More myoglobin → increased rate of O2 diffusion - Enzymes (of aerobic metabolic system) are more active - Number of capillaries is greater	- Larger in diameter (twice) - Enzymes (of phosphagen & glycogen-lactic acid energy systems) are 2 - 3 more active → max power achieved for short period is twice greater than slow-twitch - Less mitochondria & myoglobin - Enzymes (of aerobic metabolic system) are less active - Number of capillaries is less

Body fluids and salts in exercise

- Exercise for 1 hour during endurance athletic event in hot humid atmosphere, can cause weight loss of 5-10 pounds due to sweat loss.
- Loss of enough sweat reduces performance (by 5-10%) and can lead to cramps, nausea and serious effects.
- Therefore, it should be replaced by sodium tablets and supplemental fluids containing potassium such as fruit juice, which is required to athletes.
- Acclimatisation (التكيف المناخي): to exercise by gradual increase over 1-2 weeks instead of maximal exposure.
- Acclimatization decreases salt loss in sweat by increasing aldosterone secretion by adrenal cortex.
- Aldosterone hormone increases the reabsorption of sodium chloride from sweat before it is secreted.
- After an athlete is acclimatized , they rarely need salt supplements during exercise.

Body Heat in Exercise

- Almost all the energy released by the body's metabolism of nutrients is converted into body heat.
- This applies to muscle contraction where 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.

💡 MED443: What will happen if the sweating mechanism can't eliminate heat?
Heatstroke can develop
++ Even if the person has stopped exercising, the temperature does not easily decrease by itself in the heatstroke because:
1. Temperature-regulating mechanism often fails.
2. Very high body temperature → increased KE → double rates of all chemical reactions → liberating still more heat.

Heatstroke

- During endurance training body temperature rises from 37° to 40° C.
- In hot & humid conditions, body temperature rise up to 41 - 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 (disgust) & alteration in sweating.
- Confusion & unconsciousness
- Uncontrolled gait (balance) & collapse
- May lead to death

Treatment

- Remove all clothes.
- Maintain a spray of cool water on all surfaces of body or continually sponge the body.
- Blow air over the body with a fan.
- Total immersion of body in water containing a mush of crushed ice if available (preferred).

Drugs & Athletes

1- Caffeine:

- Increase athletes' performance.

2- Androgens & Anabolic Steroids:

- Male sex hormones.
- Increase athletes performance.
- Increase risk of heart attacks.

Due to:

- Hypertension
- High LDL
- Low HDL
- Decrease testicular functions.
- Decrease natural testosterone secretion in males.

3- Androgens Used by Women:

- Develop facial hair + ruddy skin + bass (deep) voice + Menses stop.

4- Amphetamine & Cocaine:

- Improve performance.
- Overuse → reduce performance.
- The action of these drugs + hormones of adrenal medulla secreted during exercise (epinephrine & norepinephrine) → death by ventricular fibrillation.

Body Fitness Improves Life

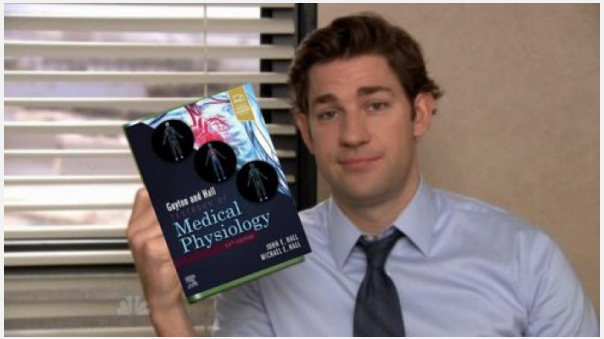
Studies show that: body fitness, exercise & weight control have additional benefit of prolonged life (between 50 - 70 years).

- Reason:

1. Low blood pressure + low blood cholesterol + low LDL + high HDL → reduced risk of CVD + heart attacks + brain stroke + kidney disease.
2. Reduces insulin resistance + type 2 diabetes.
3. Reduces the risk of breast, prostate, and colon cancers.
4. Reduces obesity

You can find the pages related to this lecture from (Guyton) here

Note: Guyton has extra information that might not be with us, but if you want to learn more about the topic make sure to check it out :3



Thanks to team 443 <3

MCQs

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

Q1:Which one of the following factors determine the ability of the muscle to perform static endurance exercise?			
A-Glycogen stores	B-Diameter of blood vessels	C-Cross sectional area	D-Number of muscle fibers
Q2:Which one of the following muscles formed mainly from slow twitch fibers?			
A-Eyelid muscle for blinking	B-Lower leg muscle for standing	C-Finger muscle for typing	D-Thigh muscle for jumping
Q3:Which one of the following changes occur in hypertrophied muscle?			
A-Inhibition of oxidative metabolic system.	B-Decrease fat storage	C-Increase in glycogen content.	D-Decrease in stored triglycerides.
Q4:The work done by a muscle in given time is defined as?			
A-Muscle fitness	B-Muscle force	C-Muscle strength	D-Muscle power

SAQs

Q1: Compare between the Slow twitch and fast twitch Muscles?

Muscle type	Fast twitch	Slow twitch
Strength of contraction	Fast & Strong	Long & sustained
Ex. movement	Running	Standing
Energy system	Anaerobic	Aerobic

Q2: Someone was exercising in a humid atmosphere after exertion:
1-What is the name of this condition?
2-Mention ways to help treat this condition?

1- Heat stroke
2- Remove all clothing.
Maintain a spray of cool water on all surfaces of the body.
Blow air over the body with a fan.
Move the body under shades away from the sun and the heat.

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