



## Altitude, Hypoxic and Hyperoxic Trainings: Facts vs Realistic Applications and its Effects

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### Abstract

*Altitude training is the practice by some endurance athletes of training for several weeks at high altitude, preferably over 2,400 metres (8,000 ft) above sea level, though more commonly at intermediate altitudes due to the shortage of suitable high-altitude locations. At intermediate altitudes, the air still contains approximately 20.9% oxygen, but the barometric pressure and thus the partial pressure of oxygen is reduced. Athletes or individuals who wish to gain a competitive edge for endurance events can take advantage of exercising at high altitude. High altitude is typically defined as any elevation above 1,500 metres (5,000 ft). Scientific studies on high-altitude training regimes were carried out on elite athletes close to their ultimate performance potential: these same training regimens are expected to be effective on ordinary athletes further from their peak potential.*

**Keywords:** Altitude, Hypoxic, Hyperoxic.

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### Introduction

The outcome of altitude on the human body, especially in relation to exercise, is gaining more popularity than ever. The many physiological effects of altitude on the body are being investigated much more thoroughly, especially in athletes who train and compete at altitude. Along with the physiological changes that are happening in the body in response to altitude, altitude training has become popular in the last few decades, and it does not seem to be losing any momentum. However, if altitude training is not done effectively, it may cause unwanted complications such as acute mountain sickness. For example, acute mountain sickness is when the body does not react to altitude in a favorable way. If not treated quickly, acute mountain sickness can turn from acute to severe in a matter of a few hours. In this paper, the body's response to altitude will be addressed, along with exercises and altitude related illnesses that may arise.

### Purpose of the study

The purpose of study is to inspect the current available literature in order to provide insight on altitude's effect on the human body in both untrained and trained individuals.

### Delimitations of the study

Sports Discus and Pub med databases were used as search engines.

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### Classifications of Altitude

The body reacts in different ways at varying levels of altitude. This will be extremely important to know when traveling to altitude and exercising at altitude. There are different classifications of high altitude, and each has its own effects on the human body.

#### High Altitude

High altitude is classified as 1,500m-3,500m. At this altitude, there is an onset of physiological changes in response to the decreased inspiratory oxygen pressure, which include a decreased exercise performance and an increased ventilation response. At this altitude, there are also minor impairments that reduce the oxygen transport to the organs of the body.

#### Very High Altitude

Very high altitude is classified as anywhere from 3,500m-5,500m. Extreme hypoxemia, with oxygen saturations falling below 90%, may occur during exercise, sleep, and in the presence of a preexisting acute lung condition, such as high-altitude pulmonary edema. Severe altitude sickness could occur at this specific altitude as well.

#### Extreme Altitude

Extreme altitude is at 5500m or greater. The peak of Mt. Everest reaches 8,848 meters. Hypoxemia, Hypocapnia, and Alkalosis are likely to occur at this altitude level.

#### Immediate Physiological Changes At High Altitude

With increasing altitude, the drop in barometric pressure causes a drop in the partial pressure of oxygen, which causes a hypobaric hypoxic effect. With the drop

in barometric pressure, the body works to protect itself in order to make sure its systems keep working. This protection system is better known as acclimatization. Acclimatization is the physiological changes the body uses to compensate for decreased oxygen when exposed to high altitude. One change experienced in the respiratory system while exercise at high altitude is an increased ventilation rate. Increased ventilation rate is a short-term change the body uses to compensate for the difference in oxygen when at altitude. It lasts anywhere from 10-14 days. Increased ventilation rate can cause respiratory alkalosis, which can be fully reversed in one day by an increase in the renal bicarbonate excretion, which decreases the buffering capacity of plasma. The importance of this mechanism is to maintain the acid base balance in the body. It is important to know ventilation rate and increased arterial saturation only increase over approximately the first two weeks after one arrives at altitude. The last major change the respiratory system makes is decreased oxygen saturation during exercise. This is primarily because of a diffusion limitation, caused by the lower alveolar pressure of oxygen, and an increased pulmonary blood flow with exercise. This drop in oxygen saturation can be more severe in endurance-trained athletes.

Some physiological changes that occur in the blood are an increase in hemoglobin concentration, a decrease in plasma volume, and a significant increase in red blood cells. The cardiovascular system changes at altitude as well. There is an increase in the sympathetic activity over time, and the maximum heart rate decreases with increasing altitude. This is due to the increase in vagal tone, and may be from the down regulation of beta-receptors. These effects can occur anywhere from four to eight hours after arriving at altitude. Cardiac output increases in order to compensate for the reduced pressure of oxygen and tissue hypoxia. Cardiac output is also affected by the increased heart rate. The increase in heart rate immediately upon arriving at altitude can be attributed to an increase in the peripheral resistance, which causes stroke volume to decrease. Therefore, the heart rate increases in order to maintain cardiac output. An increased catecholamine response can also further increase heart rate and blood pressure. Other cardiovascular changes that occur are an increase in the pulmonary artery pressure and systemic blood pressure. Skeletal muscle adaptations can also occur during extended periods at high altitude. Hypoxia is the predominant force when discussing changes in skeletal muscle. One of the most prominent changes in muscles are the transport of bicarbonate, hydrogen ions, and lactate and are up regulated when exposed to hypoxic situations. Another adaptation is the down regulation of the sodium-potassium pump; however, the significance of this particular change has not been tested. Sleep patterns are also disturbed when a person travels to altitude. When a person arrives at altitude, the reduced oxygen content in the blood produces breathing instability with periods of deep and rapid breathing. This

can affect sleep by causing periods of apnea. Apnea is a cessation of the movement of the respiration muscles, which causes the lung volume to remain unchanged. Sleep apnea can also be a risk factor to heart disease, which is why apneas are not ideal. With a lack of sleep, this can cause depressive mood, anger and fatigue. Each person's body reacts differently to altitude. In some cases, their bodies have slow acclimatization and they may become ill. This would be the onset of altitude sickness.

### **Altitude Sickness**

Altitude sickness commonly associated with the onset of headaches and nausea, and can be treated by returning to sea level or, in extreme cases, medication may be required. Altitude sickness is divided into three different levels. There is Acute Mountain Sickness (AMS), High Altitude Cerebral Edema (HACE), and High Altitude Pulmonary Edema (HAPE).

### **Acute Mountain Sickness**

AMS is most likely after the first night spent at any given altitude. AMS can either resolve spontaneously after one to three days, or get worse if a person continues to ascend. Several factors contribute to AMS, such as ascent rate, elevation obtained, intensity of physical exertion, hydration level, and individual variability. Risk factors for developing high altitude sickness are rapid ascent, strenuous physical exertion, young age, living at a low altitude, and history of altitude sickness. There is limited evidence that suggests that obesity may be a risk factor for AMS as well. Rapid ascent is a risk factor because of the stress put on the body. The body needs time to acclimatize, and with a rapid ascent, the body does not have enough time to make the required physiological changes. Living at a low altitude is a risk factor because people are not used to the thin air at altitude, and their bodies are not acclimatized to the high altitude like the people who live at high altitude. Fitness level is not an indicator for the amount of acclimatization or likelihood of getting AMS. Even elite athletes can have trouble with acclimatization. AMS is the least severe of the high altitude sicknesses. People with AMS have a headache and at least one other symptom, which could include: loss of appetite, nausea, vomiting, weakness, difficulty sleeping, and/or dizziness.

### **High Altitude Cerebral Edema**

HACE is also known as high altitude cerebral edema. HACE occurs in less than 1% of people who travel to high altitude. Generally HACE is existent for several days after arriving at altitude. Some symptoms of HACE include headache and one of the following: anorexia, nausea or vomiting, dizziness, lightheadedness, insomnia, or fatigue/weakness. If a person has a headache, one or more of the symptoms previously listed, and ataxia (an altered mental status), they are most likely to experience HACE and need to seek medical attention. HACE can progress quickly, usually from mild

ataxia to a coma, with death occurring within hours. If remained untreated, HACE can cause brain herniation from unchecked cerebral edema. Along with acetazolamide and dexamethasone, HACE can be treated with supplemental oxygen. Full recovery may take several weeks after the onset, and may leave permanent brain damage or impairment

**High Altitude Pulmonary Edema**

HAPE is a high altitude sickness and is less common than AMS. Approximately less than 1% of people will develop HAPE. However, HAPE causes the most deaths related to high altitude. Some symptoms of HAPE include dyspnea at rest, cough, weakness or decreased exercise, chest tightness or congestion, crackles or wheezing, central cyanosis, tachypnea, and tachycardia. One way to check the diagnosis of HAPE is by utilizing pulse oximetry to measure oxygen saturation levels. One of the reasons HAPE occurs is because of a

low hypoventilatory response (HVR). The low hypoventilatory response causes HAPE because it is the body’s way of trying to save energy. Exercise and the colder temperatures at high altitude elevate pulmonary hypertension. Increased stress on the capillaries from pulmonary hypertension can cause a mechanical stress on the fragile endothelium, leading to fluid extravasation into the interstitial and alveolar space. Therefore, sodium and water transport are shown to be damaged in it. When HAPE is present, it is extremely important to avoid any type of physical exertion. When traveling in high altitude, there are preventive actions that can be taken in order to try and avoid the development of any of the high altitude sicknesses. Some ways to prevent high altitude sickness are to avoid exercise within the first two days at altitude, drinking plenty of water, eating an adequate amount, and obtain sufficient sleep. The avoidance of alcohol and nicotine can also prevent high altitude sickness.

**Other Conditions Occurring at High Altitude**

Type of Problem	Example	Cause	Remedy
Sleeping Patterns	Sleep Apnea	Lack of oxygen (9)	Zolpidem (Sleep Aid)
Dehydration	Dehydration	-Increased metabolic and respiratory demands -Sweat Evaporation (6,9)	Drinking plenty of fluids
Cold Injuries	Frostbite, hypothermia	-As altitude increases the temperature drops (9)	-Warm clothing, and lots of layers
Skin Injuries	Sunburn, eye injuries	-With higher altitude one is closer to the sun -Increase in ultraviolet light (9)	-Protective eyewear, sunscreen
Thrombotic events	Pulmonary embolism	-Combination of dehydration, cold, polycythemia, and peripheral edema (9)	-Descend immediately
Cough	Cough	-Dry air (9)	-Scarf, facemask, throat lozenges, benzonatate, low dose narcotics

**Altitude Training**

Altitude training is a fairly new type of training that involves athletes training at higher altitudes in hopes of developing key physiological adaptations from the hypoxic exposure and the results of acclimatization. Altitude training is popular with middle and long distance runners, along with other endurance athletes. Typically, aerobic athletes tend to perform worse at altitude, with the exception of athletes that participate in

short, anaerobic sports such as cycling and speed skating. The reduced density of air provides these athletes with better performance. Some of the body’s adaptations at altitude include increased ventilation, increased heart rate, and reduced plasma blood flow. These adaptations occur initially in order to compensate for the lack of oxygen at altitude. After a few days to a few weeks, the body starts to acclimate to the decreased oxygen at high altitude. A few of the physiological changes that occur

are an increase in hemoglobin brought on by the increase in red blood cells. The increase in the red blood cells and hemoglobin help to increase an athlete's VO<sub>2</sub>max. There are various different theories behind altitude training.

### Live High and Train High

Maximum exposure to altitude - Indication of an optimistic effect at sea level is controversial, and there is a smaller amount of support for this method among specialists.

### Live Low and Train High

The idea behind this system is that the sportsperson is exercising in a low oxygen location, whilst relaxing in a normal oxygen environment. Moreover, training intensity is condensed so some athletes may find that they actually lose fitness using this regime.

### Live High and Train Low

The philosophy behind this system is that the body will adjust to height by living there. Hence, the useful effects of altitude exposure are harnessed whereas some of the adverse ones are avoided. However, dwelling at altitude must be for more than twelve hours per day and for at least three weeks. With this method, developments in sea-level performance have been shown in occasions lasting between 8 to 20 minutes.

### Summary

The body responds to different stimulus in different ways. The body's changes to altitude were discussed, along with different types of altitude training. As an athlete, it is important to know how your body will react to different types of training in order to determine which type is best for each individual. In the future, it will continually be important to keep investigating the body's response to altitude to find new ways to improve athlete's performance, along with preparing their body's for the changes when competing at altitude training. It is also suggested that the person have a slow ascent up to altitude. This will decrease their chances of succumbing to altitude sickness that hampers with a person's health immensely at various levels. This will also allow the body time to fully acclimatize to the change in conditions and undergo the necessary physiological changes.

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