Effects of exercise on the respiratory system

Respiratory block

PHYSIOLOGY 438 TEAMWORK

- Red: important
- Black: in male / female slides
- Pink: in female slides only
- Blue: in male slides only
- Yellow: notes
- Gray: extra information
- Textbook: Guyton + Linda

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Objectives

1. Describe the effects of moderate and severe exercise on oxygen consumption, and ventilation volumes.
2. Interpret the effects of exercise on arterial PO_2 PCO_2
3. Define the diffusing capacity of the respiratory membrane, and its typical values at rest, and explain its changes in exercise.
4. Explain causes of hyperventilation in exercise.

The respiratory system and exercise

When we exercise
- More oxygen is needed for working muscles
- More carbon dioxide must be removed from muscles

As a result :

1- the **rate of breathing** increase

2- the **depth of breathing** increase up to our vital capacity

3- the **flow of blood** through the lung increase (cardiac output increase)

4- the **oxygen taken up** and used by the body increase (metabolic reactions)

Oxygen uptake during exercise can be up to twenty times a person's normal oxygen uptake

Effect of Exercise on the respiratory system

When is respiration usually stimulated ?

When the blood gases are **abnormal**. However, They do not always have to become abnormal for respiration to be stimulated. Instead, in **exercise,** respiration is mainly stimulated by **neurogenic mechanisms**.

Regulation of respiration during exercise

In strenuous exercise :

- **O_2** consumption and **CO_2** formation may increase 20 folds
- The arterial **PO_2, PCO_2, PH** all **remain almost exactly normal.**
- **Alveolar ventilation** increases almost exactly in step with the increased levels of metabolism

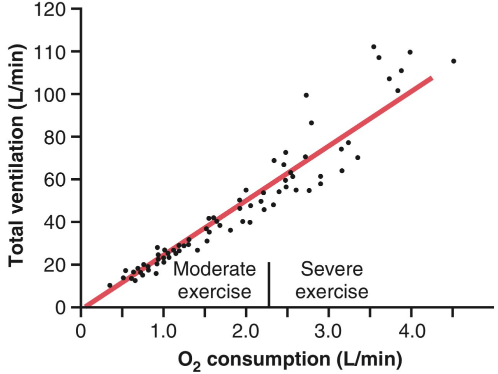


Figure 42-9. Effect of exercise on oxygen consumption and ventilatory rate. *(From Gray JS: Pulmonary Ventilation and Its Physiological Regulation. Springfield, Ill: Charles C Thomas, 1950.)*

What causes intense ventilation during exercise?

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.

A large share of the total increase in ventilation begins immediately on initiation of the exercise, before any blood chemicals have had time to change. This is mostly due to neurogenic signals.

1- Neural signals from the motor areas of the brain to the respiratory center.

2- The joint proprioceptors

3- Body temperature (hypothalamus).

4- Possibility that the neurogenic factor for control of ventilation during exercise is a **learned response**.

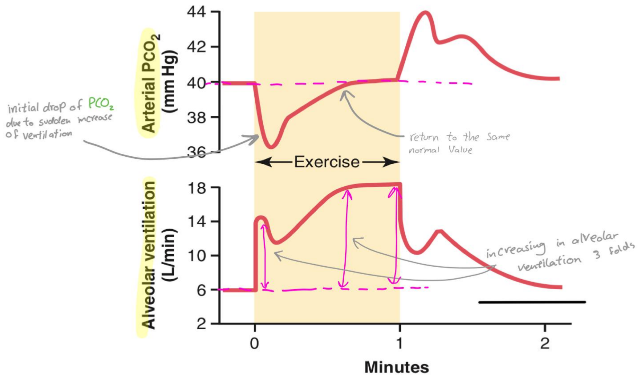
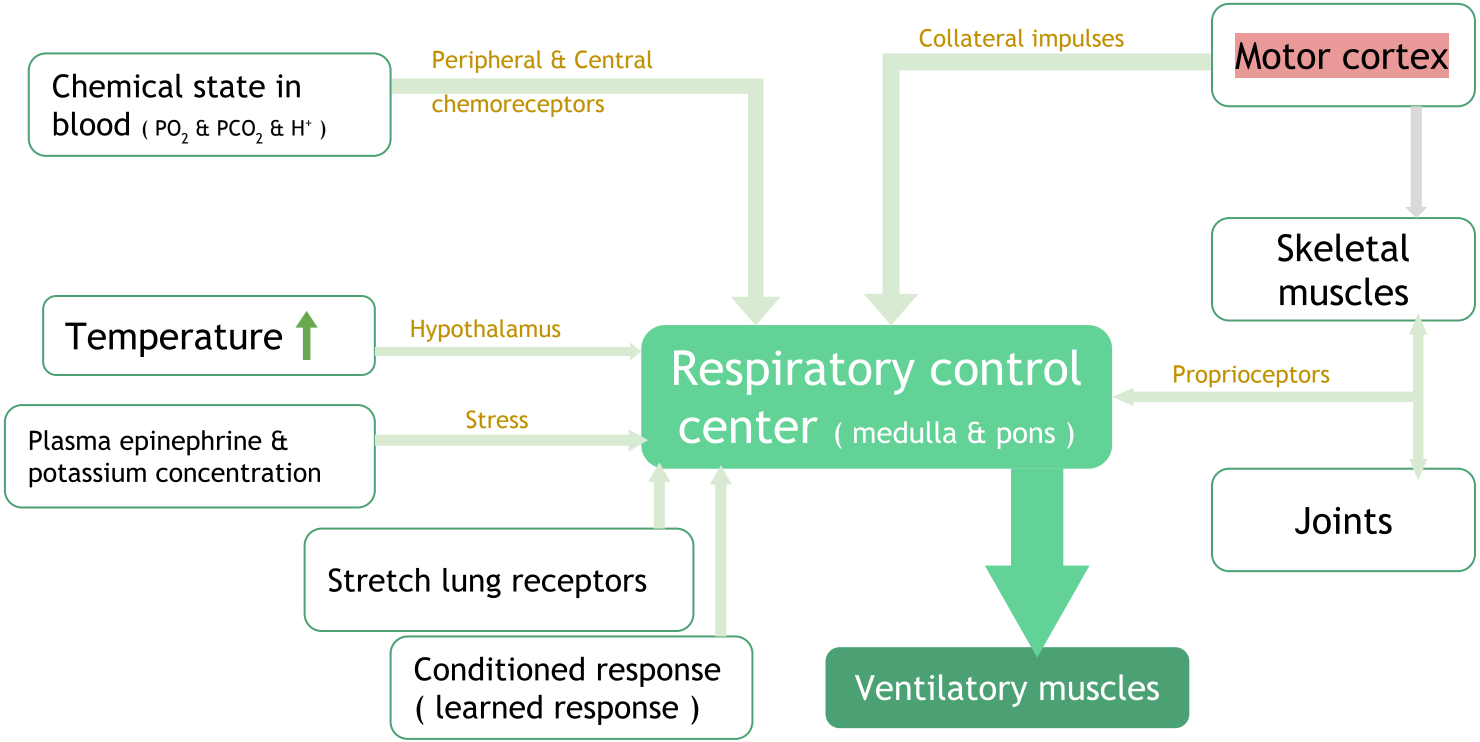


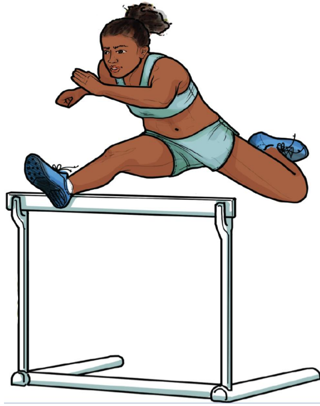
Figure 42-10. Changes in alveolar ventilation (*bottom curve*) and arterial PCO_2 (*top curve*) during a 1-minute period of exercise and also after termination of exercise.

From Guyton

At the onset of exercise, the alveolar ventilation increases almost instantaneously without an initial increase in arterial PCO_2. In fact, this increase in ventilation is usually great enough so that at first it actually decreases arterial PCO_2 below normal. The presumed reason that the ventilation forges ahead of the buildup of blood CO_2 is that "This is at least partly learned response"

Summary of factors that stimulate ventilation during exercise



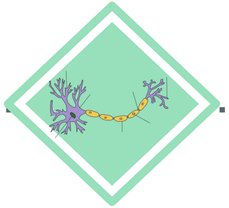


Relation Between Chemical and Nervous Factors in the Control of Respiration During Exercise.

Brain

Direct nervous signal stimulate the respiratory center almost the **proper amount** to supply the extra oxygen required for exercise and to blow off extra carbon dioxide.

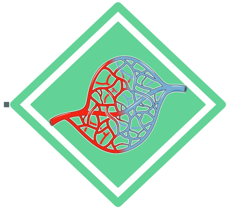
Nervous respiratory system



Occasionally, the nervous respiratory control signals are either:

- too strong
- too weak

Chemical factors



Then chemical factors play a significant role in bringing about the final adjustment of respiration required to keep the O_2, CO_2, and H^+ ion concentrations of the body fluids as nearly normal as possible

The Neurogenic Factor for Control of Ventilation During Exercise Is a Learned Response.

- The ventilatory response during exercise, is at least partly a learned response.

Sometimes we see weightlifters take few deep breaths unconsciously before even try to rise the load, so the ventilation rate increase immediately with the beginning of exercise . Also that might happen when we see the exam hall, our heart rate increase even though we don't have an exam,right?

- With repeated periods of exercise, the brain becomes more able to provide the proper signals required to keep the blood PCO_2 at its normal level.

- The **cerebral cortex** is involved in this learning, because experiments that block only the cortex also block the learned response.

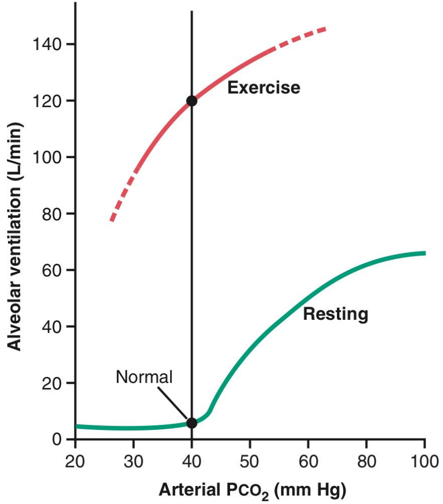


Figure 42-11. Approximate effect of maximum exercise in an athlete to shift the alveolar P_{CO_2}-ventilation response curve to a level much higher than normal. The shift, believed to be caused by neurogenic factors, is almost exactly the right amount to maintain arterial P_{CO_2} at the normal level of 40 mm Hg both in the resting state and during heavy exercise.

Diffusion capacity of the respiratory membrane

	O_2 diffusing capacity	CO_2 diffusing capacity
During rest	21 ml/min/mmHg ➢ Even if the oxygen pressure difference across the respiratory membrane is 11 mmHg —>11x21= 230ml oxygen diffusing through the membrane each minute. So, 11 mmHg is the minimal pressure difference we need to maintain normal O_2 consumption ➢ During rest tissues consume <u>250 ml O_2/min</u> =12x21	21 x 20 = 400 400 ml/min/mmHg
During exercise	65 ml/min/mmHg ★This is due to : • <u>increased number of open pulmonary capillaries</u> which was dormant, thereby increasing the surface area for gas exchange. • In addition to <u>increased alveolar ventilation</u>.	65 x 20 = 1300 The diffusing capacity increase 3 times during exercise 1200-1300 ml/min/mmHg

It diffuses 20 times greater than oxygen due to greater diffusion coefficient which is 20 times that for oxygen.

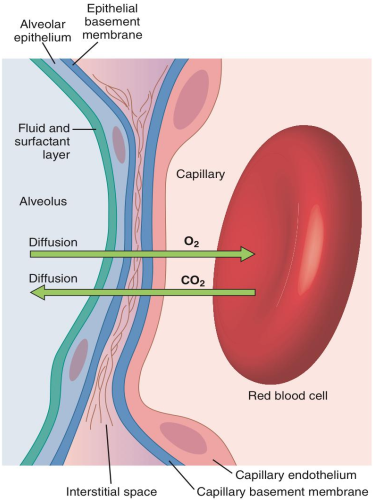


Figure 40-9. Ultrastructure of the alveolar respiratory membrane, shown in cross section.

Factors affecting diffusing capacity:
1- surface area
2- thickness of respiratory membrane

From Guyton

How to measure the diffusion capacity of Oxygen and Carbon Dioxide

The diffusing capacity for **CO_2** has never been measured because CO_2 diffuses through the respiratory membrane so rapidly that the average PCO_2 in the pulmonary blood is not far different from the PCO_2 in the alveoli—the average difference is less than 1 mm Hg

It is not practical to measure the **O_2**-diffusing capacity directly because it is not possible to accurately measure the O_2 tension of the pulmonary capillary blood.

However, the diffusing capacity for CO can be measured accurately because the CO tension in pulmonary capillary blood is zero under normal conditions. So, we measure O_2 capacity using CO

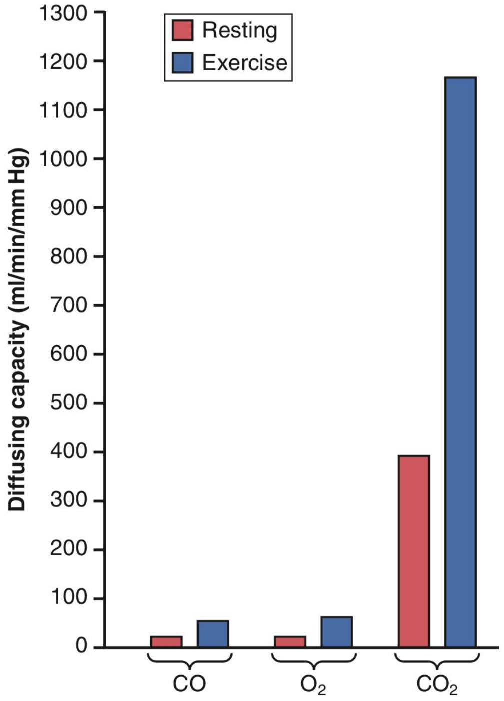
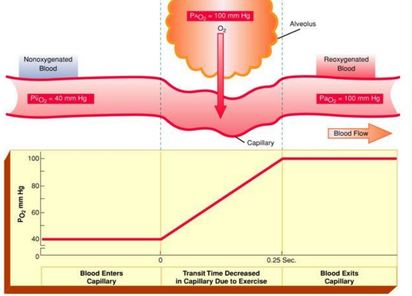


Figure 40-10. *Diffusing capacities* for carbon monoxide, oxygen, and carbon dioxide in the normal lungs under resting conditions and during exercise.

During exercise :



The curve show how the blood speed increase when it enter the pulmonary capillaries But that doesn't affect the saturation of O_2 and the blood maintain normal PO_2

the oxygen requirement increased 20 times → cardiac output increased → Additional capillaries open up → The **time** blood remained in the pulmonary capillaries becomes **less** than half normal

Despite that, the blood is almost completely saturated with oxygen when it leaves the pulmonary capillaries!

How?

1- The diffusing capacity for oxygen increases almost three fold during exercise, this results mainly from increasing numbers of capillaries participating in the diffusion, and a more even V/Q ratio all over the lung.

2- 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 in exercise, **the blood is still fully oxygenated or nearly so.**

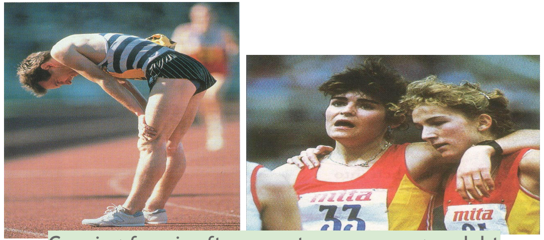
Oxygen Consumption and Pulmonary Ventilation in Exercise

Normal oxygen consumption for a young man at rest is about **250 ml/min.**

under maximal conditions

It could increase to approximately the following average levels:

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



Gasping for air after race to repay oxygen debt

Quiz

You don't understand why we choose this answer?
Click here to read the explanations

1- What happens during exercise?

A. Blood flow is uniform throughout the lung
B. Lung-diffusing capacity increases because blood flow is continuous in all pulmonary capillaries
C. Pulmonary blood volume decreases
D. The transit time of blood in the pulmonary capillaries does not change from rest

2-what is the main cause of intense ventilation during exercise ?

A. Changes in PO_2 and PCO_2
B. Changes in PCO_2 only
C. Brain cortex
D. Who said there is intense ventilation during exercise ?

3- During strenuous exercise, O_2 consumption and CO_2 formation can increase as much as 20-fold. Va increases almost exactly in step with the increase in O_2 consumption. Which option best describes what happens to the mean arterial O_2 tension (Po_2), CO_2 tension (Pco_2),and pH in a healthy athlete during strenuous exercise?

	Arterial Po_2	Arterial Pco_2	Arterial pH
A)	Decreases	Decreases	Decreases
B)	Decreases	Increases	Decreases
C)	Increases	Decreases	Increases
D)	Increases	Increases	Increases
E)	No change	No change	No change

4-Which of the following describes diffusing capacity of O2 in the lung?

A. Does not change during exercise
B. Is greater than diffusing capacity for CO_2
C. Is greater in residents at sea level than in residents At 300 meter altitude
D. Is directly related to alveolar capillary surface area

SAQ

1- which part of brain is involved in the ventilatory learned response during exercise ?

3- Despite the fact that we have an INCREASED oxygen requirement (x20) and a DECREASED time to fulfill it during exercise, how are we still able to fully saturate the blood with oxygen?

Answers: 1- cerebral cortex

2- - We will have an increased diffusion capacity (due to increased capillary openings and increased alveolar ventilation + perfusion).
- At rest we have 3 times as long as necessary to saturate the blood, so a less time of exposure *due to increased perfusion* can still be compensated

Key answers:

1- B 2- C 3- E 4- D

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