Princeton University Outdoor Action

Outdoor Action Guide to
High Altitude: Acclimatization and Illnesses

High altitude-we all enjoy that tremendous view from a high summit, but there are risks in going to high altitude, and it's important to understand these risks. Here is a classic scenario for developing a high altitude illness. You fly from New York City to a Denver at 5,000 feet (1,525 meters). That afternoon you rent a car and drive up to the trailhead at 8,000 feet (2,438 meters). You hike up to your first camp at 9,000 feet (2,745 meters). The next day you hike up to 10,500 feet (3,048 meters). You begin to have a severe headache and feel nauseous and weak. If your condition worsens, you may begin to have difficulty hiking. Scenarios like this are not uncommon, so it's essential that you understand the physiological effects of high altitude.

What is high altitude?

Altitude is defined on the following scale High (8,000 - 12,000 feet [2,438 - 3,658 meters]), Very High (12,000 - 18,000 feet [3,658 - 5,487 meters]), and Extremely High (18,000+ feet [5,500+ meters]). Since few people have been to such altitudes, it is hard to know who may be affected. There are no specific factors such as age, sex, or physical condition that correlate with susceptibility to altitude sickness. Some people get it and some people don't, and some people are more susceptible than others. Most people can go up to 8,000 feet (2,438 meters) with minimal effect. If you haven't been to high altitude before, it's important to be cautious. If you have been at that altitude before with no problem, you can probably return to that altitude without problems as long as you are properly acclimatized.

What Causes Altitude Illnesses

The concentration of oxygen at sea level is about 21% and the barometric pressure averages 760 mmHg. As altitude increases, the concentration remains the same but the number of oxygen molecules per breath is reduced. At 12,000 feet (3,658 meters) the barometric pressure is only 483 mmHg, so there are roughly 40% fewer oxygen molecules per breath. In order to properly oxygenate the body, your breathing rate (even while at rest) has to increase. This extra ventilation increases the oxygen content in the blood, but not to sea level concentrations. Since the amount of oxygen required for activity is the same, the body must adjust to having less oxygen. In addition, for reasons not entirely understood, high altitude and lower air pressure causes fluid to leak from the capillaries which can cause fluid build-up in both the lungs and the brain. Continuing to higher altitudes without proper acclimatization can lead to potentially serious, even life-threatening illnesses.

Acclimatization

The major cause of altitude illnesses is going too high too fast. Given time, your body can adapt to the decrease in oxygen molecules at a specific altitude. This process is known as acclimatization and generally takes 1-3 days at that altitude. For example, if you hike to 10,000 feet (3,048 meters), and spend several days at that altitude,

your body acclimatizes to 10,000 feet (3,048 meters). If you climb to 12,000 feet (3,658 meters), your body has to acclimatize once again. A number of changes take place in the body to allow it to operate with decreased oxygen.

- The depth of respiration increases.
- Pressure in pulmonary arteries is increased, "forcing" blood into portions of the lung which are normally not used during sea level breathing.
- The body produces more red blood cells to carry oxygen,
- The body produces more of a particular enzyme that facilitates the release of oxygen from hemoglobin to the body tissues.

Prevention of Altitude Illnesses

Prevention of altitude illnesses falls into two categories, proper acclimatization and preventive medications. Below are a few basic guidelines for proper acclimatization.

- If possible, don't fly or drive to high altitude. Start below 10,000 feet (3,048 meters) and walk up.
- If you do fly or drive, do not over-exert yourself or move higher for the first 24 hours.
- If you go above 10,000 feet (3,048 meters), only increase your altitude by 1,000 feet (305 meters) per day and for every 3,000 feet (915 meters) of elevation gained, take a rest day.
- "Climb High and sleep low." This is the maxim used by climbers. You can climb more than 1,000 feet (305 meters) in a day as long as you come back down and sleep at a lower altitude.
- If you begin to show symptoms of moderate altitude illness, don't go higher until symptoms decrease ("Don't go up until symptoms go down").
- If symptoms increase, go down, down, down!
- Keep in mind that different people will acclimatize at different rates. Make sure all of your party is properly acclimatized before going higher.
- Stay properly hydrated. Acclimatization is often accompanied by fluid loss, so you need to drink lots of fluids to remain properly hydrated (at least 3-4 quarts per day). Urine output should be copious and clear.
- Take it easy; don't over-exert yourself when you first get up to altitude. Light activity during the day is better than sleeping because respiration decreases during sleep, exacerbating the symptoms.
- Avoid tobacco and alcohol and other depressant drugs including, barbiturates, tranquilizers, and sleeping pills. These depressants further decrease the respiratory drive during sleep resulting in a worsening of the symptoms.
- Eat a high carbohydrate diet (more than 70% of your calories from carbohydrates) while at altitude.
- The acclimatization process is inhibited by dehydration, over-exertion, and alcohol and other depressant drugs.

Preventive Medications

Diamox (Acetazolamide) allows you to breathe faster so that you metabolize more oxygen, thereby minimizing the symptoms caused by poor oxygenation. This is especially helpful at night when respiratory drive is decreased. Since it takes a while for Diamox to have an effect, it is advisable to start taking it 24 hours before you go to altitude and continue for at least five days at higher altitude. The recommendation of the Himalayan Rescue Association Medical Clinic is 125 mg. twice a day (morning and night). (The standard dose was 250 mg., but their research showed no difference for *most* people with the lower dose, although some individuals may need 250 mg.) Possible side effects include tingling of the lips and finger tips, blurring of vision, and alteration of taste. These side effects may be reduced with the 125 mg. dose. Side effects subside when the drug is stopped. Contact your physician for a prescription. Since Diamox is a sulfonamide drug, people who are allergic to sulfa drugs should **not** take Diamox. Diamox has also been known to cause severe allergic reactions to people with no previous history of Diamox or sulfa allergies. Frank Hubbell of

SOLO recommends a trial course of the drug before going to a remote location where a severe allergic reaction could prove difficult to treat.

Dexamethasone (a steroid) is a prescription drug that decreases brain and other swelling reversing the effects of AMS. Dosage is typically 4 mg twice a day for a few days starting with the ascent. This prevents most symptoms of altitude illness. **It should be used with caution and only on the advice of a physician because of possible serious side effects.** It may be combined with Diamox. No other medications have been proven valuable for preventing AMS.

Acute Mountain Sickness (AMS)

AMS is common at high altitudes. At elevations over 10,000 feet (3,048 meters), 75% of people will have mild symptoms. The occurrence of AMS is dependent upon the elevation, the rate of ascent, and individual susceptibility. Many people will experience mild AMS during the acclimatization process. Symptoms usually start 12-24 hours after arrival at altitude and begin to decrease in severity about the third day. The symptoms of Mild AMS are headache, dizziness, fatigue, shortness of breath, loss of appetite, nausea, disturbed sleep, and a general feeling of malaise. Symptoms tend to be worse at night and when respiratory drive is decreased. Mild AMS does not interfere with normal activity and symptoms generally subside within 2-4 days as the body acclimatizes. As long as symptoms are mild, and only a nuisance, ascent can continue at a moderate rate. When hiking, it is essential that you communicate any symptoms of illness immediately to others on your trip. AMS is considered to be a neurological problem caused by changes in the central nervous system. It is basically a mild form of High Altitude Cerebral Edema (see below).

Basic Treatment of AMS

The only **cure** is either acclimatization or descent. Symptoms of Mild AMS can be treated with pain medications for headache and Diamox. Both help to reduce the severity of the symptoms, but remember, reducing the symptoms is not curing the problem.

Moderate AMS

Moderate AMS includes severe headache that is not relieved by medication, nausea and vomiting, increasing weakness and fatigue, shortness of breath, and decreased coordination (ataxia). Normal activity is difficult, although the person may still be able to walk on their own. At this stage, only advanced medications or descent can reverse the problem. Descending even a few hundred feet (70-100 meters) may help and definite improvement will be seen in descents of 1,000-2,000 feet (305-610 meters). Twenty-four hours at the lower altitude will result in significant improvements. The person should remain at lower altitude until symptoms have subsided (up to 3 days). At this point, the person has become acclimatized to that altitude and can begin ascending again. The best test for moderate AMS is to have the person “walk a straight line” heel to toe. Just like a sobriety test, a person with ataxia will be unable to walk a straight line. This is a clear indication that immediate descent is required. It is important to get the person to descend before the ataxia reaches the point where they cannot walk on their own (which would necessitate a litter evacuation).

Severe AMS

Severe AMS presents as an increase in the severity of the aforementioned symptoms, including shortness of breath at rest, inability to walk, decreasing mental status, and fluid buildup in the lungs. Severe AMS requires immediate descent to lower altitudes (2,000 - 4,000 feet [610-1,220 meters]).

There are two other severe forms of altitude illness, High Altitude Cerebral Edema (HACE) and High Altitude Pulmonary Edema (HAPE). Both of these happen less frequently, especially to those who are properly acclimatized. When they do occur, it is usually with people going too high too fast or going very high and staying there. The lack of oxygen results in leakage of fluid through the capillary walls into either the lungs or the brain.

High Altitude Pulmonary Edema (HAPE)

HAPE results from fluid buildup in the lungs. The fluid in the lungs prevents effective oxygen exchange. As the condition becomes more severe, the level of oxygen in the bloodstream decreases, and this can lead to cyanosis, impaired cerebral function, and death. Symptoms include shortness of breath even at rest, “tightness in the chest,” marked fatigue, a feeling of impending suffocation at night, weakness, and a persistent productive cough bringing up white, watery, or frothy fluid. Confusion, and irrational behavior are signs that insufficient oxygen is reaching the brain. One of the methods for testing yourself for HAPE is to check your recovery time after exertion. If your heart and breathing rates normally slow down in X seconds after exercise, but at altitude your recovery time is much greater, it may mean fluid is building up in the lungs. In cases of HAPE, immediate descent is a necessary life-saving measure (2,000 - 4,000 feet [610-1,220 meters]). Anyone suffering from HAPE must be evacuated to a medical facility for proper follow-up treatment.

High Altitude Cerebral Edema (HACE)

HACE is the result of swelling of brain tissue from fluid leakage. Symptoms can include headache, loss of coordination (ataxia), weakness, and decreasing levels of consciousness including, disorientation, loss of memory, hallucinations, psychotic behavior, and coma. It generally occurs after a week or more at high altitude. Severe instances can lead to death if not treated quickly. Immediate descent is a necessary life-saving measure (2,000 - 4,000 feet [610-1,220 meters]). There are some medications that may be prescribed for treatment in the field, but these require that you have proper training in their use. Anyone suffering from HACE must be evacuated to a medical facility for proper follow-up treatment.

Other Medications for Altitude Illnesses

Ibuprofen is effective at relieving altitude headache.
Nifedipine rapidly decreases pulmonary artery pressure and relieves HAPE.
Breathing oxygen reduces the effects of altitude illnesses.

Gamow Bag (pronounced ga´ mäf)

This clever invention has revolutionized field treatment of high altitude illnesses. The bag is basically a sealed chamber with a pump. The person is placed inside the bag and it is inflated. Pumping the bag full of air effectively increases the concentration of oxygen molecules and therefore simulates a descent to lower altitude. In as little as 10 minutes the bag can create an “atmosphere” that corresponds to that at 3,000 - 5,000 feet (915 - 1,525 meters) lower. After a 1-2 hours in the bag, the person’s body chemistry will have “reset” to the lower altitude. This lasts for up to 12 hours outside of the bag which should be enough time to walk them down to a lower altitude and allow for further acclimatization. The bag and pump weigh about 14 pounds (6.3 kilos) and are now carried on most major high altitude expeditions. Bags can be rented for short term trips such as treks or expeditions.

Cheyne-Stokes Respirations

Above 10,000 feet (3,000 meters) most people experience a periodic breathing during sleep known as Cheyne-Stokes Respirations. The pattern begins with a few shallow breaths and increases to deep sighing respirations then falls off rapidly. Respirations may cease entirely for a few seconds and then the shallow breaths begin again. During the period when breathing stops the person often becomes restless and may wake with a sudden feeling of suffocation. This can disturb sleeping patterns, exhausting the climber. Acetazolamide is helpful in relieving the periodic breathing. This type of breathing is **not** considered abnormal at high altitudes. However, if it occurs first during an illness (other than altitude illnesses) or after an injury (particularly a head injury) it may be a sign of a serious disorder.

Sources:

Mountain Sickness, Peter Hackett, The Mountaineers, Seattle, 1980.
High Altitude Illness, Frank Hubble, Wilderness Medicine Newsletter, March/April 1995.
The Use of Diamox in the Prevention of Acute Mountain Sickness, Frank Hubble, Wilderness Medicine Newsletter, March/April 1995.
The Outward Bound Wilderness First Aid Handbook, J. Isaac and P. Goth, Lyons & Burford, New York, 1991.
Medicine for Mountaineering, Fourth Edition, James Wilkerson, Editor, The Mountaineers, Seattle, 1992.
Gamow Bags - can be rented from Chinook Medical Gear, 100 Arapahoe Avenue, Suite 10, Boulder, CO 80302, 303-444-8683

Additional Reading:

Altitude Illness Prevention & Treatment, Steven Bezruchka, The Mountaineers, Seattle, 1994.
Going Higher, Charles Houston, Little Brown, 1987.
High Altitude Sickness and Wellness, Charles Houston, ICS Books, 1995.
High Altitude Medicine and Physiology, Ward Milledge, West, Chapman and Hall, New York, 1995.