

Effects of Barometric Pressure on the Pulmonary System

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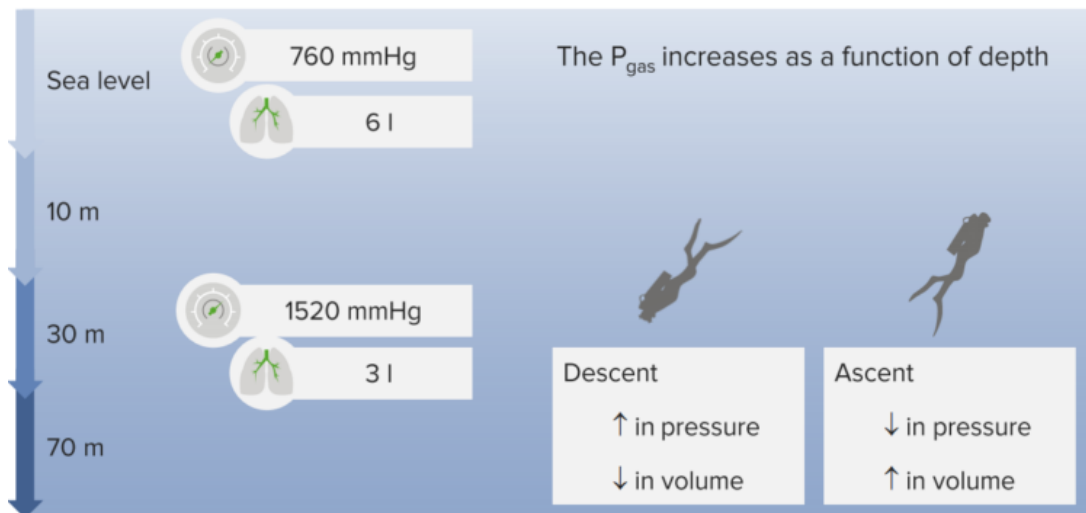
Barometric pressure is also called atmospheric pressure. It presents the pressure applied by the weight of the air in the atmosphere. Changes in barometric pressure experienced by breath-hold divers or mountain climbers have a significant impact on the body's pulmonary physiology.



Sea Pressure

On land, you cannot feel atmospheric pressure because the weight of the air on your body is being counteracted by the fluids in your body that are pushing back with the same force. However, the deeper the person goes into the sea, the more pressure is felt on the eardrums. This is due to **hydrostatic pressure**; the force per unit area exerted by the fluid on the body.

Pulmonary Physiology of Breath-Hold Diving



Breath-Hold Break Points

Breath-holding is a conscious and voluntary act. The breakpoint is described as the moment in which **involuntary mechanisms of the body supersede this voluntary act** in order to protect the body from the long-term effects of breath-holding.

The central respiratory rhythm is maintained by the **brainstem** which persistently gives signals to the diaphragm to contract. It is majorly the inability of the body to suppress the central respiratory rhythm that leads to breaking points during breath-holding. Other factors that contribute to breath-hold breaking points are **hypocapnia**, **hyperoxia** and large lung inflations.

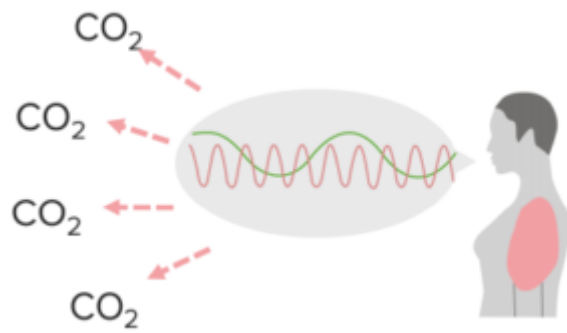
Stages of Breath-Hold Diving

Example of alveolar gas changes during breath-hold diving

	O_2		CO_2	
	%	mmHg	%	mmHg
Resting	14.0	100	5.6	40
Before descent	16.7	120	4.0	29
Apex of dive	11.1	149	3.2	42
Ascent	5.9	41	5.9	5.9

Factors that Affect Breath-Holding

During breath-holding, the oxygen partial pressure decreases, whereas that of carbon dioxide increases. There are sensors in the body that detect **blood** concentrations of oxygen and carbon dioxide; these include carotid and aortic bodies for oxygen and sensors placed on the medulla for carbon dioxide detection.



■ Hyperventilation

Hyperventilating prior to breath-holding increases breath-holding time. This is because hyperventilating decreases carbon dioxide levels in the blood so sensors in the medulla are not so quick to send signals and induce the need to breathe right away.

- **If the arterial oxygen partial pressure** falls lower than 60–70 mm Hg, the carotid and aortic bodies send signals to resume breathing.

Adaptation to Chronic Breath-Hold Diving

The body makes certain chronic adaptations in the respiratory system in those people who practice breath-hold diving constantly, for example, fishermen. These include increased [pulmonary function tests](#), decreased ventilatory sensitivity to the partial pressure of oxygen and carbon dioxide, as well as heightened diving reflexes.

Pulmonary function tests

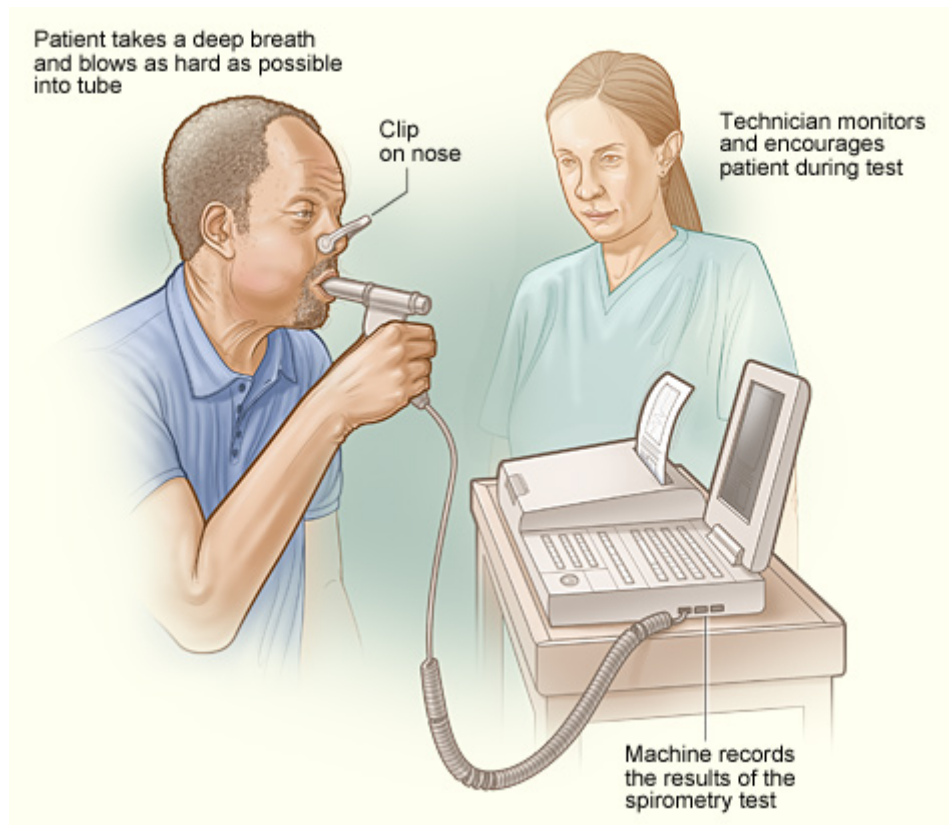


Image: "The image shows how spirometry is done. The patient takes a deep breath and blows as hard as possible into a tube connected to a spirometer. The spirometer measures the amount of air breathed out. It also measures how fast the air was blown out." by National Heart Lung and Blood Institute (NIH).
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There are a group of tests that measure how well the lungs are functioning; its components include total lung capacity, vital capacity, inspiratory and expiratory capacities, forced vital capacities and residual volume. The instrument used is called a **spirometer**.

- **Total lung capacity (TLC):** This is the volume of air in the lungs after maximal inspiration.
- **Tidal volume (TV):** The amount of air that is breathed in and out in normal, quiet breathing.
- **Vital capacity (VC):** Volume of air exhaled followed by the deepest inspiration.
- **Inspiratory capacity (IC):** This is a sum of inspiratory reserve volume (the amount of air that can be taken in followed by a normal inhalation) and tidal volume.

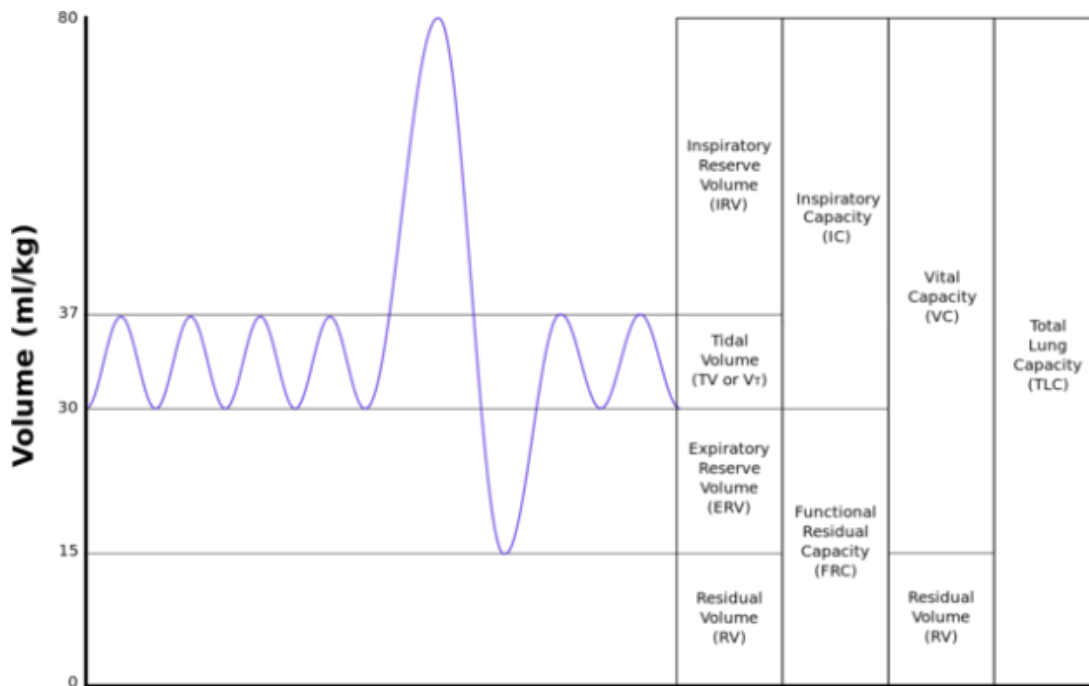


Image: "Typical output from a spirometer of a normal person taking 4 tidal breaths, followed by maximal inspiration and expiration. Corresponding volumes and capacities are noted in the right-hand boxes" by Vihsadas. License: [CC BY-SA 3.0](#)

Reflexes Developed in Response to Chronic Breath-Hold Diving



Image: "Vasoconstriction of a Microvessel" by Robert M. Hunt. License: [CC BY 3.0](#)

Bradycardia: Slowing the [heart](#) rate decreases the workload on the heart, hence reducing the need for oxygen by the heart, or oxygen can then be delivered to other organs.

- **Peripheral vasoconstriction:** Capillaries supplying blood to the extremities

constrict and reduce blood flow, blood that can be redirected towards the brain, heart, and [lungs](#).

Effects of Decrease in Barometric Pressure on the Pulmonary System

Hypobaric Hypoxia

This is a decreased supply of oxygen to the body in a **high altitude environment** due to the fall in air density, pressure and oxygen concentration.

Signs and Symptoms of Hypobaric Hypoxia:

- Headache and loss of consciousness
- Shortness of breath
- Fatigue
- Mental disturbance/lack of cognitive functions
- Cyanosis

Hypobaric Hypoxia Acclimatization

Acclimatization is when the body makes adjustments in order to conform to gradually changing environmental conditions.

- Hypoxia causes the person to hyperventilate, which results in hypocapnia.
- Increased cardiac output in order to supply more blood (hence oxygen) to the body.
- Polycythemia: Increase in erythrocyte count in chronic cases to increase the concentration of oxygen being supplied to tissues.
- Acid-base changes: hypocapnia and hypoxia lead to metabolic compensations which bring about acid-base changes in the body.

If the body fails to put up an acclimatization response in order to adjust to hypobaric conditions, the following high altitude illnesses can occur:

- **Acute mountain sickness**
- **High altitude cerebral edema**
- **High altitude pulmonary edema**

Acute Mountain Sickness

This condition occurs due to low oxygen partial pressure at high altitude.

Signs and Symptoms



- **Image:** "Right: A woman with peripheral edema (swollen face) while trekking at high altitude (Annapurna Base Camp, Nepal; 4130 m). Left: The same woman on a normal day at normal altitude." by Natalia Menezes. License: Public Domain

Weakness

- Peripheral **edema**
- Insomnia
- Dizziness
- Shortness of breath at an exertion

Prevention

- Ascending slowly into high altitude conditions - gives time to the body for acclimatization. Don't fly or drive directly to high altitude, starting below 3000 meters and walking the rest of the way up helps the body to properly adapt.
- Avoid respiratory depressants like alcohol and sleeping pills.
- Avoid strenuous physical activity in high altitude areas.

Pharmacological Treatment

- **Acetazolamide:** It is a carbonic anhydrase inhibitor - accumulation of carbonic acid resulting in bicarbonaturia and metabolic acidosis, this offsets the hyperventilation-induced respiratory alkalosis so the chemoreceptors are free to respond to hypobaric hypoxia caused by the altitude.
- **Dexamethasone:** It is a steroid that decreases the brain and other swellings around the body, effectively undoing the effects of acute mountain sickness.

High Altitude Cerebral Edema

The brain swells up due to the accumulation of fluid because of the high altitude conditions. This is a progression from acute mountain illness and presents with more severe symptoms, such as:

- Confusion and altered mental state

- Loss of consciousness
- Ataxia (inability to coordinate voluntary muscle movement)
- Hallucinations
- **Worst symptoms:** Retinal hemorrhage and blurred vision

High Altitude Pulmonary Edema (HAPE)

This is the accumulation of fluid in the lungs due to a high altitude condition, and the failure of the body to acclimatize. Fluid build-up prevents a proper oxygen exchange in the alveoli, leading to hypoxia and cyanosis.

Symptoms

- Shortness of breath
- Tightness around the chest
- Coughing up frothy white/pink fluid
- Nocturnal suffocation

It is of utmost importance to come down 600 meters in order to save the person suffering from HAPE.

Pharmacological Treatment

- **Nifedipine:** This is a calcium channel blocker that works to relax **blood vessels** (mainly relaxing the pulmonary arteries, which reduce arterial pulmonary pressure, which helps in managing pulmonary edema).

Review Questions

The correct answers can be found below the references.

1. A 38-year-old male arrives within a state of emergency in a remote clinic in the foothills of a mountain range presenting with nausea, vomiting, shortness of breath, fatigue, rapid heartbeat and swelling of the hands and feet. The patient says he's a tourist from the city-side mountain climbing on a vacation. The doctor diagnoses the patient with acute mountain illness. Which of the following best describes the progression of the patient's condition if his body's acclimatization response fails?

- A. Stroke
- B. High altitude cerebral edema
- C. Hemorrhage
- D. Disseminated intravascular coagulation
- E. Aspiration pneumonia

2. A 28-year-old college student attends her doctor's outpatient clinic to refer to her trip to the French Alps that she is about to take next week. She explains that she has done mountain climbing training in indoors facilities in town, but has not been on an actual high altitude mountain climb before. Which of the following is the best advice the doctor can give the patient regarding high altitude mountain sickness prevention?

- A. Gradual ascend
- B. Remaining hydrated

- C. Not going mountain climbing while on her period
- D. Taking high doses of an iron supplement prior to the trip
- E. Keep prescribed NSAIDs for the duration of the trip

References

[How does pressure change with ocean depth?](#) via oceanservice.noaa.gov

[Pulmonary function tests](#) via nlm.nih.gov

[Hypobaric Hypoxia](#) via aviationknowledge.wikidot.com

[Altitude or Mountain Sickness](#) via traveldoctor.co.uk

Correct answers: 1B, 2A

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Notes