MEDICINE
KING SAUD UNIVERSITY

Physiology Team 436

Muscle Adaption to Exercise

Revised by
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Red: very important.
Green: Doctor's notes.
Yellow: numbers.
Gray: notes and explanation.

Physiology Team 436 – Musculoskeletal Block Lecture 9

Lecture: If work is intended for initial studying.
Review: If work is intended for revision.

Objectives

- 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 VO2 max).
- 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.

Strength & Power

- **Muscle Strength:** The amount of force a muscle can produce.

Also known as the maximal overload of this muscle.

- **Size of muscles:** Influences the maximal contractile **force** (increased muscle diameter -> increased muscle strength) Normally 3 - 4 kg/cm^2
- **Example :** a cross-sectional area 150 cm^2 cause maximal contractile strength of 525

($150\ cm^2 \times 3.5 = 525$)

*3.5 is the average of size

- **Mechanical work of muscle** = W= F x D

force applied by the muscle X distance

- **Muscles Power:** amount of work that the muscle performs in period of **time** (kg-m/min)

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

The maximal **Power** achieved by all the muscles working together of a highly trained athlete:

		kg-m/min
First 8 to 10 seconds	Can't do it twice	7000
Next 1 minute		4000
Next 30 minutes	Anabolic pathway	1700

Physics recall: Work= Force x Distance - Power= Work (FD) x Time

Endurance of Muscles

- Muscles Endurance: Ability of muscles to sustain **repeated** contractions against a resistance (e.g. gravity) for a period of time.
- It depends on **glycogen** stored in the muscle.
- Dynamic Endurance: is defined as a muscle's ability to contract and relax repeatedly.
- Static Endurance: is a muscle's ability to remain **contracted** for a long period.

مهمة جدا

The difference between Endurance and strength

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

قدرة تحمل العضلة هي القدرة على تحمل الانقباضات المتكررة **ضد المقاومة** لوقت محدد وتعتمد على كمية الجلايكوجين في العضلة.
اللي يسوون تمارين مقاومة عارفين هالكلام زين ☺

Effects of Exercise on The Body

Muscle Performance

Body Heat

Cardiovascular System

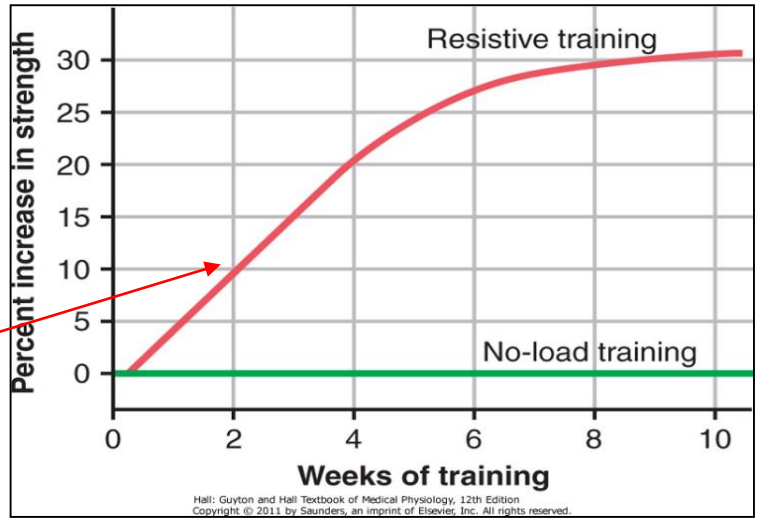
Respiratory System

مثل تمارين المقاومة "استخدام أثقال "تزيد من قوة تحمل العضلة اعتماداً على كمية الجلايكوجين أما التمارين الهوائية مثل "الجري "لا تتطلب مقاومة بالتالي لا تعمل على تقوية العضلات بالمقدار الكافي

مثل تمارين المقاومة.

Maximal Resistance Training

- 6 Maximal muscle contraction sets against a load **X** 3 days a week = great increase in muscle strength, No muscle fatigue.
- Muscles that function under no load, even if they are exercised for hours on end, increase little in strength
- 10 weeks training against load increases muscle's strength up to 30%



Muscle Hypertrophy

Exercise Hypertrophy: is due to an increase in contractile protein

(number of actin &myosin filaments in each muscle fiber = muscle cell)

Increase in number of contractile proteins

↓

Myofibrils split within each muscle fiber to form new myofibrils.

↓

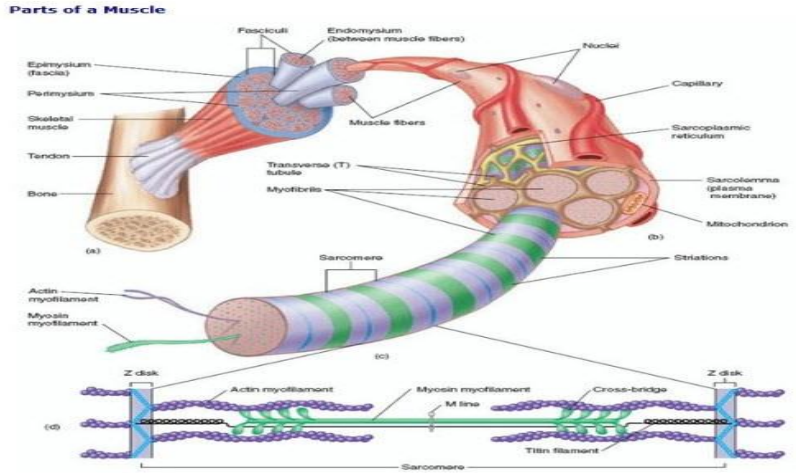
GREAT increase in the number of additional myofibrils

↓

Hypertrophy

Hypertrophy results primarily from the growth of each muscle cell, rather than an increase in the number of cells.

With training, muscles are hypertrophied by 30 - 60 %



Changes in Hypertrophied Muscle:

- Increased myofibrils
- Increased 120 % in mitochondrial enzymes(tricarboxylic acid)
- Increased ATP and phosphocreatine
- Increased 50 % in stored glycogen
- Increased 75 -100 % in stored triglyceride
- Increased oxidative metabolic system rate by 45 %
- Increased capability of aerobic and anaerobic metabolic systems

Fast Twitch and Slow Twitch Muscles Fibers

الفيديو بطل ويختصر عليكم

- Muscles in the human body are usually composed of two types of Fibers:

Fast-twitch fibers	Slow-twitch fibers
For forceful and rapid contraction	For prolonged muscle activity
e.g. Gastrocnemius muscle used for jumping.	e.g. Soleus muscle in the lower leg muscles for standing.
Achieves maximal power: in very short periods of time (few seconds to a minute).	Prolonged strength of contraction (minutes to hours)
-	Organized for (provides) endurance
Organized for Anaerobic energy	For Aerobic energy

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**.

مب موجود في السلايدات بس
الدكتور عاد أكثر من مره انه نقراه
ومطلوب منا بالباثولوجي

Fast Twitch and Slow Twitch (Extra.)

- **These are the differences between fast and slow twitch fibers found in Guyton & Hall Textbook of Medical Physiology 12E Unit XV chapter 84 page 1036.**

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 fibers.

Respiration In Exercise

تنبيه: الفيديو يحتوى على موسيقى

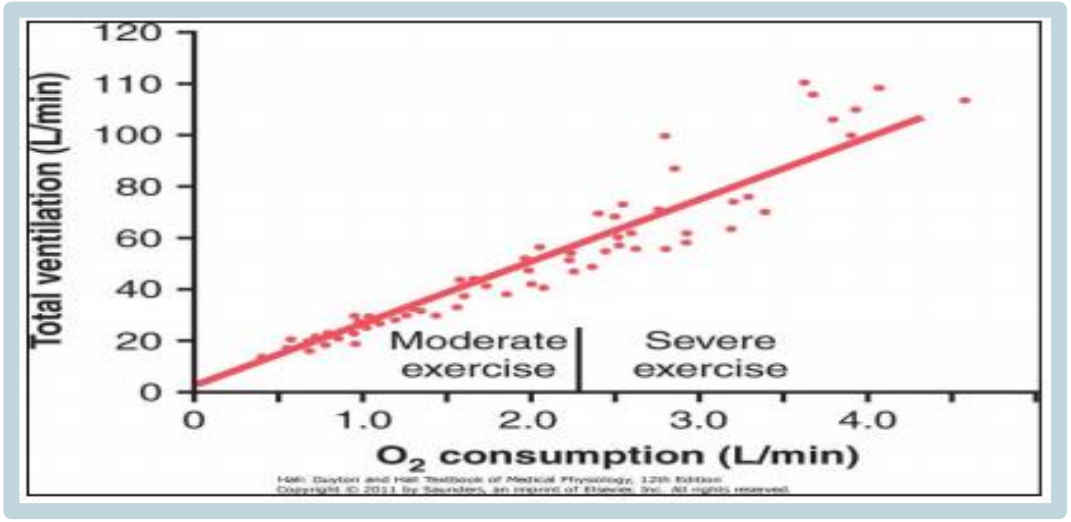
Oxygen Consumption (VO2) and Pulmonary Ventilation (VE) in Exercise

- Oxygen consumption (VO2) at rest is about 250 ml/min.

However, at maximal efforts, this can be increased to the following levels:

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

O2 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



Both Oxygen Consumption (VO2) and Pulmonary Ventilation (VE) increase about 20 folds between resting state and maximal intensity as shown in the graph.
لازم الاثنين يزيدون مع بعض –علاقة طردية-

Effect of Training on VO2 Max (Max Oxygen consumption)

- In the study below, VO2 Max increased only about 10 percent by training. Depending on number of factors:

I. Chest sizes in relation to body size.

II. Increase respiratory muscles' strength.

شرح الرسمة:

- الرسمة تقارن بين استهلاك الاكسجين وعدد أسابيع التمرين لثلاث أشخاص: واحد يتمرن ٥ أيام بالأسبوع وواحد ٤ وواحد ٢.
- من الرسمة نقدر نشوف انه الي تمرن مرتين بالأسبوع هو أكثر واحد زاد عنده استهلاك الاكسجين.

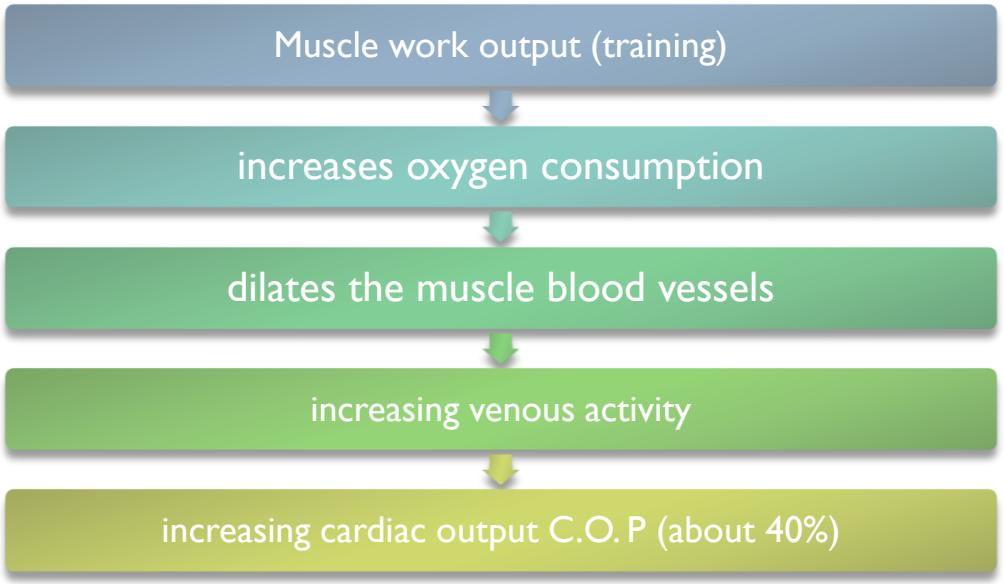
(مب شرط انه الي يتمرن اكثر أحسن)

- الرياضة ما تزود VO2 كثير.

Pulmonary Ventilation = VE / Oxygen Consumption = VO2
كلهم يزيدون مع قوة نشاط العضلات

Cardiovascular System In Exercise

- **Work Output , Oxygen Consumption , and Cardiac Output During Exercise:**
- All are directly related to one another by :



- So, heart chambers (Heart size) of marathoners enlarge about 40% in contrast to non-trained individuals.

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

يكونون مروقين – HR السيمباثاتك اقل عندهم فلذلك يقل ال

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)

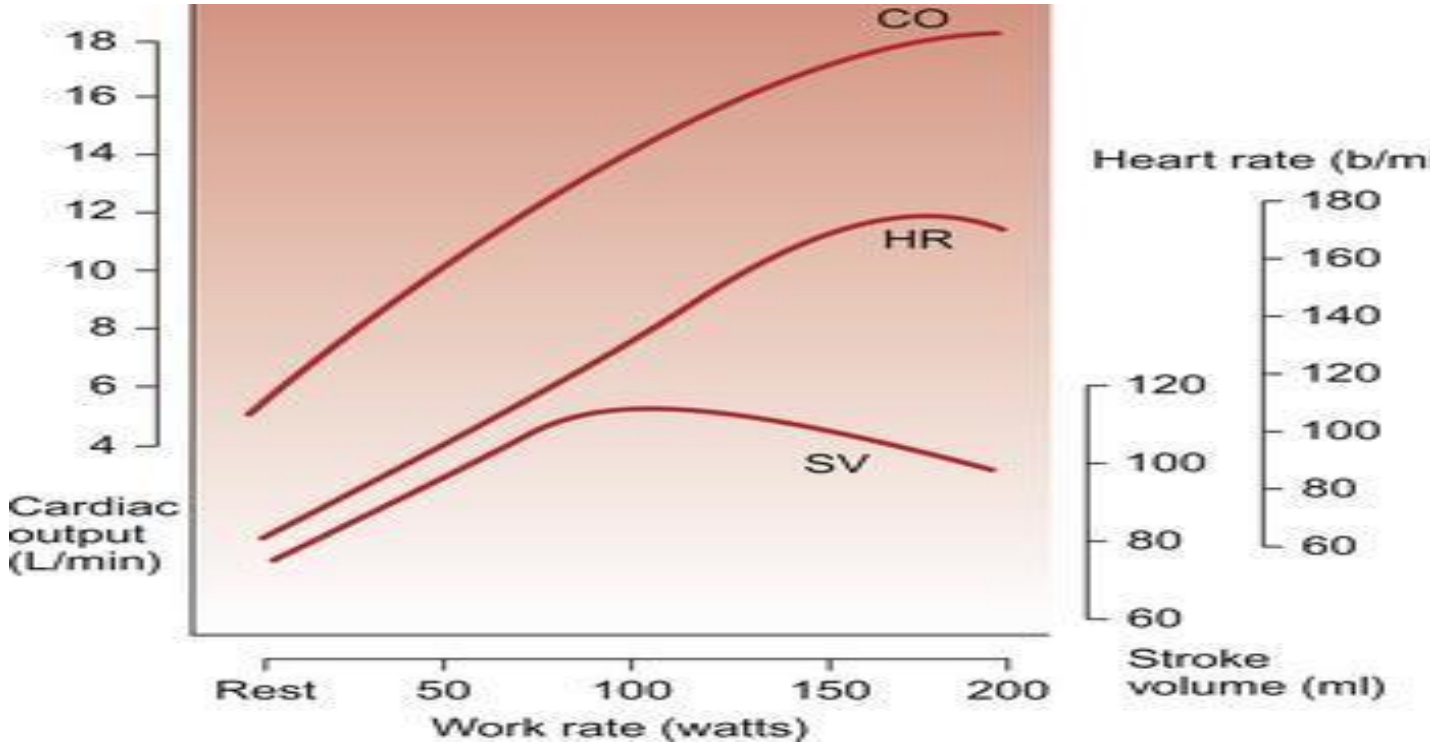
a-vO_2 difference
(↑ extraction)

Stroke Volume
4 factors

Blood Pressure
↑ Systolic
↔Diastolic

Blood Flow to Muscle
Rest = 20%
Maximal Exercise = 85 - 90%
How?

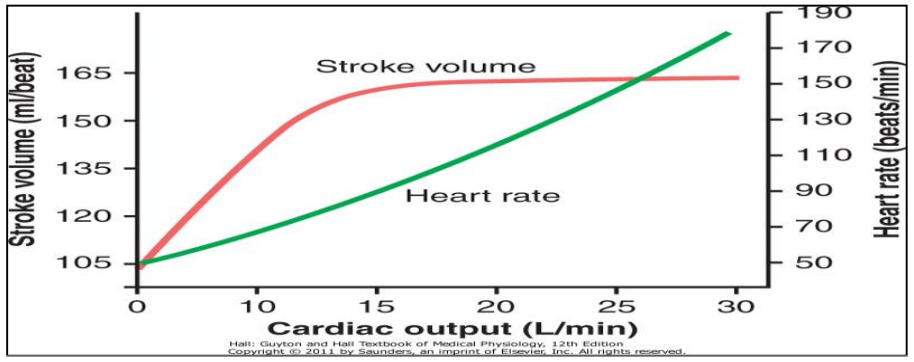
Cont.


CO
HR
SV
18
16
14
12
10
8
6
4
Cardiac output (L/min)
Rest
50
100
150
200
Work rate (watts)
Heart rate (b/m
180
160
140
120
100
80
60
120
100
80
60
Stroke volume (ml)


CARDIAC OUTPUT
Ready... Set... GO!
CO = HR X Stroke Volume
Cardiac Output
Heart Rate

Cardiovascular System in Exercise

- The cardiac output 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 about 270%
- The heart rate increase is a greater proportion of the increase in cardiac output than the increase in stroke volume (Why?????)



Approximate stroke volume output and heart rate at different levels of cardiac output in a marathon athlete.

شرح

- Cardiac output = heart rate x stroke volume
- Stroke Volume= volume of blood pumped (ml per beat.)
- اذا زاد الجهد تزيد نبضات القلب ويزيد الستروك فوليوم. في مرحلة معينة تستمر نبضات القلب بالزيادة ولكن الستروك فوليوم ما يزيد (steady state stroke volume) ليش؟
- Because Stroke Volume depends on venous return (عودة الدم الى القلب).

When Venous return reaches its max, Stroke volume does not increase

- Girls' doctor: Because Stroke volume is restricted by the size of the heart

At the beginning the increase in cardiac output is due to heart rate and stroke volume but later it is due to heart rate only.

* Again: The increase in heart rate holds a greater proportion of the increase in cardiac output than the increase in stroke volume does

Body Heat in Exercise

- Almost all the energy released by the body's metabolism is converted into body heat.
- Working muscle uses only 20-25% of that energy
- The rest is converted into **heat** as a result of:

Resistance to the movement of the muscles and joints.

Friction of the blood flowing through the blood vessels

Muscle contractile converted into heat

During endurance training body temperature rises from 98.6° to 102° or 103°F (37° to 40°C) with very high heat and humidity body temperatures could easily rise to 106° to 108°F (41° to 42°C)
High temperature is destructive (-ve) to tissue cells mainly **(brain cells)**

If sweating mechanism cannot eliminate the heat, Heatstroke will occur.

Symptoms and Treatment of Heatstroke

Symptoms


Body weakness


Headache

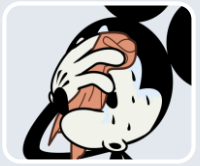

Exhaustion


Dizziness


nausea (disgust)


Unconsciousness 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 إذاً تتلف 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.

Heatstroke Cont.

You are done! Good luck!

Link to Editing File

(Please be sure to check this file frequently for any edits or updates on all of our lectures.)

References:

- Girls' and boys' slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

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