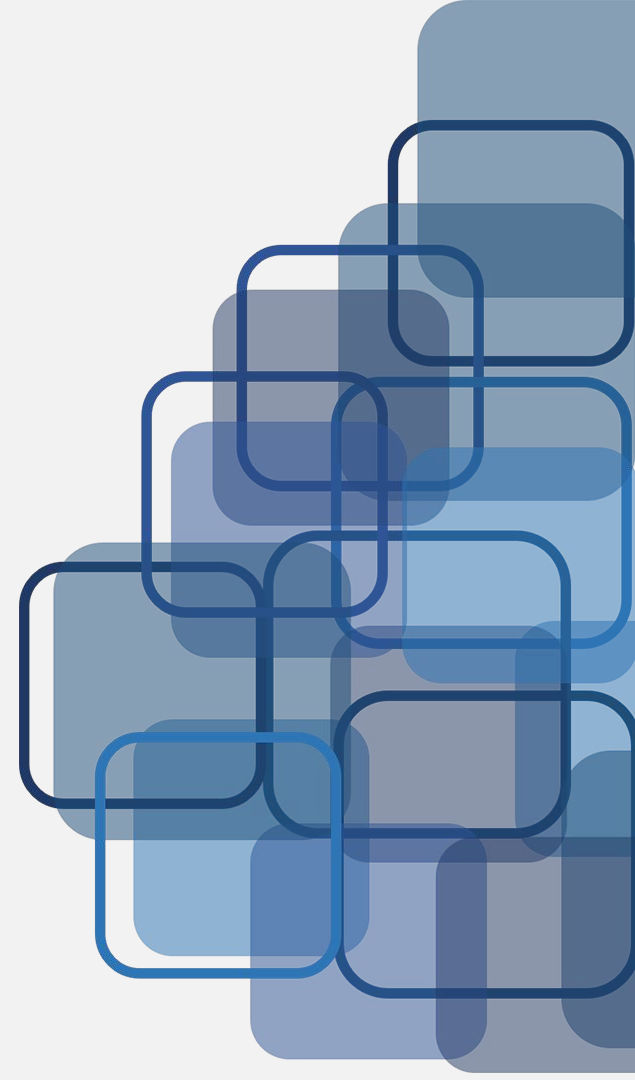


9

Muscle Adaptation to Exercise



Editing file

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Red: Important
Black: In Male & Female slides
Blue: In male slides
Pink: In female slides
Gray: Notes & extra information

Objectives



01 Define strength, power, and endurance of muscles.

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

03 Discuss the mechanism of muscle hypertrophy.

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

05 Explain the respiratory changes in exercise (Oxygen consumption, pulmonary ventilation and VO_{2max}).

06 Identify the cardiovascular changes in exercise (Work output, cardiac output, heart hypertrophy).

07 Interpret the role of stroke volume and heart rate in increasing the cardiac output.

08 Explain the body heat in exercise and the heatstroke.



Muscles strength

Definition:

-Refers to the amount of force (push or pull) a muscle can produce against a resistance in a single maximal effort. (high resistance with few repetitions).

- ◆ -Size of the muscle influences the maximal contractile force. **
- Normally 3-4 kg/cm² of the cross section of the muscle.*

example

The cross-sectional area of quadriceps in a world class weight lifter is 150cm² causes maximal contractile strength of 525 kg.

increasing strength of a muscle could be by:

weight lifting

digging



** مهم تعرفون أنه عامل مؤثر في Muscles

. strength

* بمعنى انه العضلة ممكن تنتج ما بين 3 الى 4

اضعاف ال Cross sectional area of the

.muscle

فلو جينا للمثال اللي عاليمين معطينا المساحة القطعية

للعضلة 150 والقوة الناتجة 525 نلقى انه القوة 3.5

اضعاف المساحة القطعية.

Mechanical work of muscle (W)

W

=

L

X

D

W: Mechanical work of muscle. (unit: kg-m)

L: The force applied by the muscle.

D: The distance over which the force is applied.

why do we study mechanical work?

In sport medicine, there is a test called gate(walking) analysis where the doctors measure work and performance of the muscle.

Muscles Power

Definition:

-Refers to the amount of work a muscle produces **in a period of time**.
-It is expressed in (kg-m/min).

◆ The maximal power is 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

-إذا نتذكرون قانون القدرة كان مقدار الشغل المبذول خلال فترة زمنية وهذا نفس الشيء ما فيه فرق يعني عشائه فزيولوجي بيتغير!
- الوحدة قبل شوي ذكرنا وحدة الشغل وكانت kg-m أو بما أن القدرة الشغل خلال الزمن إذا kg-m/min
- نلاحظ في الجدول أن القدرة تنقص كل ما مضى وقت أكثر.
-احفظوا الأرقام لكن افهموا الفكرة أهم شيء.

Muscles Endurance

Definition:

-The ability of the muscle to sustain repeated contractions against a resistance for a period of time. (low resistance with many repetitions).

- It depends on the glycogen stored in the muscle* before the exercise. Therefore, endurance is enhanced by a high-carbohydrate diet.

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

Endurance

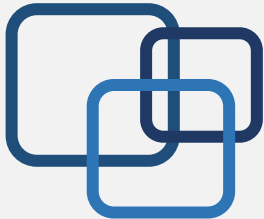
Dynamic

is defined as the muscle's ability to contract and relax repeatedly.



Static

is the muscle's ability to remain contracted for a long period.



Effect of Training on Muscle structure and Muscle Performance

Maximal Resistance Training:

Muscles that contract (exercise) with more than 50 percent of its maximal force of contraction: develop strength rapidly even if the contractions are performed only a few times each day.

Muscles that exercise with no load: even if they are exercised for hours, at the end, there will be only little increase in strength. (it takes multiple weeks to see that little increase)

Example:

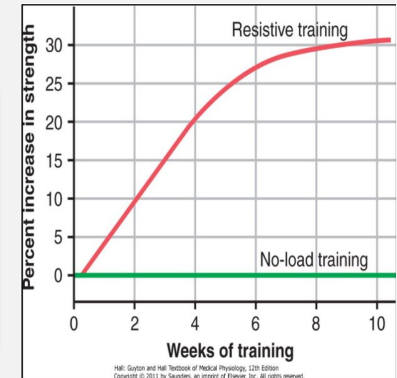
3 days
a
week

3
times
a
day

6 maximal
muscle
contractions
each time

-This suggested program above will provide approximately optimal increase in muscle strength without producing chronic muscle fatigue.

You need at least 8 weeks of training to see the results.



Muscle Hypertrophy

Definition:

-It is an increase in 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**.

how does the muscle diameter increase ?

-when a person is training there will be micro injury in muscle fibers (with internal bleeding), the person is asked to take break for a day so that the bleeding stops (forming clot) and begin healing, this healing will make the muscle fiber grow .

*كلما اعطيت العضلة load
أثقل كلما انبنت العضلة بشكل
أقوى .

-note that increase in load should be gradually.



Con.

Changes in the hypertrophied muscle fiber

*It will lead to increase in appetite.

01

Increase in actin and myosin filaments numbers.

02

120% increase in mitochondrial enzymes.

03

Increase ATP and phosphocreatine.

04

50% increase in stored glycogen.

05

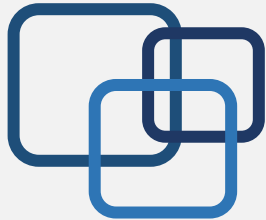
75-100% increase in stored triglycerides.

06

Increased both the aerobic & anaerobic metabolism*.

07

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.** ميزة قوتها
- ◆ Adapted for forceful and rapid contraction.
- ◆ Depends on anaerobic energy.

Example:

-gastrocnemius muscle used for jumping.

Slow-Twitch fibers

- ◆ Provide endurance, **prolonged** strength of contraction minutes to hours.
- ◆ adapted for prolonged muscle activity
- ◆ Depends on aerobic energy.

Example:

-soleus muscle in the lower leg used for standing.

Summary

-Fast-twitch fibers can deliver extreme amounts of power for a few seconds to a minute or so.

-Slow-twitch fibers provide endurance, delivering prolonged strength of contraction over many minutes to hours.

-Fast/slow twitch are all present but one of them is dominant and this is determined by genetic inheritance.



Respiration In Exercise

كل ما زاد VE
زاد معه VO2

VE* هو كمية الهواء المستنشق ككل (اكسجين، ثاني اكسيد الكربون، الخ).
VO2** هو كمية الاكسجين المستنشق والمستخدم في العمليات الايضية.



Oxygen Consumption (VO2)** Pulmonary Ventilation (VE)* in Exercise.



In the study (chart 1), VO2 Max increased only about 10% by training.



VO2 and VE increase about 20-fold (times) between the resting state and maximal intensity. (chart 2)



VO2 at rest is about 250 ml/min تمثل. However, at Maximal effort it can be as shown in the table

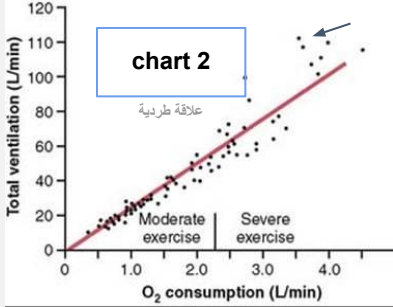
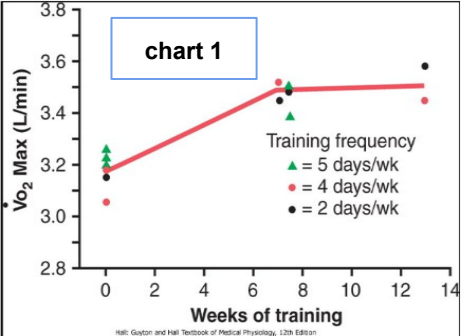


Other factors that increase the VO2 Max:
1-Chest sizes in relation to body size.
2-The power of respiratory muscles contraction.



VO2 Max: The rate of oxygen usage under maximal aerobic metabolism is VO2 Max.

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



النقاط العالية التي عندها سهم في (chart 2) معناها انه هذا الشخص بدأ يتنفس هواء كثير لكن استهلاك الاكسجين اقل وبالتالي يدخل مرحلة anaerobic.

cardiovascular system in Exercise

During Exercise

Work Output, Oxygen Consumption, and Cardiac Output (C.O.P) are directly related to one another. (proportional relationship)

venous return
(عودة الدم للقلب عن طريق vein تكون اسرع.)



effects of training on HEART hypertrophy & cardiac output

جميع هذه التأثيرات تظهر على الشخص الرياضي (Marathoner)

- ↑ Cardiac output(C.O.P) about 40%. {from restal level about (5.5L/min) to (30L/min)}.
- heart chambers enlarge (dilate) about 40% in contrast to non trained.
- heart size is larger than normal person.

C.O.P= cardiac output
HR: heart rate.
SV= stroke volume.
SV هو حجم الدم الخارجة من القلب في النبضة (الدفعة) الواحدة.

$$C.O.P \equiv HR \times SV$$

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..

Marathon runner

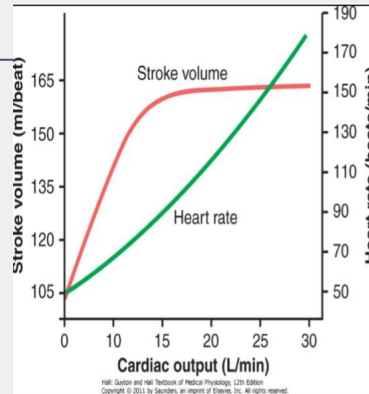
	increases	increases (%)	unit
Cardiac output (C.O.P)	from 5.5L/min to 30L/min	increase of about 40%.	L/min.
stroke volume (SV)	from 105 ml/beat to 162ml/beat.	increasing of about 50%.	ml/bear.
hear rate (HR)	from 50 beats/min to 185 beats/min.	increasing of 270%.	beats/min.

لأحد يشيل همّ الوحدات وكيف تُحفظ،
(C.O.P)
هي كمية الدم الخارج من القلب باللتر في الدقيقة
الواحدة، يعني L/min.

(SV)
هي كمية الدم الخارجة من القلب في النبضة الواحدة، يعني
. ml/beat

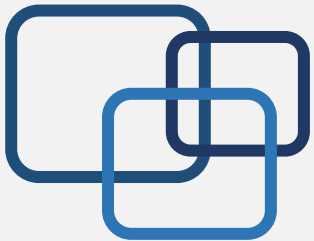
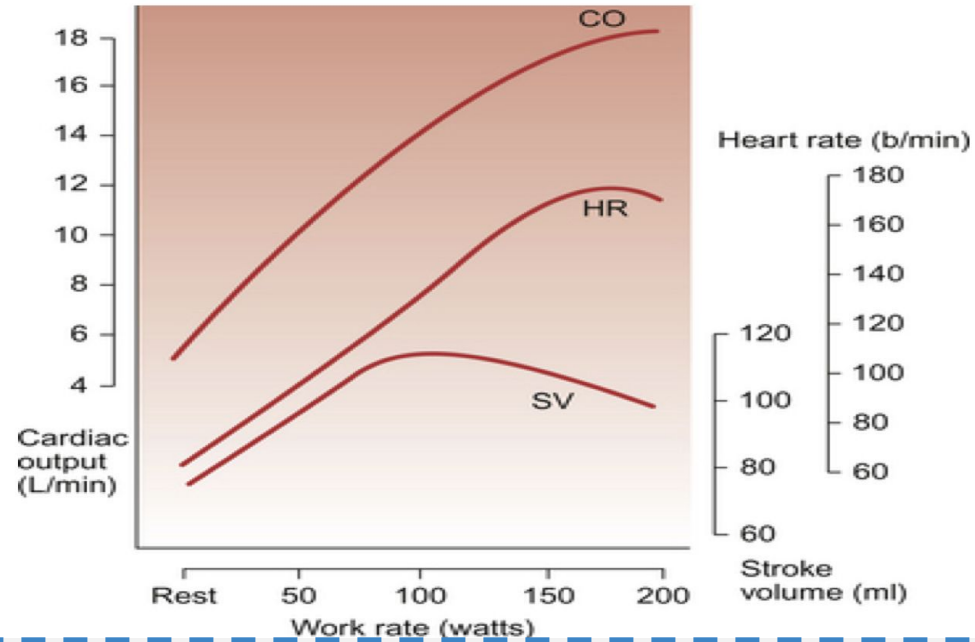
(HR)
هي عدد نبضات القلب في الدقيقة (اوسكي الـ ..)، يعني
. beat/min

heart rate و stroke volume
كلهم يكونون علاقة طردية مع C.O.P، لكن HR علاقتها الطردية تستمر
باستمرار زيادة C.O.P، على عكس SV التي تستمر بعلاقة طردية مع
C.O.P الى ان يصل 15 فما فوق، والسبب؟
زيادة C.O.P المبالغ فيها مراح تعطي وقت كافي للقلب انه يعبي
chambers كاملة، فمهما انقبض القلب مراح يفيد لان chambers ما
امتلات بالدم فنقل عندنا stroke volume. (دم في chambers قليل،
SV قليل والعكس)



The heart rate increase a greater proportion of the increase in cardiac output than does the increase in the stroke volume.

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 %.

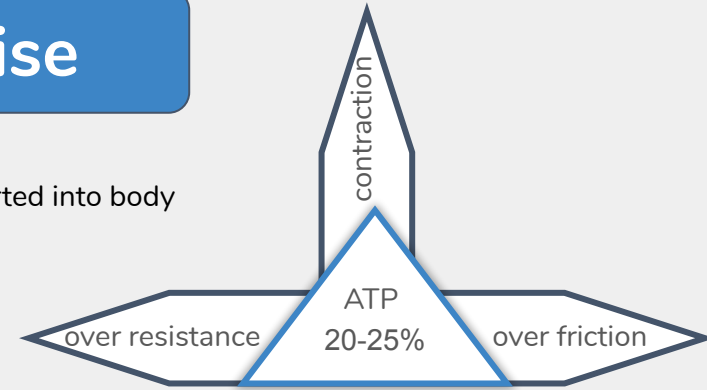
A small portion (20-25)% of energy is used

overcoming viscous resistance to the movement of the muscles and joints.

overcoming the friction of the blood flowing through the blood vessels.

similar effects—all of which convert the muscle contractile energy into heat.

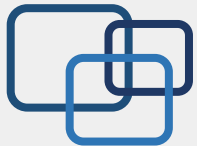
almost all the **energy** that does go into **creating muscle work** still **becomes** body heat.



what will happen if the sweating mechanism can not eliminate the heat?

Heat stroke*

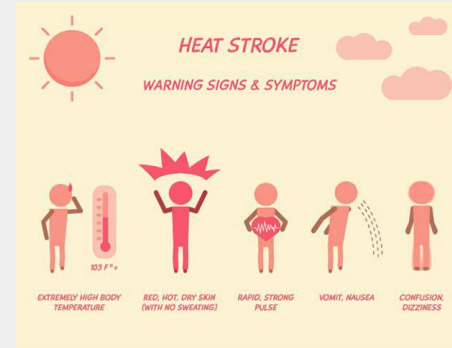
* (Guyton) The person has stopped exercising, the temperature does not easily decrease by itself in the heat-stroke Because:
1.temperature-regulating mechanism often fails. 2. very high body temperature doubles the rates of all intracellular chemical reactions due to increase of K.E, thus liberating still more heat.



Heat stroke

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

unconsciousness

uncontrolled gait (balance)

collapse

may lead to death

Treatments

Remove all clothes.

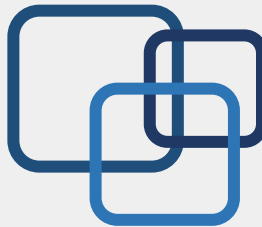
Maintain a spray of cool water on all surfaces of the body or continually sponge the body.

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.

S U M M A R Y

- Fast-twitch fibers can deliver extreme amounts of power for a few seconds to a minute or so.
- Slow-twitch fibers provide endurance, delivering prolonged strength of contraction over many minutes to hours.
- increasing strength of a muscle could be by: Weight lifting , digging
- Muscles Endurance can be dynamic or static
- High temperature is destructive to tissue cells mainly (brain cells).
- Muscle power refers to the amount of work a muscle produces in a period of time. It is expressed in (kg-m/min).



MCQs

Q1: If the cross section of a muscle is 95, the rational maximal contractile force could be:

- | | | | |
|--------|--------|--------|----------------|
| A) 285 | B) 190 | C) 475 | D) non of them |
|--------|--------|--------|----------------|

Q2 : (Low resistance with many repetitions) this sentence is associated with:

- | | | | |
|-------------|---------|-------------|----------|
| A) Strength | B)Power | C)Endurance | D) A & C |
|-------------|---------|-------------|----------|

Q3 endurance is enhanced by:

- | | | | |
|----------------------|---------------------------|------------------|------------------------|
| A) High protein diet | B) High carbohydrate diet | C) High fat diet | D) High phosphate diet |
|----------------------|---------------------------|------------------|------------------------|

Q4 : High temperature is destructive for Which cells?

- | | | | |
|-----------------|------------------|------------------|----------------|
| A) bone cells . | B) Brain cells . | C) muscle cells. | D) skin cells. |
|-----------------|------------------|------------------|----------------|

Q5 : Which one of the following is NOT an effect of training on heart hypertrophy and C.O.P?

- | | | | |
|-----------------------------|--------------------------------|------------------------|---------------------------------|
| A) heart size is increased. | B) heart chambers are dilated. | C) C.O.P is increased. | D) skeletal muscle hypertrophy. |
|-----------------------------|--------------------------------|------------------------|---------------------------------|

Q6 : Which of the following increase is greater proportion of the increase in cardiac output?

- | | | | |
|---------------------|-----------------------|---------|--------------|
| A) Heart rate (HR). | B) stroke volume(SV). | C) A&B. | D) Nothing . |
|---------------------|-----------------------|---------|--------------|

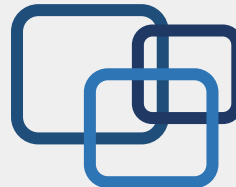
SAQ

Q1: *List the changes that occur to hypertrophied muscle.*

Q2: *What are the symptoms of Heat stroke? (three is enough).*

MCQs key answer :
1A
2C
3B
4B
5D
6A

SAQ answer key :
1) slide (8).
2) slide (15).



THANK
you 😊

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