Effect of Exercise on

Dr. Aida Korish
Assoc. Prof Physiology
KSU

Objectives

By the end of this lecture the students should be able to: -

1- Explain the respiratory changes in exercise (e.g Oxygen consumption, pulmonary ventilation and VO2 max).

2- Describe the effects of moderate and severe exercise on oxygen consumption, and ventilation volumes.

3- Interpret the effects of exercise on arterial PO2, PCO2 and PH+.

4- Define the diffusing capacity of the respiratory membrane, and its typical values at rest, and explain its changes in exercise.

5- Explain the concept of oxygen debt (definition, value, types, significance).

6- Discuss the effects of smoking on pulmonary ventilation in exercise.

7- Discus the factors stimulate ventilation (hyperventilation) in exercise.

8- Outline the relationship between the chemical and nervous Factors in the control of respiration during exercise.

Effect of Exercise on ventilation

- During heavy exercise, O2 consumption and CO2 formation can increase as much as 20-fold.
- Yet, in the healthy athlete, alveolar ventilation ordinarily increases almost exactly in step with the increased level of oxygen metabolism.
- Therefore the arterial PO2, PCO2, PH all remain almost exactly normal.

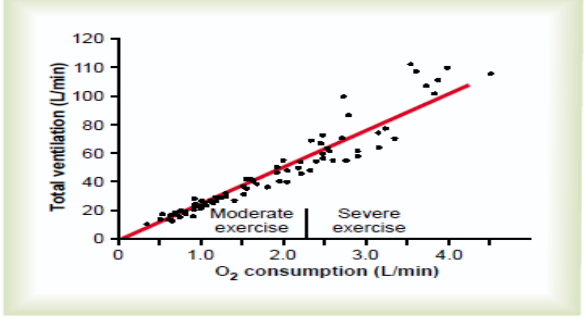


Figure 41–8

Effect of exercise on oxygen consumption and ventilatory rate. (From Gray JS: Pulmonary Ventilation and Its Physiological Regulation. Springfield, Ill: Charles C Thomas, 1950.)

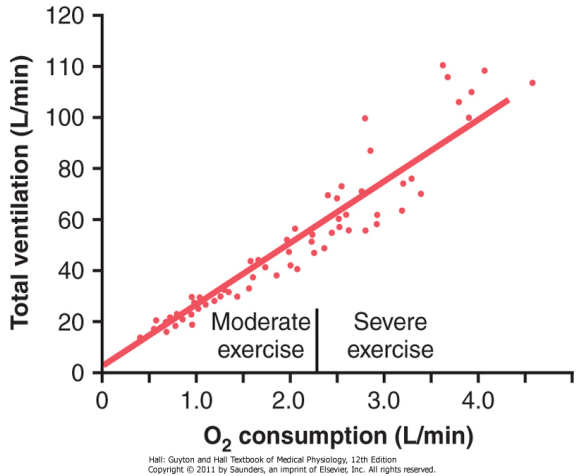
Oxygen Consumption (VO2) and Pulmonary Ventilation (VE) in Exercise

The normal oxygen consumption (VO2) for a young man at rest is about 250 ml/min.

The rate of oxygen usage (L/min) under maximal aerobic metabolism ***(VO2 Max)*** can be approximately the following average levels:

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

VO2 and **VE** increase about 20-fold between the resting state and maximal intensity exercise.



Effect of exercise on oxygen consumption and ventilatory rate.)

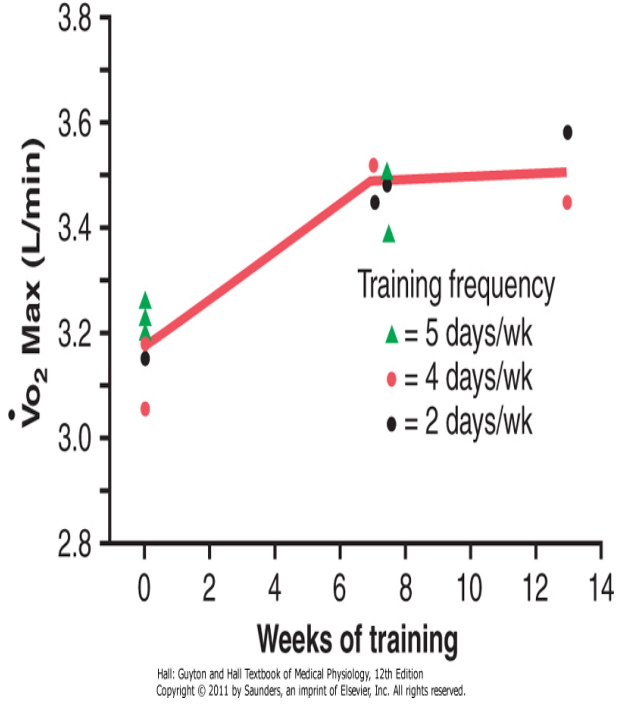
Effect of Training on VO2Max

- In the below study VO2 Max increased only about 10% by training.

Other factors that increase the VO2 Max are genetically determined in the form of:

- Chest sizes in relation to body size
- The power of respiratory muscles contraction

Guyton & Hall 14 E Unit XV chapter 85 page 1079



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

Diffusion capacity of the respiratory membrane

Def: Is the volume of gas that diffuses through the membrane each minute for a pressure difference of 1mmHg.

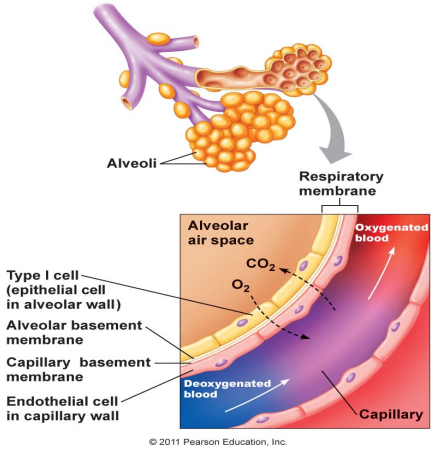
The oxygen diffusion capacity: is a measure of the rate at which oxygen can diffuse from the pulmonary alveoli into the blood.

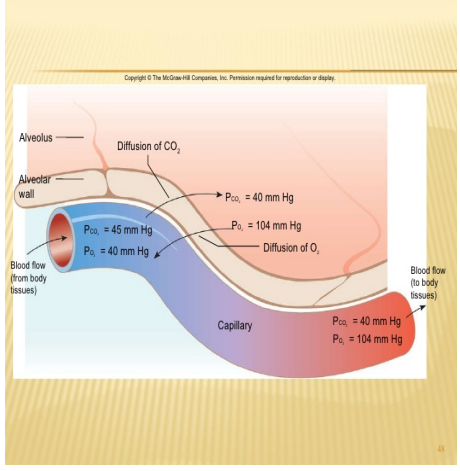
* This capacity is expressed in terms of *milliliters (mls) of O2 that will diffuse each minute for each millimeter of mercury (mmHg) difference between alveolar PO2 and pulmonary blood PO2.*

➢**Diffusing capacity for oxygen at rest =**
21 ml/min/mmHg

➢e.g : If the oxygen pressure difference across the respiratory membrane is 11 mmHg. The volume of O2 diffusing through the membrane each minute will be (11x21) = 230 ml . { enough to supply the O2 needed by the tissues during rest]

➢[N.B: During rest tissues consume 250 ml O2 /min]





Increased Oxygen Diffusing Capacity During Exercise.

The diffusing capacity for oxygen increases about three times during exercise (~ 64 ml/mmHg/min).

This is due to:

1- Increased number of the open pulmonary capillaries which were dormant, and dilation of the already opened vessels to their maximal. This increases the surface area for gas exchange.

2- Increased alveolar ventilation per minute.

3- Better matching of ventilation of the alveoli (V) with the perfusion of the pulmonary capillaries (Q) i.e (V/Q ratio).

➢At rest the blood normally stays in the lung capillaries about three times as long as necessary to cause full oxygenation.

➢Therefore, **even with shortened time of exposure of the blood to the alveolar air in exercise, the blood is still fully oxygenated or nearly so.**

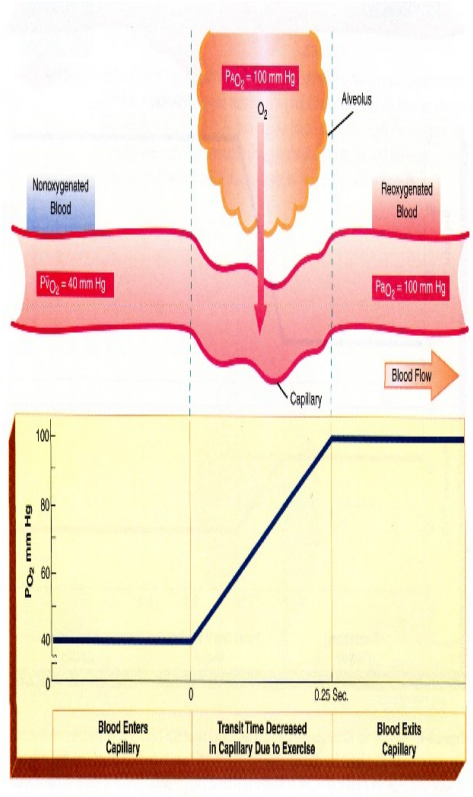


Figure 3–5. *During exercise or stress, the total transit time for blood through the alveolar-capillary membrane is less than normal (normal = 0.75 sec). In the healthy individual, however, oxygen equilibrium usually occurs. $P\bar{v}_{O_2}$ = partial pressure of oxygen in mixed venous blood; $P_{A_{O_2}}$ = partial pressure of oxygen in alveolar gas; $P_{a_{O_2}}$ = partial pressure of oxygen in arterial blood.*

Diffusing capacity for carbon dioxide

- It diffuses 20 times greater than oxygen due to greater diffusion coefficient which is 20 times that for oxygen.
- Diffusion capacity for CO2 during rest = 400ml/min/mmHg.
- During exercise 1200 to 1300ml/min/mmHg.
- CO2 is the most diffusing gas across the respiratory membrane.

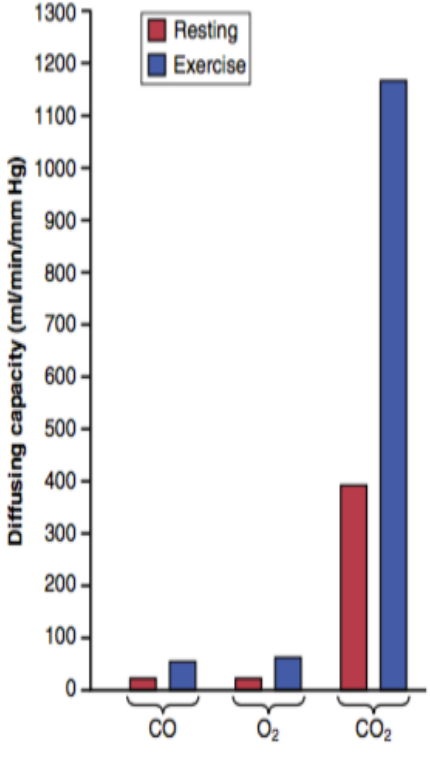


Figure 40-10. *Diffusing capacities* for carbon monoxide, oxygen, and carbon dioxide in the normal lungs under resting conditions and during exercise.

Recovery of the aerobic system after exercise

Oxygen Debt is the amount of extra O2 that must be taken after strenuous exercise to restore the muscles to the resting conditions.

*When a person stops exercising, the rate of oxygen uptake does not immediately return to the pre-exercise levels;

* It returns slowly (the person continues to breathe heavily for at least a few minutes and sometimes for as long as 1 hour thereafter).

This extra oxygen is used to repay the **oxygen debt** acquired during exercise.

Gasping for air after a hard race, to repay the oxygen debt.

How much is the Oxygen Debt after heavy exercise?.

The body contains about 2 liters of stored oxygen. This can be used for aerobic metabolism even without breathing any new oxygen.

<u>This stored oxygen consists of:</u>

(1) 0.5 liter in the air of the lungs, (2) 0.25 liter dissolved in the body fluids,

(3) 1 liter combined with the hemoglobin of the blood,

(4) 0.3 liter stored in the muscle fibers, combined mainly with myoglobin, and hemoglobin.

** In heavy exercise, almost all this stored oxygen is used within a minute or so for aerobic metabolism.

** After the exercise is over, this stored oxygen must be replenished by breathing extra amounts of oxygen over and above the normal requirements.

** In addition, about 9 liters more oxygen must be consumed to reconstitute the phosphagen system and the lactic acid system.

All this extra oxygen that must be "repaid," about 11.5 liters, is called *the oxygen debt.*

The principles of O2-debt

- Figure 85-3 shows that during the first 4 minutes, the person exercises heavily, and the rate of oxygen uptake increases more than 15-fold.
- Even after the exercise, the oxygen uptake still remains above normal;
- At first it is very high while the body is reconstituting the phosphagen system and repaying the stored oxygen portion of the oxygen debt [Alactacid O2 debt]= 3.5 L
- Then it is still above normal at a lower level for another 40 minutes while the lactic acid is removed [Lactic acid O2 debt] = 8 L.

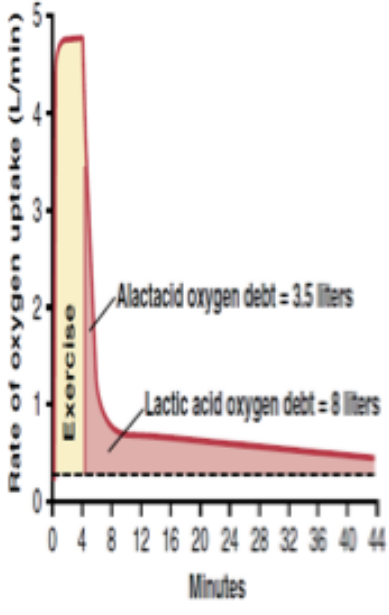


Figure 85-3 Rate of oxygen uptake by the lungs during maximal exercise for 4 minutes and then for about 40 minutes after the exercise is over. This figure demonstrates the principle of oxygen debt.

Dr.Aida Korish (iaidakorish@yahoo.com)

Uses of the *Oxygen Debt* After Completion of Strenuous Exercise

Oxygen Debt is about 11.5 L of O2

This additional oxygen is used to:

(1) reconvert the lactic acid that has accumulated during exercise back into glucose,

(2) reconvert adenosine monophosphate and ADP to ATP,

(3) reconvert creatine and phosphate to phosphocreatine,

(4) re-establish normal concentrations of oxygen bound with hemoglobin and myoglobin, and

(5) raise the concentration of oxygen in the lungs to its normal level.

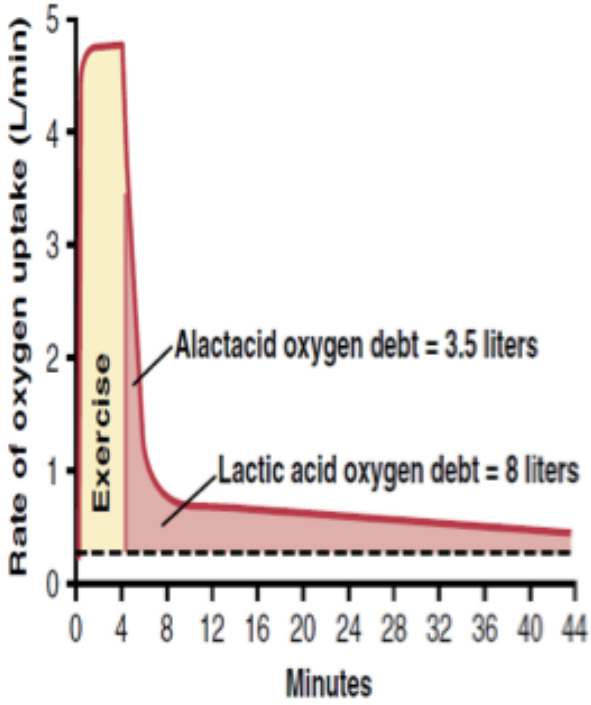


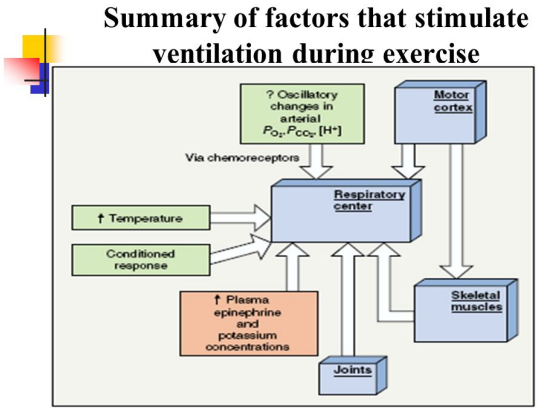
Figure 85-3 Rate of oxygen uptake by the lungs during maximal exercise for 4 minutes and then for about 40 minutes after the exercise is over. This figure demonstrates the principle of *oxygen debt*.

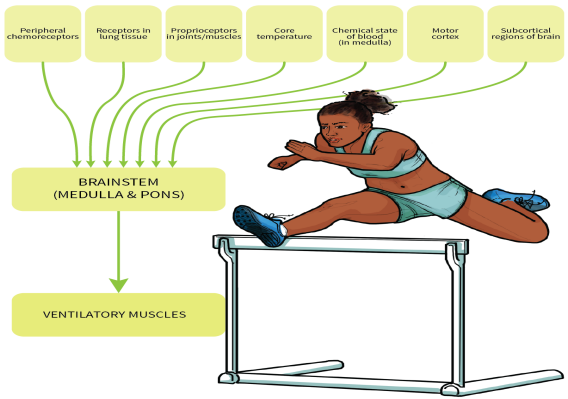
Effects of smoking on pulmonary ventilation in exercise

- Nicotine ***constricts*** *the terminal bronchioles* and ***increases resistance*** of airflow into and out of the lungs.
- Smoke irritation causes ***increased fluid secretion*** into the bronchial tree and swelling of epithelial layer.
- Nicotine ***paralyze the cilia*** of the respiratory epithelial cell surface. This lead to fluid and waste accumulation and ***reduced*** level of ***performance***.
- Chronic smokers ***may develop emphysema*** (obstruction of bronchioles+ chronic bronchitis+ destruction of alveoli) so slight exercise cause respiratory distress.

What cause hyperventilation during exercise?

- Neural signals from the motor areas of the brain to the respiratory center. The motor cortex of the brain, on transmitting motor impulses to the exercising muscles, transmits at the same time collateral impulses into the brain stem to excite the respiratory center.
- An additional sensory signals transmitted into the respiratory center from the contracting muscles and moving joints (proprioceptors).
- Increased body temperature stimulates the (hypothalamus) which stimulates the respiratory centers.
- Possibility that the neurogenic factor for control of ventilation during exercise is a learned response (conditioned reflex).





Relation Between Chemical and Nervous Factors in the Control of Respiration During Exercise.

- *Direct nerve impulses from the motor cortex* stimulate the respiratory center *almost* the proper amount to supply the extra oxygen required for exercise and to blow off extra carbon dioxide.
- Occasionally, the nervous respiratory control signals are either too strong or too weak.
- Then chemical factors play a significant role in bringing about the final adjustment of respiration required to keep the O2, CO2, and H+ ion concentrations of the body fluids as nearly normal as possible.


thank
you!