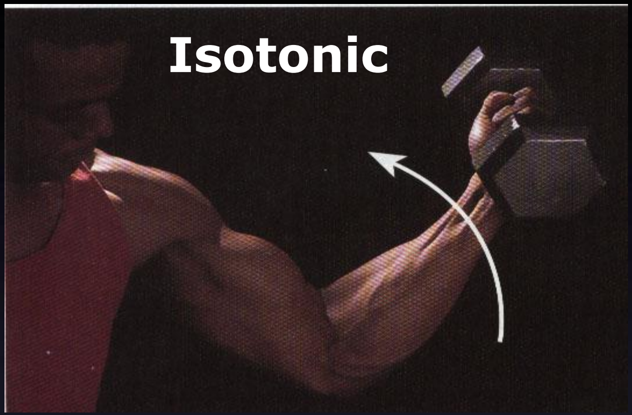
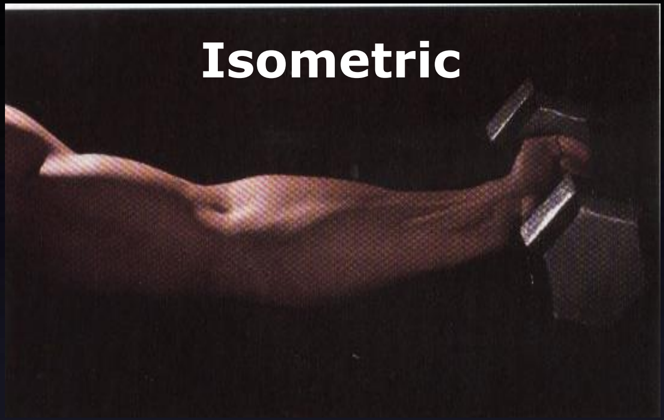
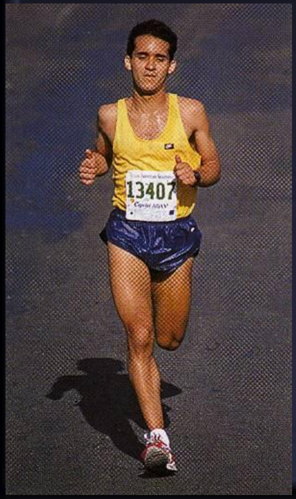

بسم الله الرحمن الرحيم

MUSCLE ADAPTATION IN EXERCISE







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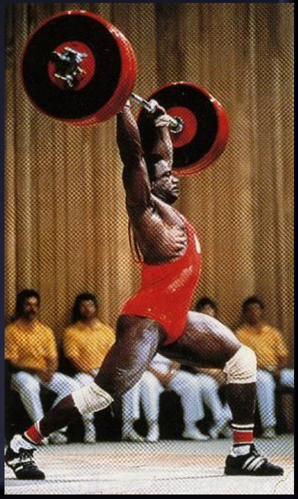
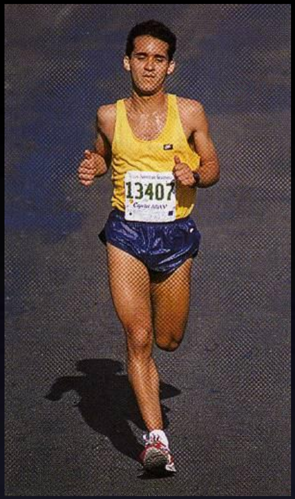


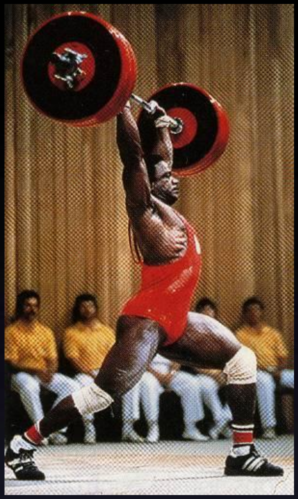
Objectives

At the end of this lecture you should be able to:

1. ***Define strength, power and endurance of muscles***
2. ***Describe Muscle Metabolic Systems in Exercise***
3. ***Recovery of the Muscle Metabolic Systems After Exercise***
4. ***Effect of Athletic Training on Muscles and their Performance***
5. ***Respiratory & Cardiovascular System in Exercise***
6. ***Body Heat in exercise & Heat Stroke***

FUNCTIONS

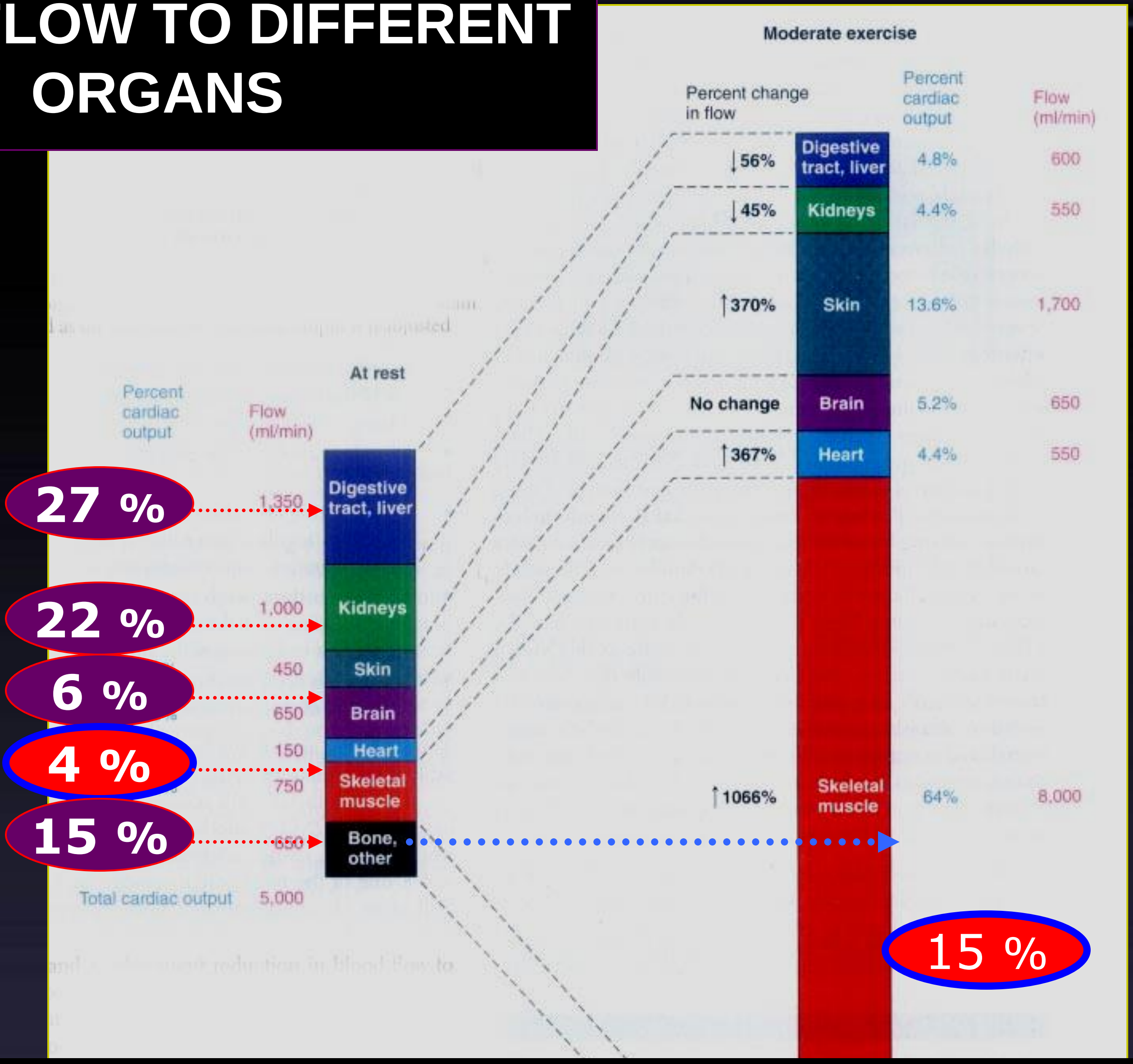




- **Muscle plays four important roles in the body.**

1. **movement,**
2. **maintains posture**
3. **stabilizes joints and**
4. **generates heat.**

BLOOD FLOW TO DIFFERENT ORGANS



During rest, blood flow through skeletal muscle averages 3 to 4 ml/min/100 g of muscle. In exercise, this can increase 15- to 25-fold, rising to 50 to 80 ml/min/100 g of muscle.

MAXIMAL CONTRACTILE FORCE & HOLDING STRENGTH

- **The strength of a muscle is determined mainly by its size, with a maximal CONTRACTILE FORCE between 3 and 4 kg/cm2 of muscle cross-sectional area.**
- **The HOLDING STRENGTH of muscles is, if a muscle is already contracted and a force then attempts to stretch out the muscle, as occurs when landing after a jump. It is about 40 per cent greater than the contractile strength.**

Eg: Quadriceps muscle of 150 cm^2 cross-sectional area has a contractile strength of 525 kilograms, and 735 kilograms of holding strength.

NEUROLOGICAL STRENGTH : meaning how many of the anterior horn cells (AHC) motor neurons of the spinal cord supplying that muscle are recruited + frequency of action potentials in them to supply the muscle. (↓Motivation)

MECHANICAL WORK, POWER OF MUSCLE & ENDURANCE

- **MECHANICAL WORK** is the amount of force applied by the muscle multiplied by the distance over which the force is applied. **[Force x Distance]**

- **POWER** of muscle is of the total amount of work that the muscle performs in a unit period of time. Power is determined by the number of times that it **contracts** and **distance** of contraction in **unit time**. It is measured in kilogram meters **(kg-m) per minute**.

- **ENDURANCE** is ability of sustained contractions depends on **nutritive support of** muscle (glycogen) stored before the period of exercise.

Maximal power Achievable by all the muscles in the body of a highly Trained athlete with all the muscles working together

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

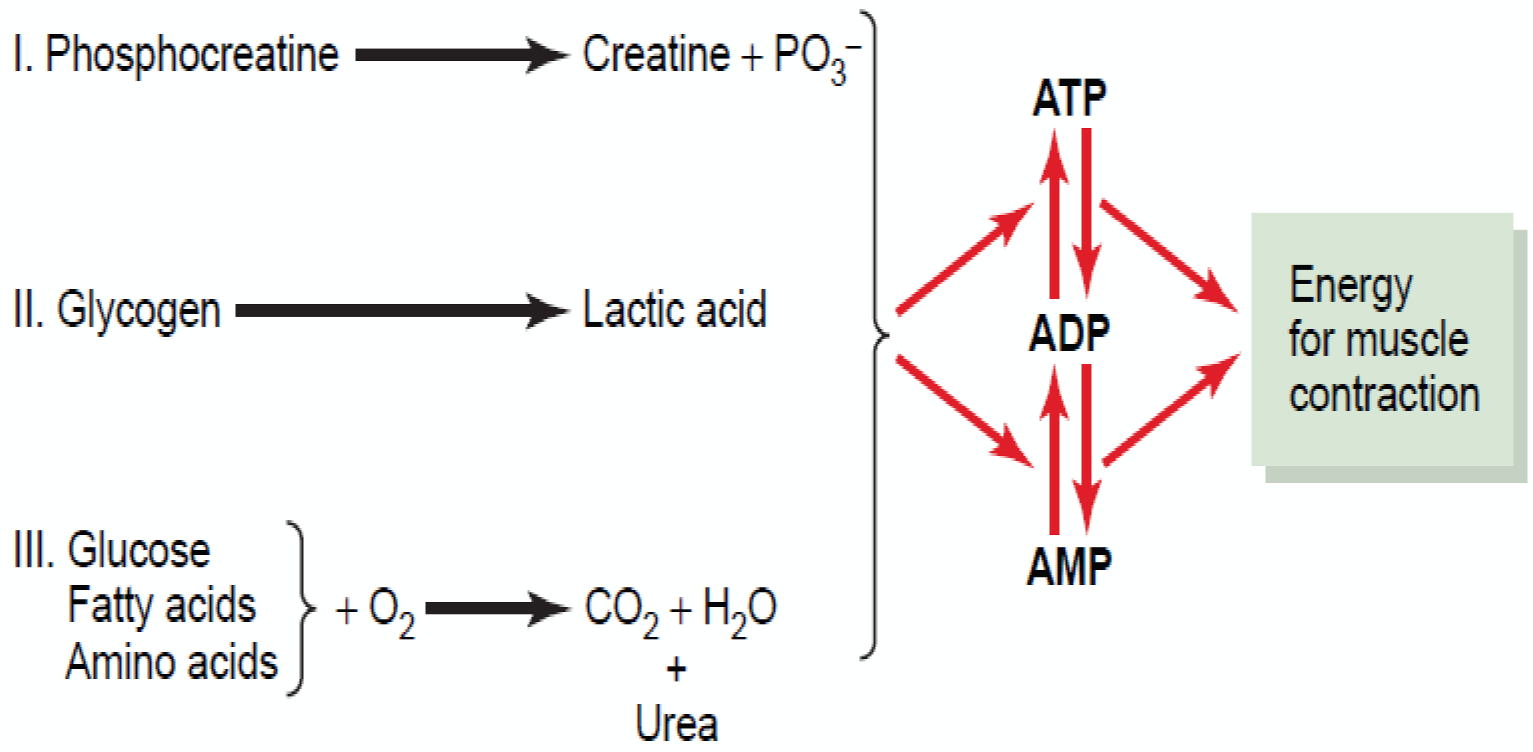
Time of endurance in marathon race, that they can sustain the race until Complete exhaustion

	Minutes
High-carbohydrate diet	240
Mixed diet	120
High-fat diet	85

The corresponding amounts of glycogen stored in the Muscle before the race started

	g/kg Muscle
High-carbohydrate diet	40
Mixed diet	20
High-fat diet	6

MUSCLE METABOLIC SYSTEMS IN EXERCISE



MUSCLE METABOLIC SYSTEMS IN EXERCISE

The main source of energy actually used to cause muscle contraction is adenosine triphosphate (ATP):

Adenosine-PO3 ~ PO3 ~ PO3

Each of these bonds stores yields 7300 calories of energy per mole of ATP

The amount of ATP present in the muscles, even in a well-trained athlete, is sufficient to sustain maximal muscle power for only about 3 seconds, maybe enough for one half of a 50-meter dash

THE PHOSPHOCREATINE-CREATINE SYSTEM

The combined amounts of cell ATP and cell phosphocreatine are called the phosphagen energy system → Can provide maximal muscle power for 8 to 10 seconds, almost enough for the 100-meter run.

GLYCOGEN-LACTIC ACID SYSTEM

- The stored glycogen in muscle is split into glucose and the glucose then used for energy. Initial stage of this process, called glycolysis, occurs without use of oxygen and, therefore, is said to be anaerobic metabolism.
- Under optimal conditions, the glycogen-lactic acid system can provide 1.3 to 1.6 minutes of maximal muscle activity

AEROBIC SYSTEM.

It is the oxidation of foodstuffs in the mitochondria to provide energy. Glucose, fatty acids, and amino acids combine with oxygen to release tremendous amounts of energy that are used to convert AMP and ADP into ATP (hours)

The relative maximal rates of power generation in terms of moles of ATP generation per minute

	Moles of ATP/min
Phosphagen system	4
Glycogen–lactic acid system	2.5
Aerobic system	1

Comparing the energy systems for endurance

	Time
Phosphagen system	8 to 10 seconds
Glycogen–lactic acid system	1.3 to 1.6 minutes
Aerobic system	Unlimited time (as long as nutrients last)

What Types of Sports Use Which Energy Systems?

Table 84–1

Energy Systems Used in Various Sports

Phosphagen system, almost entirely
- 100-meter dash
- Jumping
- Weight lifting
- Diving
- Football dashes

Phosphagen and glycogen-lactic acid systems
- 200-meter dash
- Basketball
- Baseball home run
- Ice hockey dashes

Glycogen-lactic acid system, mainly
- 400-meter dash
- 100-meter swim
- Tennis
- Soccer

Glycogen-lactic acid and aerobic systems
- 800-meter dash
- 200-meter swim
- 1500-meter skating
- Boxing
- 2000-meter rowing
- 1500-meter run
- 1-mile run
- 400-meter swim

Aerobic system
- 10,000-meter skating
- Cross-country skiing
- Marathon run (26.2 miles, 42.2 km)
- Jogging

Recovery after Exercise

1. Muscle Metabolic Systems
2. Aerobic System

Recovery of the Muscle Metabolic Systems After Exercise.

In the same way that the energy from phosphocreatine can be used to reconstitute ATP,

Energy from the glycogen-lactic acid system can be used to reconstitute both phosphocreatine and ATP.

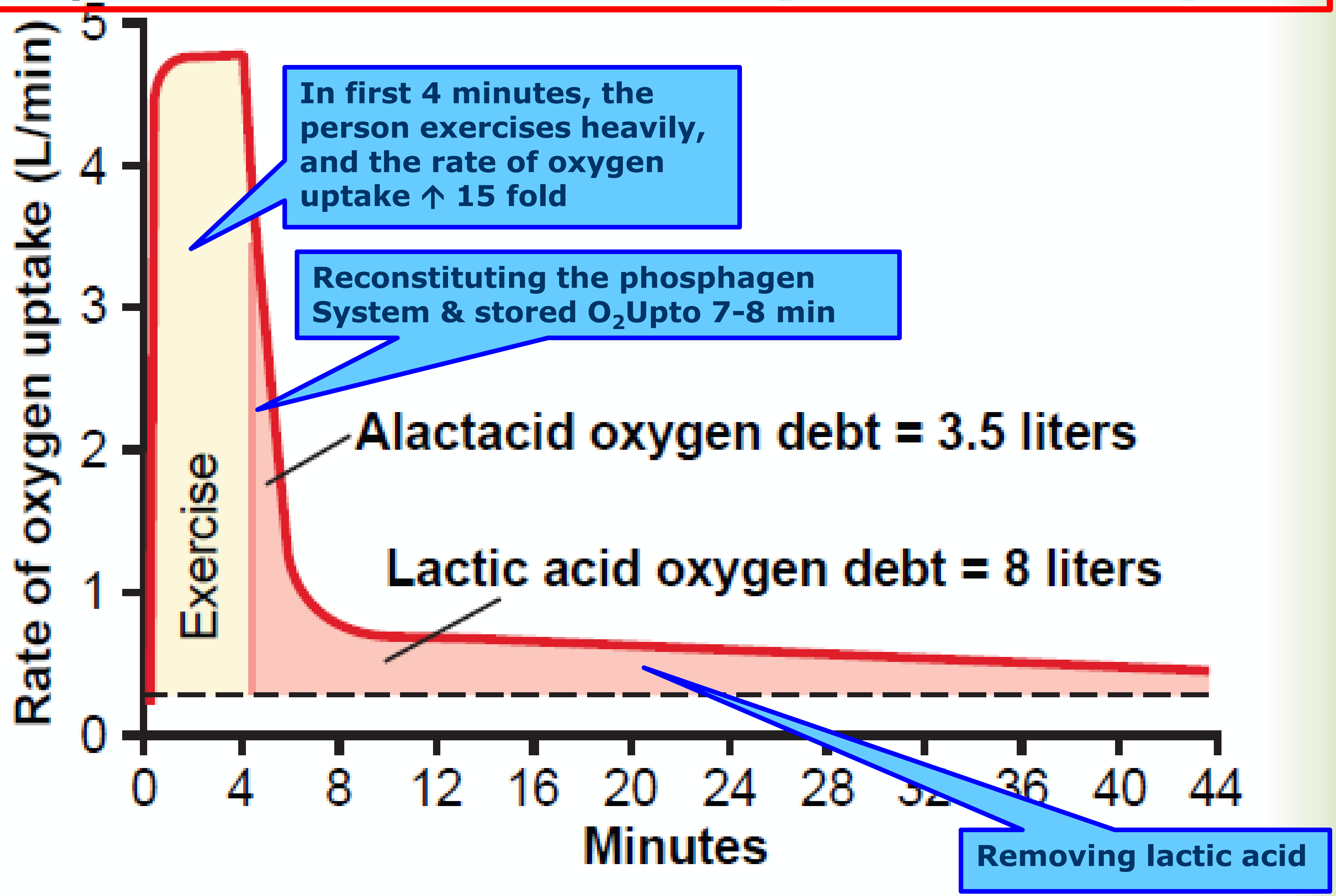
Energy from the oxidative metabolism of the aerobic system can be used to reconstitute all the other systems-the ATP, the phosphocreatine, and the glycogen-lactic acid system.

Recovery of the Aerobic System

After Exercise. Even during the early stages of heavy exercise, a portion of one's aerobic energy capability is depleted. This results from two effects:

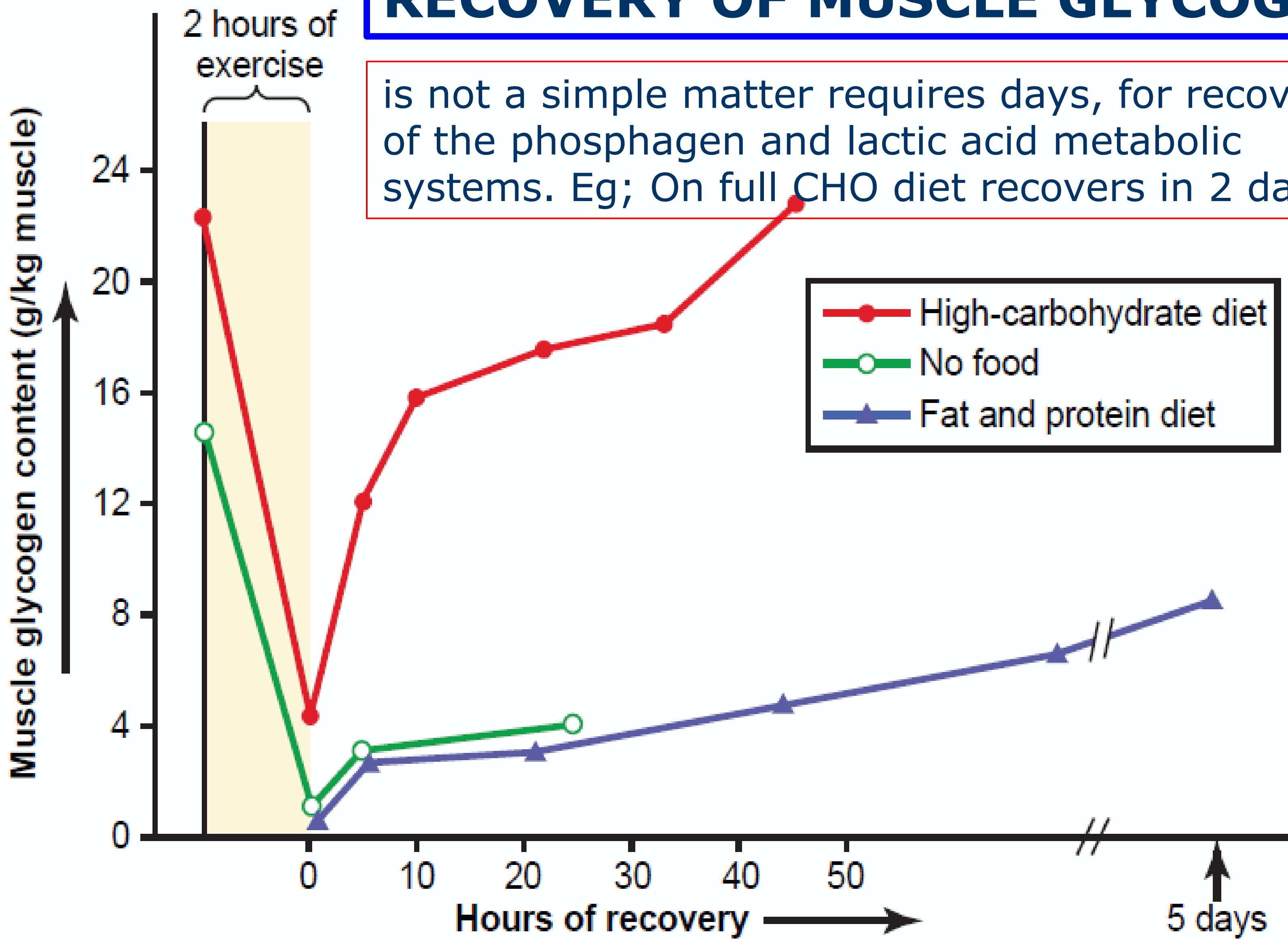
(1) the so-called oxygen debt
(2) depletion of the glycogen stores of the muscles.

Oxygen Debt Is the Extra Consumption of Oxygen After Completion of Strenuous Exercise. [about 11.5 liters]

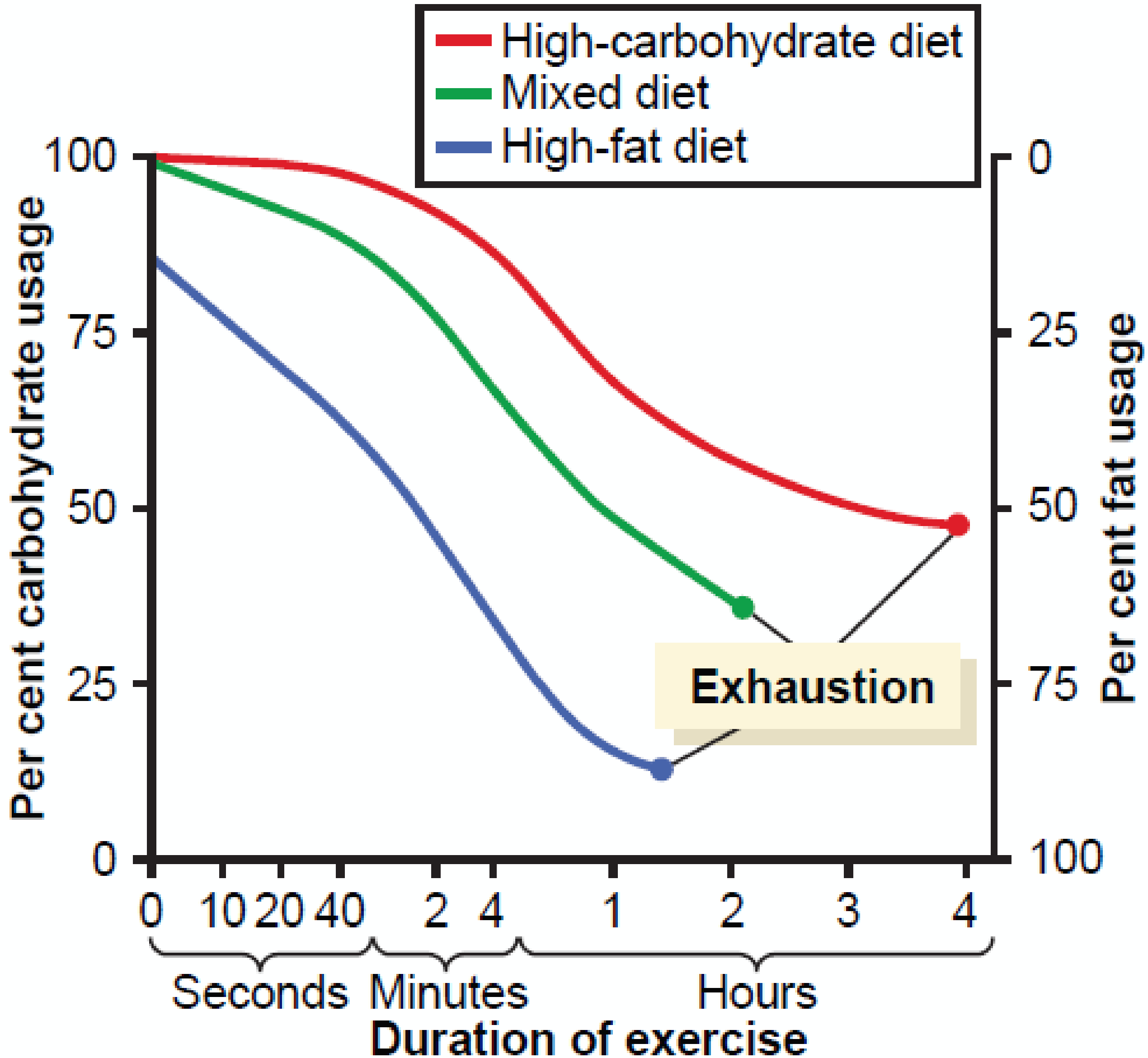


RECOVERY OF MUSCLE GLYCOGEN

is not a simple matter requires days, for recovery of the phosphagen and lactic acid metabolic systems. Eg; On full CHO diet recovers in 2 days



It is important for an athlete to have a high-carbohydrate diet before a grueling athletic event



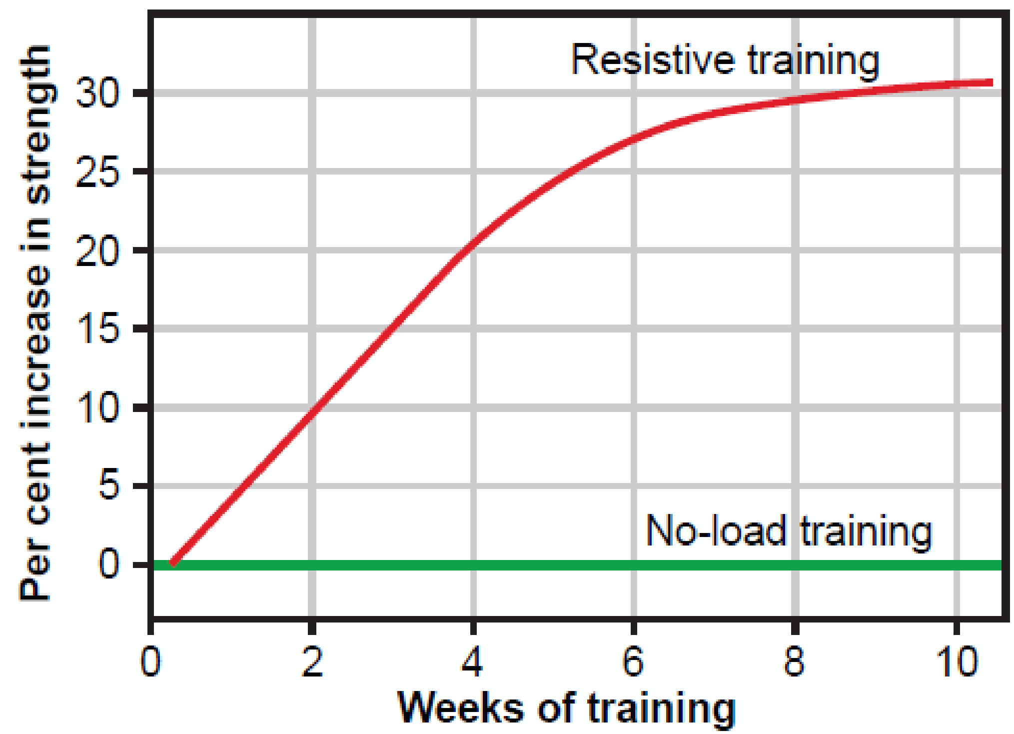
High-carbohydrate diet
Mixed diet
High-fat diet
Per cent carbohydrate usage
100
75
50
25
0
Per cent fat usage
0
25
50
75
100
Exhaustion
0
10
20
40
2
4
1
2
3
4
Seconds
Minutes
Hours
Duration of exercise

Effect of Athletic Training on Muscles and Muscle Performance

- ❑Muscles that contract at more than 50 per cent maximal force of contraction will develop strength rapidly
- ❑6 maximal muscle contractions sets against a load 3 times 3 days a week greatly increase in muscle strength, without producing fatigue.

About 10 weeks training increase strength 30% and plateau after that.

Muscles exercising under no load cause little increase in strength



MUSCLE HYPERTROPHY

WITH TRAINING MUSCLES ARE HYPERTROPHIED

By 30- 60 %

- ↑ diameter of the muscle fibers (mainly)
- ↑ number of fibers (change is little)

CHANGES IN HYPERTROPHIED MUSCLE:

- ↑ number of myofibrils
- ↑ in mitochondrial enzymes by 120 %
- ↑ ATP and phosphocreatine
- ↑ in stored glycogen by 50 %
- ↑ in stored triglyceride by 75 -100 %
- ↑ oxidation rate by 45 %
- ↑ capability of aerobic and anaerobic metabolic system

Each muscle is composed of combination of 2 types of muscle fibers but one is usually dominant in every person by inheritance.

	FAST TWITCH	SLOW TWITCH
Size	Larger	Smaller
Duration of max power	Short (1 min)	Longer (hours)
energy release	Rapid	Slow
speed of contraction	Fast	Slow
Myosin ATPase activity	High	Low
Oxidative phosphorylation	Low	High
Enz Anaerobic glycolysis	High	Low
Mitochondria	Few	Many
Sarcoplasmic Reticulum	Abundant	Less
Capillaries	Few	Many
Myoglobin content	Low	High
Color	White	Red
Intensity of contraction	High	Low
Endurance	Low	High (Prolonged)

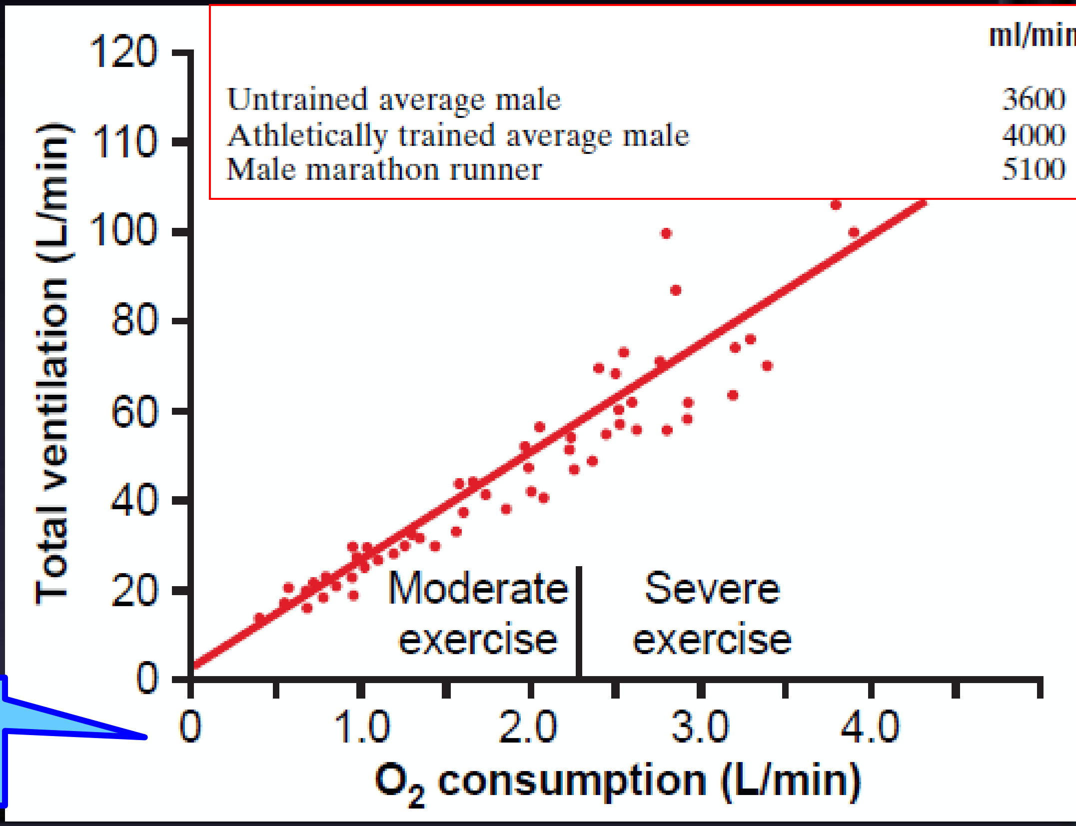
	Fast-Twitch	Slow-Twitch
Marathoners	18	82
Swimmers	26	74
Average male	55	45
Weight lifters	55	45
Sprinters	63	37
Jumpers	63	37

RESPIRATION IN EXERCISE

- VO_2 max is **rate of oxygen usage under maximal aerobic metab**
- VO2 at rest is about 250 ml/min and ↑ 20 folds in maximal exercise

O2 UPTAKE IN PULM VESSELS IN EXERCISE: ↑ CO leads to rapid blood flow in lungs that is for short duration. But because of the **great safety factor** for diffusion of O2 through the blood still becomes almost saturated with oxygen by the time it leaves the pulmonary capillaries.

Utilization Coefficient. It is the %age of the blood that gives up its oxygen as it passes through the tissue capillaries. ↑ **from 25 % to 75-85%** in the body and in local tissues upto **100%**.



Oxygen Consumption VO_2 and Pulmonary Ventilation VE in Exercise

EFFECT OF TRAINING ON VO2 MAX.

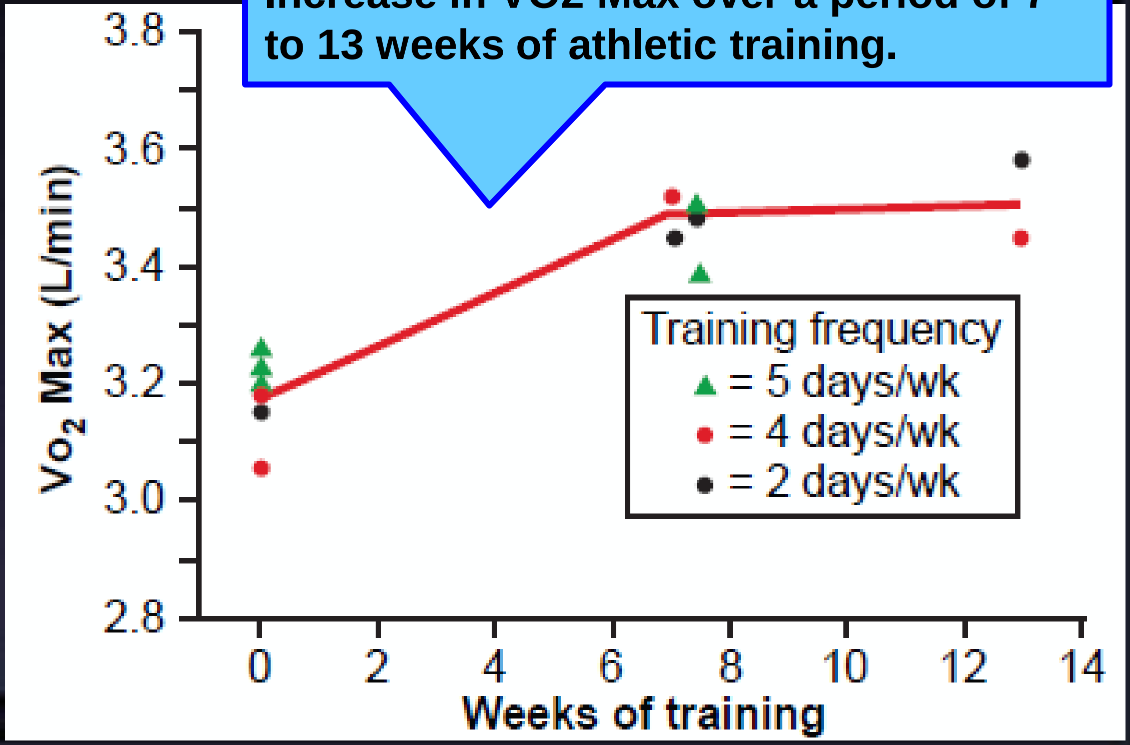
❖ Vo_2Max increased only about **10%** by training, Genetic factors are important like….. Chest sizes in relation to body size and strong resp muscles

O2 diffusion capacity increases 3 folds during exercise due to:-

1-↑ surface area for O2 to diffuse

2- Direct stimulation of respiratory center by nervous signals from brain and sensory signals from contracting muscle and moving joints while blood gases during exercise are normal in concentration (no ↑ in CO_2 or ↓ in O_2)

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 these are directly related to one another, muscle work output increases oxygen consumption, and increased oxygen consumption in turn dilates the muscle blood vessels, thus increasing venous return and cardiac output.

Effect of Training on Heart Hypertrophy and on Cardiac Output:

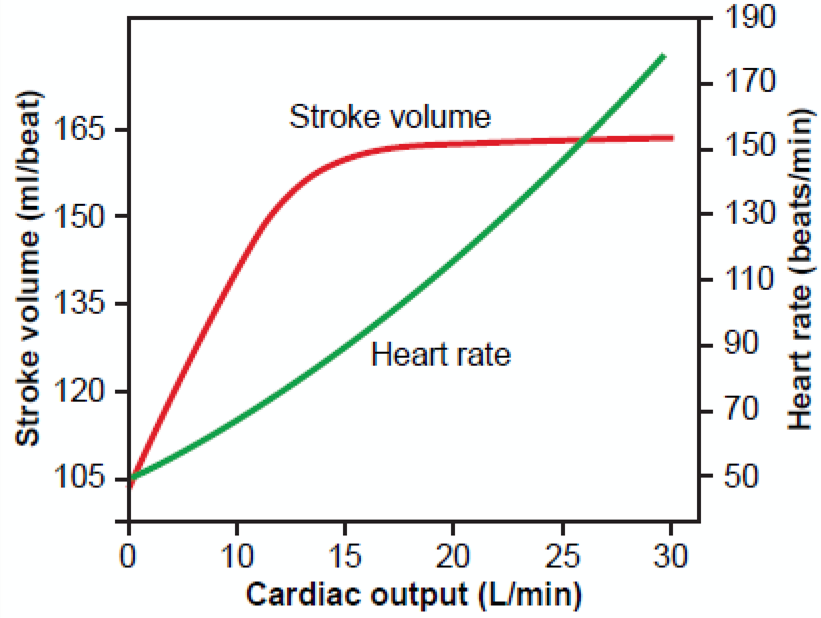
- Training increase C.O about 40 % greater than untrained persons SO,
- Heart chambers of marathoners enlarge about 40 percent in contrast to non trained
- Heart size of marathoner larger than normal person

☐ 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 %**

☐ whereas 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



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

Table 84–2

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

BODY HEAT IN EXERCISE

□Almost all the energy released by the body's metabolism converted into body heat.

□Muscle work use only 20 - 25 % of energy released from metabolism. While remainder 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.

HEAT STROKE

- During endurance training body temperature rises 98.6° to 102° or 103°F (37° to 40°C)
- In hot and humid conditions body temperature rise to 106° to 108°F (41° to 42°C)
- Consequently, temperature destructive tissue cells mainly (brain cells) and symptoms !!! :
- Body weakness, exhaustion, headache, dizziness, nausea (disgust), sweating, confusion, uncontrolled gait, collapse, and unconsciousness and may lead to death

TREATMENT OF HEAT STROKE

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.**


THANKS