



MED437
KING SAUD UNIVERSITY

جامعة
الملك سعود
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Muscle adaptations

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Revised by



437

PHYSIOLOGY TEAM

➤ Color index:

Red: important

Green: doctor's notes

Grey: extra information

Pink: found only in
female's slides

blue: found only in
male's slides

Physiology 437 team work

Objectives:

By the end of the lecture you will be able to:

- 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 $\dot{V}O_2$)
- Identify the cardiovascular changes in exercise (Work output, oxygen consumption, and cardiac output, heart hypertrophy).
- Interpret the role of stroke volume and heart rate in increasing the cardiac output.
- Explain the body heat in exercise & the heatstroke max).

Strength and Power of Muscles

- Strength refers to FORCE
- Work refers to FORCE & DISTANCE
- Power refers to WORK (force & distance) & TIME

Muscles strength: Refers to **the amount of force** (push or pull) **a muscle can produce.**

- ❖ Size of the muscle influences the maximal contractile force. Normally 3-4 kg/cm² of the cross section of the muscle يعني كل 1cm² من الجسم يعطي قوة بمقدار 3-4 kg
- **e.g.** a cross-sectional area 150cm² causes maximal contractile strength of 525 kilograms.

Mechanical work of muscle: **The force applied by the muscle x the distance** (kg-m).

$$W = F \times D$$



Muscles Power: The **amount of work the muscle performs in a period of time.** It is expressed in (kg-m/min). كل ما مارسنا نشاط لفترة أطول كل ما القوة العضلية تبدأ تضعف وتقل

- ❖ 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

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 glycogen stored in the muscle. → كل ما قل ال repetition ، كل ما استهلكنا ال glycogen أكثر ،

Dynamic endurance: is defined as the muscle's ability to **contract and relax repeatedly**.

فيه حركة



Static endurance: is the muscle's ability to remain contracted for a **long period**.

Stability فيه وعدم حركة



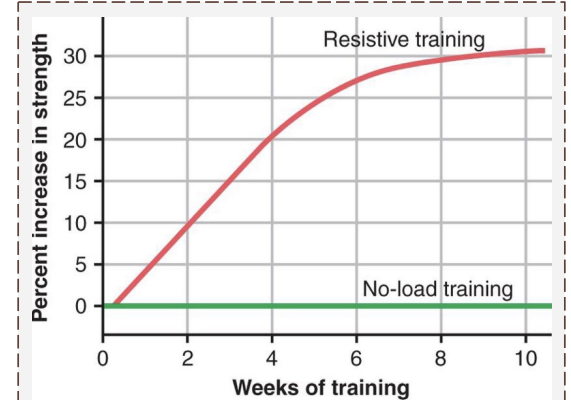
Endurance	Strength
increased repetition	decreased repetition
decreased resistance	increased resistance
increase in cardiovascular fitness	increase in muscle mass

Effect of Training on Muscle and Muscle Performance

Maximal Resistance Training: Six nearly maximal muscle contractions (ست مرات ترفع بالماكسميم) performed 3 times, 3 days a week give approximately optimal increase in muscle strength, without producing chronic muscle fatigue.

(مثل تمارين المقاومة) سلايدات البنات أنه 6 مرات فقط باليوم (الأولاد ست عدات مع ثلاث جولات في نفس اليوم 6x3)

- **However**, multiple weeks of muscles function under no increased load will cause little increase in strength. (مثل التمارين الهوائية)



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

الشرح: ، في خلال 6 أسابيع :
- المتدرب الأحمر قلنا له يسوي تمرين ويزيد المقاومة ، فقوته العضلية زادت.
- المتدرب الأخضر قلنا له يسوي تمرين بدون ما يزيد المقاومة ، فقوته العضلية ما تغيرت.

Muscle Hypertrophy

*بعد التمرين يزداد عدد WBC "كأن فيه" "inflammation" ، بسبب وجود Micro internal bleeding
لذلك بعد التمرين لازم يكون فيه يوم break علشان ال Healing.
بعد ال Healing راح يزداد عدد وحجم ال muscle fibers.

With training muscles hypertrophied 30-60%, Due to increase diameter of the muscle fibers with some increase in number of fibers. *

Changes in the hypertrophied muscle fiber :

Increase myofibrils number

Increase 120% in mitochondrial enzymes

Increase ATP & phosphocreatine

Increase 50% in stored glycogen

Increase 75-100% in stored triglycerides

The efficiency of the oxidative metabolic system increase by 45%

Increase both the aerobic & anaerobic metabolism

*الرياضي إذا أكل وجبة دسمة راح يهضمها ويتخلص من ال Fat بشكل أسرع من الغير رياضي



Fast-Twitch and Slow-Twitch Muscle Fibers



Fast-Twitch "White muscle fiber"	Slow-Twitch "Red muscle fiber"
For forceful and rapid contraction.	For prolonged muscle activity.
E.g. Gastrocnemius muscle used for jumping.	E.g. Soleus muscle in the lower leg muscle for standing.
Achieves maximal power in very short periods of time.	Provide endurance , prolonged strength of contraction minutes to hours . Is organized for generation of aerobic energy .
In summary	
Deliver extreme amounts of power for a few seconds to a minute.	Provide endurance, delivering prolonged strength of contraction over many minutes to hours.

Fast-Twitch and Slow-Twitch Muscle Fibers

Extra and may
help in pathology

1. Fast-twitch fibers are about twice as large in diameter than Slow-twitch fibers.
2. The enzymes that promote rapid release of energy from the phosphagen and glycogen-lactic acid energy systems are two to three times as active in fast-twitch fibers as in slow-twitch fibers, thus making the maximal power that can be achieved for very short periods of time by fast-twitch fibers about twice as great as that of slow-twitch fibers.
3. Slow-twitch fibers are mainly organized for endurance, especially for generation of aerobic energy. They have far more mitochondria than the fast-twitch fibers. In addition, they contain considerably more myoglobin, a hemoglobin-like protein that combines with oxygen within the muscle fiber; the extra myoglobin increases the rate of diffusion of oxygen throughout the fiber by shuttling oxygen from one molecule of myoglobin to the next. In addition, the enzymes of the aerobic metabolic system are considerably more active in slow-twitch fibers than in fast-twitch fibers.
4. The number of capillaries is greater in the vicinity of slow-twitch fibers than in the vicinity of fast-twitch.

Respiration In Exercise



صامت وهدئة
2:30

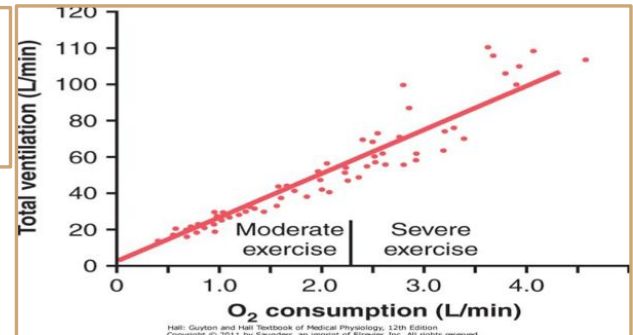
- Oxygen Consumption (VO_2) and Pulmonary Ventilation (VE) in Exercise.
- **VO_2** at rest is about 250 ml/min. However at Maximal efforts can be as follows:

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

- **VO_2** and **VE** increase about 20- fold between the resting state and maximal intensity.
"كل ما زاد دخول الهواء إلى الرئتين كل ما زاد استهلاك ال O_2 " (علاقة طردية)

O_2 consumption : The amount of oxygen needed to meet the metabolic needs of the tissues.

Pulmonary ventilation refers to the total exchange of air between the lungs and the ambient air
بالعربي كمية الهواء التي تأخذها الرئة



Effect of exercise on oxygen consumption and ventilatory rate

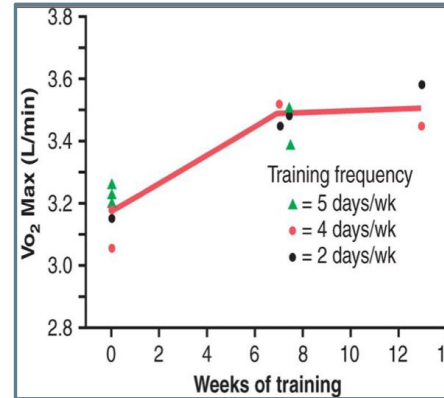
Effect of Training on VO_2 Max

- ❖ **VO2 Max** : The rate of oxygen usage under maximal aerobic metabolism is VO2 Max. In the below study VO₂ Max increased only about 10% by training.
- ❖ **Moreover other factors such as :**

Increase chest size in relation to body size.*

Increase respiratory muscles contraction can also increase VO2 Max.

*كل ما صار حجم الصدر أكبر ، كل ما صار دخول الهواء أكثر واستهلاك O₂ أكثر.
مثال : السباحين يعتمدوا على التنفس أثناء التدريب ، فحجم صدورهم تكون كبيرة.



موكل ما زاد عدد مرات
التدريب بالإسبوع يعني أفضل
المتدرب الأسود أقلهم مرات
تدريب ، وأصبح استهلاك
O₂ عنده أفضل من البقية.

Increase in Vo2 Max over a period of 7 to 13 weeks of athletic training.

Cardiovascular System in Exercise

- **Work Output, Oxygen Consumption, and Cardiac Output During Exercise**
- All are directly related to one another, muscle work output >> increases oxygen consumption >> dilates the muscle blood vessels >> increasing venous return >> cardiac output C.O.P.
- **Effect of Training on Heart Hypertrophy and on Cardiac Output:** C.O = stroke volume x heart rate
- Training increase C.O.P about 40 % greater than untrained persons So,
- heart chambers of marathoners enlarge about 40% in contrast to non trained
- Heart size of marathoner larger than normal person

عملية مترابطة ومتسلسلة . لما تتمرّن أنت تحتاج استهلاك أكثر للاوكسجين فبناء على هذا تتوسع الفيسلس ولما تتوسع يكون الدم عودته أسرع للقلب وبكذا ينبض بشكل أسرع (لانه قبل كانت عودة الدم أبطأ) وبكذا ارتفع المخرج النهائي للقلب

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

حجم دفع الدم بالقلب في الدفعة الواحدة

Cardiovascular System in Exercise cont...

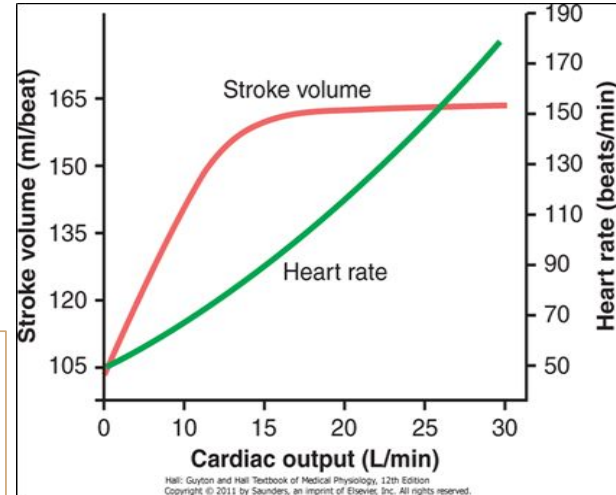


1:26

$$\text{Cardiac output} = \text{Stroke Volume} \times \text{Heart Rate}$$

- **the cardiac output:** In Marathon runner 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%
- **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 stroke volume **why ??????**

عندنا سببين :
1- أن ال venous return وصل الماكس فالقلب يضح قبل ال chamber heart يمتلي فخلاص ما تزداد الستروك فوليوم.
2- أن حتى لو كان ال venous return ملأ التشامير بسرعة فنحن محكومين بحجم هالتشامير يعني هذا أقصى شيء تستطيع غرف القلب أن تحمل من الدم



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

Cardiovascular Response To Exercise Complete: Any Questions

Heart Rate
(↑ before exercise)



Heart Rate
↑ during exercise
(similar to VO_2)

a-v O_2 difference
(↑ extraction)

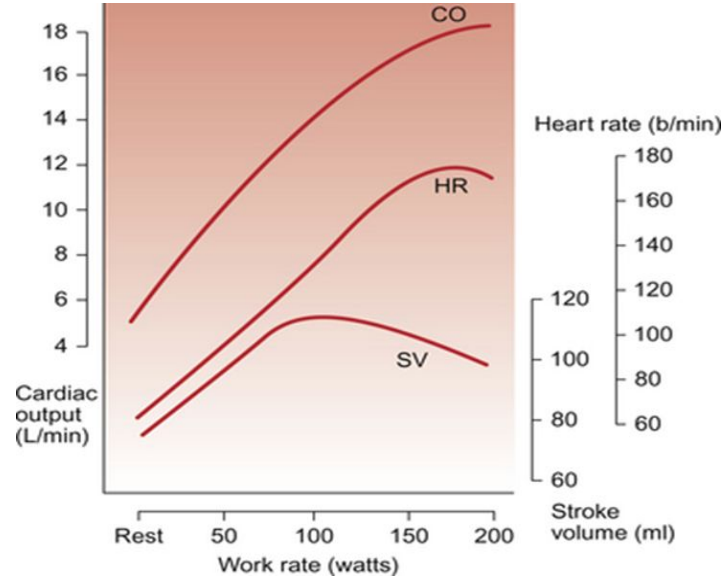
Stroke Volume
4 factors

Blood Pressure

↑ Systolic
↔ Diastolic

Blood Flow to Muscle

Rest = 20%
Maximal Exercise = 85 - 90%
How?



Body Heat In Exercise

جزء كبير من الطاقة يروح لتبريد الجسم "تخفيض حرارة الجسم"

- Almost all the energy released by the body's metabolism converted into body heat. To cool down
- Working muscle use only 20 - 25 %.
- The rest 75-80% converted into heat as result of :
 - 1-resistance to the movement of the muscles and joints.
 - 2-friction of the blood flowing through the blood vessels, and
 - 3-muscle contractile converted into heat.
- What will happen if sweating mechanism cannot eliminate the heat ???? next slide :) **heart stroke**



Heatstroke

-During endurance training body temperature rises

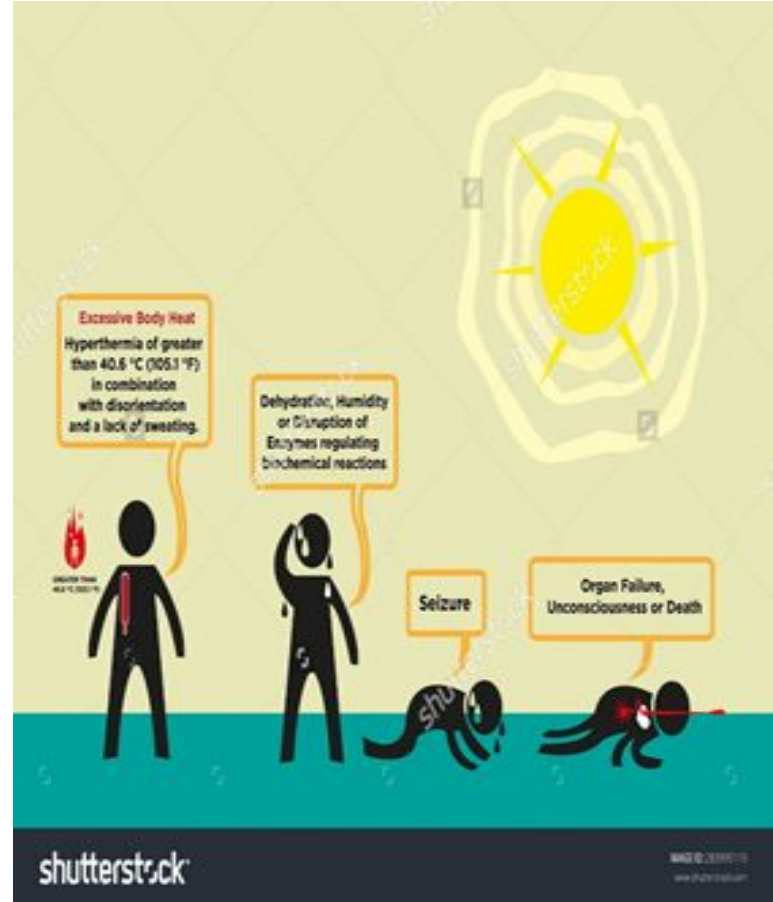
98.6° to 102° or 103°F
(37° to 40°C)

-hot and humid conditions:

body temperature rise to 106° to 108°F
(41° to 42°C)

-High temperature is destructive (-ev)to tissue cells mainly (brain cells)

اللي تعرضوا ل Heatstrok يخرب عندهم ال Thermoregulatory
فما بتعرقون ، وبتصير الحرارة كامنة فيهم ، فتتوقف عملية تبريد الجسم



Symptoms and treatment of heatstroke

Symptoms



Body
weakness



Headache



Exhaustion



Dizziness



nausea
(disgust)



Unconscio
usness or
collapsing



Uncontrolled
gait



Sweating



Death
(in
Extreme
conditions
)

Treatment

If body temperature reaches $41 >$ damage of brain cells $>$ highly fragile cells $>$ زيادة الحرارة تسبب تلف في البروتينات وبما أنها خلايا ضعيفة إذا تلفت البروتينات داخلها



Remove all clothing



Maintain a spray of
cool water on all
surfaces of 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.

Female's team:

1. Ahad Algrain
2. Hadeel
3. Maha Alnahdi
4. Majd AlBarrak
5. Rahaf Alshammari
6. Rinad Alghoraiby
7. Munira Alhadlg
8. Sarah Alblaihed
9. Renad Almogren

Male's team:

1. Naif Almutairi
2. Anas alsaif
3. Mohammed Alhassan



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