CHAPTER – 6

Climate Stress

Climate Stress

Effects of Extreme Heat & Cold

There are many types of heat related and cold related illnesses that affect the performance of an athlete. The most famous heat related illnesses are:

1) Heat Stroke

2) Heat Fatigue

3) Heat Cramps

4) Heat Exhaustion

5) Hyperthermia

The most famous cold related illnesses are:

1) Frostbite

2) Hypothermia

Before discussing the heat related and cold related illnesses, it is so important to know about the dehydration. In a common sense, dehydration is known as lack of water in human body but its effects are so harmful if an athlete becomes a victim of dehydration.

Dehydration

Water is a critical element of the body, and adequate hydration is a must to allow the body to function. Up to 75% of the body's weight is made up of water. Most of the water is found within the cells of the body (intracellular space). The rest is found in the extracellular space, which consists of the blood vessels (intravascular space) and the spaces between cells (interstitial space).

Dehydration occurs when the amount of water leaving the body is greater than the amount being taken in. The body is very dynamic and always changing. This is especially true with water in the body. We lose water routinely when we:

- breathe and humidified air leaves the body (this can be seen on a cold day (the breath you see in the air is water that has been exhaled);
- sweat to cool the body; and
- eliminate waste by urinating or having a bowel movement.

In a normal day, a person has to drink a significant amount of water to replace this routine loss.

The formula for daily fluid requirements depends upon an individual's weight. Normally, fluid and weight are calculated using the metric system. If you would like to calculate your body weight and daily fluid requirements using the metric system, please use this formula.

- For the first 10kg (kilogram) of body weight the daily fluid intake required is 100cc per kg.
- For the next 10kg of body weight, the fluid required is an additional 50 cc/kg.
- For every additional kg of body weight, an additional 10cc/kg

The body is able to monitor the amount of fluid it needs to function. The thirst mechanism signals the body to drink water when the body is dry. As well, hormones like anti-diuretic hormone (ADH) work with the kidney to limit the amount of water lost in the urine when the body needs to conserve water.

Causes of Dehydration

Dehydration occurs because there is too much water lost, not enough water taken in, or most often a combination of the two.

- **Diarrhea:** Diarrhea is the most common reason for a person to lose excess amounts of water. A significant amount of water can be lost with each bowel movement. Worldwide, more than four million children die each year because of dehydration from diarrhea.
- **Vomiting:** Vomiting can also be a cause of fluid loss. It is lost in the vomitus, but it is difficult for a person to replace water by drinking it if they have nausea and are unable to tolerate liquids.
- **Sweat:** The body can lose significant amounts of water when it tries to cool itself by sweating. Whether the body is hot because of the

environment (for example, working in a warm environment), intense exercising in a hot environment or because a fever is present due to an infection; the body uses water in the form of sweat to cool itself. Depending upon weather conditions, a brisk walk may generate up to 16 ounces of sweat (a pound of water) to allow body cooling and that water needs to be replaced by the thirst mechanism signaling the person to drink fluids.

- **Diabetes:** In people with diabetes, elevated blood sugar levels cause sugar to spill into the urine and water then follows, which may cause significant dehydration. For this reason, frequent urination and excessive thirst are among the early symptoms of diabetes.

- **Burns:** The skin acts as a protective barrier for the body and is also responsible for regulating fluid loss. Burn victims become dehydrated because the damaged skin cannot prevent fluid from seeping out of the body. Other inflammatory diseases of the skin are also associated with fluid loss.

- **Inability to drink fluids:** The inability to drink adequately is the other potential cause of dehydration. Whether, it is the lack of availability of water, intense nausea with or without vomiting, or the lack of strength to drink, this, coupled with routine or extraordinary water losses can compound the degree of dehydration.

Signs and Symptoms of Dehydration

The body's initial responses to dehydration are thirst to increase water intake, and decreased urine output to try to conserve water loss. The urine will become concentrated and more yellow in color.

As the level of water loss increases, more symptoms can become apparent. The following are further signs and symptoms of dehydration.

- Dry mouth
- The eyes stop making tears
- Sweating may stop
- Muscle cramps
- Nausea and vomiting

- Heat Palpitations
- Light headedness (especially when standing)
- Weakness
- Decreased urine output

The body tries to maintain cardiac output (the amount of blood that is pumped by the heart to the body); and if the amount of fluid in the intravascular space is decreased, the body tries to compensate for this decrease by increasing the heart rate and making blood vessels constrict to try to maintain blood pressure and blood flow to the vital organs of the body. This coping mechanism begins to fail as the level of dehydration increases.

With severe dehydration, confusion and weakness will occur as the brain and other body organs receive less blood. Finally, coma, organ failure, and death eventually will occur if the dehydration remains untreated.

Dehydration Diagnose

Dehydration is often a clinical diagnosis. Aside from diagnosing the reason for dehydration, the health care practitioner's examination of the patient will assess the level of dehydration. Initial evaluations may include:

- **Mental status** tests to evaluate whether the patient is awake, alert, and oriented. Infants and children may appear listless and have whiny cries and decreased muscle tone.
- **Vital signs** may include postural readings (blood pressure and pulse rate are taken lying down and standing). With dehydration, the pulse rate may increase and the blood pressure may drop because the blood is depleted of fluid. People taking beta blocker medications for high blood pressure, heart disease, or other indications, occasionally lose the ability to increase their heart rate as a compensation mechanism since these medications block the adrenaline receptors in the body.
- **Temperature** may be measured to assess fever.
- **Skin** may be checked to see if sweat is present and to assess the degree of elasticity (turgor). As dehydration progresses, the skin loses its water content and becomes less elastic. The amount of sweat is often felt in the armpit or groin, two areas that tend to have moisture normally.

- **The mouth can become dry** and the health care practitioner may look or feel the tongue for fluid.

- **Infants** may have additional evaluations performed, including checking for a soft spot on the skull assessing the suck mechanism, muscle tone, or loss of sweat in the armpits and groin. All are signs of potential significant dehydration.

Dehydration Treatment

As is often the case in medicine, prevention is the important first step in the treatment of dehydration.

Fluid replacement is the treatment for dehydration. This may be attempted by replacing fluid by mouth, but if this fails, intravenous fluid (IV) may be required. Should oral rehydration be attempted, frequent small amounts of clear fluids should be used.

Clear fluids include:

- water or

- other replacement fluids that may contain electrolytes

Decisions about the use of intravenous fluids depend upon the health care practitioner's assessment of the extent of dehydration and the ability for the patient to recover from the underlying cause.

The success of the rehydration therapy can be monitored by urine output. When the body is dry, the kidneys try to hold on to as much fluid as possible, urine output is decreased, and the urine itself is concentrated. As treatment occurs, the kidneys sense the increased amount of fluid, and urine output increases. Medications may be used to treat underlying illnesses and to control fever, vomiting, or diarrhea.

Complications of Dehydration

Complications of dehydration may occur because of the dehydration, and/or because of the underlying disease or situation that causes the fluid loss.

Kidney Failure

Kidney failure is a common occurrence, although if it is due to dehydration and is treated early, it is often reversible. As dehydration progresses, the volume of fluid in the blood decreases, and blood pressure may fall. This can decrease blood flow to vital organs like the kidneys, and like any organ with a decreased blood flow; it has the potential to fail to do its job.

Coma

Decreased blood supply to the brain may cause confusion and even coma. If enough organs begin to malfunction, the body itself may fail, and death can occur.

Shock

When the fluid loss overwhelms the body’s ability to compensate, blood flow and oxygen delivery to the body’s vital organs become inadequate and cell and organ function can begin to fail.

Associated Complications

In heat-related illness, the body’s attempt to cool itself by sweating may cause dehydration to the point that muscles may go into spasm (heat cramps). It is often the muscles that are being stressed that will spasm (for example, in people who work outside in a hot environment, arm and leg muscles may spasm from lifting and moving heavy objects or equipment; in athletes, leg muscles may cramp from running).

As fluid loss increases, the patient may be so dehydrated that there is not enough water to sweat and heat exhaustion or heat stroke may occur. Heat stroke is a true medical emergency and the emergency response system should be activated immediately in this situation.

Electrolyte Abnormalities

In dehydration, electrolyte abnormalities may occur since important chemicals (like sodium, potassium, and chloride) are lost from the body through sweat. For example, patients with profuse diarrhea or vomiting may lose significant amounts of potassium, causing muscle weakness and heart rhythm disturbances. The doctor is often aware of the fluid and electrolyte balance in the dehydrated patient and may decide to monitor electrolyte levels by checking blood tests.

Some examples of symptoms caused by abnormal electrolyte levels include muscle weakness due to low potassium, heart rhythm disturbances due to either low or high potassium, and seizures due to low (hyponatremia) or high sodium (hypernatremia). In many patients with dehydration, the kidneys are able to compensate and regulate electrolyte levels.

It is reasonable to remember that dehydration does not occur quickly, and sometimes it may take hours to slowly correct the fluid deficit and allow the electrolytes to redistribute themselves appropriately in the different spaces in the body. If rehydration is done too slowly, the patient may remain hypotensive and in shock for too long. If done too quickly, water and electrolyte concentrations within organ cells can be negatively affected, causing cells to swell and eventually die.

Dehydration Prevention

- **Environment:** Dehydration due to the weather is a preventable condition. If possible, activities should not be scheduled in the heat of the day. If they are, adequate fluids should be available, and cooler, shaded areas should be used if possible. Of course, people should be monitored to make certain they are safe. Those working in hot environments need to take care to rehydrate often.

- **Exercise:** People exercising in a hot environment need to drink adequate amounts of water. People can become dehydrated in the ocean, lakes, or pools if the water and environmental temperatures are warm enough.

- **Age:** The young and elderly are most at risk because of poor temperature regulation systems. During heat waves, attempts should be made to check on the elderly in their homes. During the Chicago heat wave of 1995, more than 600 people died in their homes from heat exposure.

- **Heat related conditions:** Know the signs and symptoms of heat cramps, heat rash, heat exhaustion, and heat stroke. Preventing dehydration is one step to avoid these conditions.

Effects of Extreme Heat

1) Heat Stroke **2) Heat Fatigue**

3) Heat Cramps **4) Heat exhaustion**

5) Hyperthermia

Heat Stroke

Heat stroke is a form of hyperthermia, an abnormally body temperature with accompanying physical and neurological symptoms. Unlike heat cramps and heat exhaustion, two forms of hyperthermia that are less nature, heat stroke is a true medical emergency that can be fatal if not properly and promptly treated.

The body normally generates heat as a result of metabolism and is usually able for radiation of heat through the skin or by evaporation of sweat.

However, in extreme heat, high humidity, or vigorous exertion under the sun, the body may not be able to radiate the heat and the body temperature rises, sometimes up to 106°F (41.1°C) or higher. Another cause of heat stroke is dehydration. A dehydrated person may not be able to sweat fast enough to radiate heat which causes the body temperature to rise.

Those most susceptible to heart strokes include:

infants,

the elderly (often with associated heart diseases, lung diseases, kidney diseases, or who are taking medications that make them vulnerable to heat strokes),

athletes, and

outdoor workers physically exerting themselves under the sun.

Causes of Heat Stroke

Summer temperatures in the United States can climb above 100 degrees Fahrenheit (38 degrees Celsius), making heat stroke a big problem. Heat stroke can be fatal in many cases because it happens so quickly -- there is not much time to react.

Let’s say that it really is 100 degrees F outside. The human body wants to stay at 98.6 degrees F. The only way to stay at 98.6 is to sweat. By putting moisture on the skin and letting it evaporate, your body can cool itself very effectively and keep its temperature in the proper range.

Sweat works really well as long as there is plenty of water in your body -- it takes water to manufacture sweat. If you run out of water, sweat stops and your body rapidly overheats. It turns out that it is extremely easy to run out of water -

- your body can produce 0.5 gallons (2 liters) of sweat every hour in a hot environment. Unless you are drinking water at the same rate, you will dehydrate and then stop sweating.

Your internal thirst meter often is not sensitive enough when you need that much water (and it has been said that by the time you feel thirsty, you are already dehydrated), so you have to keep drinking regardless of how thirsty you feel.

Your body can produce a half gallon of sweat every hour in a hot environment.

The other thing that can lead to heat stroke is very high humidity, which keeps sweat from evaporating. In either case -- be it the lack of sweat or the inability to evaporate it -- the core body temperature can raise very quickly if it is hot outside. Once the core gets to 106 degrees F, it is a serious problem.

Symptoms include red, hot, dry skin (the body dilates skin blood vessels to try to release heat, making the skin red, and the dryness comes from lack of sweat), rapid heart rate and confusion. The rapid heart rate and confusion come from the high body temperature, which affects the brain.

Symptoms of Heat Stroke

Symptoms of heat stroke can sometimes like those of heart attack or other conditions. Sometimes a person experiences symptoms of heat exhaustion before progressing to heat strokes.
However, some individuals can develop symptoms of heat stroke suddenly and rapidly without warning.

Different people may have different symptoms and signs of heat stroke. **But common symptoms and signs of heat stroke include:**

high body temperature

the absence of sweating, with hot red or flushed dry skin

rapid pulse

difficulty breathing

strange behavior

confusion

disorientation

coma

Treatment of a Heat Stroke Victim

Victims of heat stroke must receive immediate treatment to avoid permanent organ damage. First and foremost, cool the victim.

Get the victim to a shady area, remove clothing, apply cool or tepid water to the skin (for example you may spray the victim with cool water from a garden hose), fan the victim to promote sweating and evaporation, and place ice packs under armpits and groins.

Monitor body temperature with a thermometer and continue cooling efforts until the body temperature drops to 101-102°F (38.3-38.8°C).

Always notify emergency services immediately. If their arrival is delayed, they can give you further instructions for treatment of the victim.

Heat Stroke Prevention

The most important measures to prevent heat strokes are to avoid becoming dehydrated and to avoid vigorous physical activities in hot and humid weather.

If you have to perform physical activities in hot weather, drink plenty of fluids (such as water and sports drinks), but avoid alcohol, caffeine, and tea which may lead to dehydration.

Your body will need of electrolytes (such as sodium) as well as fluids if you sweat excessively or perform vigorous activity in the sunlight for prolonged periods.

Take frequent breaks to hydrate yourself. Wear hats and light-colored, lightweight, loose clothes.

The only solution for heat stroke is to cool the person down. You can:

Try to get the person to drink water if the person is conscious.
Put the person's entire body in cool water.
Sponge with cool water onto the person's body.
Apply ice packs to the head, neck, armpits.
If not treated, heat stroke can be fatal in less than an hour.

Heat Fatigue

One such heat-related illness is heat fatigue. It is generally caused by fluid loss and responds well to dehydration and rest.

Because an inadequate diet or caloric intake is common with the summer athlete, it too should be evaluated when fatigue is experienced.

Like heat-related fatigue, heat cramps are also a result of insufficient fluid intake. These painful muscle spasms generally occur in hot and/or humid environments when the athlete overexerts him or herself.

Heat Fatigue, the second warning of a heat stress problem. Heat fatigue impairs our thought processes and causes us to make mistakes.

Signs & Symptoms of Heat Fatigue

Heat fatigue is a condition that occurs when your body cannot get rid of heat fast enough. Heat fatigue is a precursor to the more serious conditions of heat exhaustion and ultimately heat stroke. While heat fatigue is not a serious condition, heat stroke can require hospitalization and can even cause death if not treated. You should learn the symptoms of heat fatigue so you can treat them and not progress to a more serious condition.

Early Symptoms

As the name heat fatigue indicates, the first symptom will be feeling more tired than your activity merits. You may start to have a slight headache. You will find that these conditions will persist even if you take a short rest.

More Serious Symptoms

If you continue to participate in your activity, more serious symptoms may appear. You will find that you are sweating profusely. You may also find that your pulse rate is increasing rapidly. This may be accompanied by what feels like a pounding in your chest. You may also note that you are having a hard time catching your breath. Finally, you may become disoriented or confused. You may find that you are having trouble organizing your thoughts and difficulty expressing ideas to others.

Treatment of Heat Fatigue

As soon as you recognize the symptoms of heat fatigue, you should immediately try to rest in a cool shaded area. The best thing you can, drink is a sports drink that replaces salts. The salts will help your body to eliminate heat. It is very important that you rest. If you continue your activity you can eventually have a stroke and need to be hospitalized.

Sometimes those mistakes are FATAL. Learn to recognize the onset of heat fatigue. Take immediate steps to keep heat fatigue from causing an accident in your workplace.

NEVER allow a worker suffering from heat stress to leave work alone, or to be left unattended, unless a physician has evaluated them and says it’s OK.

Heat Cramps

Heat cramps are the intermittent, involuntary spasm of muscles that occur in an individual who is physically active (for example, working or exercising) in hot or humid weather. They are often associated with dehydration. Heat cramps usually affect the major muscles that are being stressed in the hot environment. Most often these are the thigh and leg (quadriceps, hamstrings) the core muscles (abdominal wall and back) and the arm muscles (biceps, triceps).

Heat cramps can also occur after the activity has been completed. For example, construction workers or roofers can develop cramps a few hours after their work shift is over.

Who is at risk for Heat Cramps?

While heat cramps tend affect those who are active in a hot environment, it should be noted that heat cramps are one of the symptoms associated with heat exhaustion as part of the spectrum of heat-related illness. Those individuals who have impaired temperature control mechanisms are at higher risk for developing heat-related illness. The body's most effective way of cooling itself is through sweat, and then the sweat evaporates into the environment. Those at most risk for heat cramps include:

- Infants and young children because they depend upon others to avoid the heat, dress them appropriately (avoid swaddling an infant since it prevents air movement over the skin to promote sweat evaporation) and provide enough fluid to drink

- The elderly because they may have underlying medical conditions, including heart and lung disease, and they can easily become dehydrated

- People who live by themselves or who cannot afford air conditioning are at higher risk for heat related illness

- A variety of medications can impair the body's sweat and heat regulation. Examples of drugs include medication prescribed for psychiatric conditions, including antipsychotic medications and tranquilizers. Over-the-counter cold medications and antihistamines also impair the body's temperature control mechanism.

- Alcohol consumption

Causes Heat Cramps

While it was thought that dehydration and electrolyte imbalance was the cause of muscle cramping, there are alternative theories as to why muscles cramp when the body is exposed to heat.

Since heat cramps begin after significant exercise in a hot environment where the affected individual begins sweating profusely, the theory was that muscles were depleted of water and sodium affecting their ability to contract and relax. Some new research suggests that as the muscles tire from excess activity and work, the ability for the muscle to regulate its own contraction is lost and this is called altered neuromuscular control. Regardless of the cause, the diagnosis and treatment for heat cramps remain the same.

Signs and Symptoms of Heat Cramps

Heat cramps are the earliest symptoms of the spectrum of heat-related illness. There is usually significant sweating with involuntary spasm of the large muscles in the body. The muscles that cramp are usually those that have been stressed. Runners and football players tend to get leg muscle cramps, but people who lift can get cramps in the muscles of the arms or the core trunk muscles like the abdominal muscles. Heat cramps usually begin after significant activity has occurred but they can occur after the activity has been completed.

Individuals with heat cramps tend only to have muscle cramps. If an individual has other signs or symptoms such as lightheadedness, weakness, nausea and vomiting, and headache he or she may be suffering from heat exhaustion. Affected individuals who have stopped sweating or who develop a fever and become confused may have heat stroke which is a true medical emergency.

Medical Care for Heat Cramps

Heat cramps can usually be treated when and where they occur. The affected individual should stop all activity and find a cool place to rest. The muscle cramps and spasms can be overcome by gently stretching the cramped muscle(s). Individuals can often replace their fluid loss by drinking a combination of water, sports drinks, or other electrolyte replacement solutions.

If the cramps cannot be controlled, the affected individual should seek medical care. There is no specific condition that differentiates heat cramps from heat exhaustion. The symptoms of these conditions form a spectrum from mild to moderate heat-related illness and symptoms can overlap. Severe heat cramps may actually be heat exhaustion. This is especially true if the person has nausea or vomiting and cannot replace the fluid loss, if they have significant fatigue and weakness, or of they have profuse sweating that does not stop when placed in a cooler environment.

Heat stroke is a true medical emergency and can be deadly. The body's ability to cool itself no longer functions, and as the temperature spikes, sometimes greater than 106 F (41 C), confusion and coma can occur. Emergency medical services should be activated (call 911) immediately if an individual is thought to have heat stroke. While waiting for help to arrive, the person should be moved to a cool place, clothes should be removed to help air circulate over the body, and cool water should be sprayed or sponged to attempt to cool the affected individual’s body.

Prevention is the key to avoiding heat cramps, or other heat-related illness. A person who has had heat cramps is more prone to developing them again. Some professions are at higher risk for heat cramps, for example, construction workers and roofers are potentially exposed not only to the heat from the sun but also from the radiant heat from the hot shingles and liners on the roof. It may be helpful to acclimate to the hot environment over a period of days to allow the body and its muscles to adapt to its water and electrolyte needs.

Heat Cramps diagnosis

The diagnosis of heat cramps is usually made after taking the patient's history. It is important to know about the environment where the person affected by heat cramps.

- How hot was it?
- How humid was it?
- Was there adequate air circulation?
- What activity was being performed and for how long?
- When did the cramps start? What muscles were involved?
- Was there associated sweating?
- Had the affected individual been acclimated to the hot environment?

One sign of heat cramps or a heat-related illness may be the color of urine. When the body becomes dehydrated, the kidneys conserve water and the result is concentrated, strong smelling, darker, yellow urine. If there is adequate water in the body the urine tends to be clear.

Often the physical examination will be relatively normal. The cramped muscles may be sore to touch and if there hasn't been adequate fluid replacement, the muscle may cramp again when taken through its normal range of motion. The physical exam may find signs of dehydration such as a dry mouth and tongue, lack of sweat in the armpits and groin, and decreased urine output. The vital signs can be a clue (for example, low blood pressure) and rapid heart rate (tachycardia). The affected person's blood pressure may be much lower upon standing compared to lying down (orthostatic hypotension).

Heat Cramps Treatment

Most treatment for heat cramps can occur before seeking medical care:

- stop the activity being performed,
- get to a cooler place,
- drink plenty of fluids, and

- gently, stretch the muscles that are cramping.

At the health care practitioner’s office or a hospital, medical care focuses on symptom relief.

It makes it difficult to replace body fluids if the patient has nausea or vomiting, so intravenous fluids may be administered. Anti-nausea medications may be used to control those symptoms.

Painful muscles may be treated with over-the-counter anti-inflammatory medications, such as ibuprofen or naproxen. Though it is a non-prescription medication, it is important to remember that there may side effects or interactions with prescription medications. When you are not certain which medication to consider, consult your health care practitioner as a helpful information resource.

Complications of Heat Cramps

There are few long-term consequences of heat cramps, however, once a person experiences heat cramps, they may be at risk for future episodes.

Heat Cramps prevention

Prevention is the best treatment for heat cramps. If possible, try to avoid working or exercising in the heat of the day, but if it is required, acclimating to the hot weather is important. Drink plenty of fluids and if the activity lasts a prolonged period of time, consider using sports or balanced electrolyte drinks. This is especially true if significant sweating occurs and electrolytes are lost through sweat. Try to rest in cool or shaded areas whenever possible.

Heat Exhaustion

The body cools itself most efficiently by sweating and then the sweat evaporating. Should sweating be unable to meet the cooling demands of the body, heat-related illness can occur. This is a spectrum of conditions with minor symptoms such as prickly heat or heat rash, progressing to heat cramps, then heat exhaustion, and finally to heat stroke, a life-threatening medical condition.

The line between each diagnosis is not sharply drawn. Heat cramps tend to involve involuntary spasm of the large muscles of the body while heat exhaustion has more systemic complaints. These can include profuse sweating, weakness, nausea, vomiting, headaches, and muscle spasms. The affected individual may be a low grade fever. Heat stroke is a life-threatening situation where the body's cooling system fails. The body temperature spirals out of control usually greater than 106F (41C), sweating stops and there are mental status changes like confusion, seizure, or coma.

Heat exhaustion occurs when a person exercises or works in a hot environment and sweating cannot dissipate the heat generated within the body. Often dehydration occurs because the person has not replaced the water lost by sweating.

Causes Heat Exhaustion

Heat exhaustion occurs when a person exercises and works in a hot environment and the body cannot cool itself adequately. Dehydration occurs with water loss from excessive sweating, which causes muscle cramps, weakness, and nausea and vomiting. This makes it difficult to drink enough fluid to replenish the body's water supply, and the lack of body water impairs further sweating, evaporation and cooling.

Relative humidity is an important factor in developing heat exhaustion. If the humidity is too high, sweat on the skin cannot evaporate into the surrounding air and body temperature cooling fails.

Risk Factors for Heat Exhaustion

Heat exhaustion usually affects people who are working or exercising in a hot environment. Those at risk for heat exhaustion include:

- Infants and young children are at risk because their temperature regulation mechanisms are not fully developed. They also are dependent upon others for water and appropriate clothing.
- The elderly are similarly at risk because of underlying medical conditions that limit the ability to sweat including poor circulation, skin changes, and chronic medication usage.
- Socioeconomic issues increase the risk of heat exhaustion if access to air conditioning is limited. During heat waves, large cities often open cooling centers to help minimize the risk of large numbers of people succumbing to heat-related illness.
- Certain medications such as antidepressants, antipsychotics, and tranquilizers may impair the ability of the body to sweat.
- Alcohol consumption

- The overweight or obese

The body has the ability to acclimate to hot weather but if heat waves come suddenly, or if a person travels from a cooler environment to a hot environment, the risk of heat exhaustion increases.

Symptoms of Heat Exhaustion

Individuals with heat exhaustion tend to have symptoms such as:

- profuse sweating,
- weakness,
- muscle cramps,
- headache, and
- nausea and vomiting.

As dehydration increases from the loss of body water, lightheadedness may occur and fainting (syncope) may occur especially, if the affected individual stands up quickly (orthostatic hypotension). A low grade fever also may be present.

Medical Care for Heat Exhaustion

Heat exhaustion usually can be treated at home as long as the affected individual can maintain proper hydration. Water, electrolyte replacement solutions or sport drinks are appropriate to consume. If nausea and vomiting prevent rehydration, the individual should seek medical attention.

Muscles cramps can be severe and if stretching and rehydration cannot relieve recurrent cramps, medical care may be necessary.

It is important to recognize that if the person stops sweating, becomes confused, or has a seizure, heat stroke, a life-threatening condition, may be developing. Emergency medical services should be activated immediately and move the affected individual to a cooler place, remove their clothing, and try to cool the body with cold compresses, ice, and oscillating fans.

Heat Exhaustion diagnose

Diagnosis of heat exhaustion is made by circumstantial evidence:

1. history (exercising or working in a hot environment)

2. symptoms (excess sweating, headache, weakness, nausea and vomiting)

3. physical examination (signs of dehydration)

Laboratory tests are not mandatory unless the health care practitioner is concerned about electrolyte imbalance or significant dehydration.

However, it is important for the health care practitioner to consider other diagnoses, since there are many infectious illnesses that accompany a fever, weakness, nausea and vomiting. This is especially the case in the elderly and very young. In these groups, heat exhaustion may be a diagnosis of exclusion, meaning that other more serious illnesses should be considered before settling on heat as the cause of the problem. Careful history and physical examination may be all that is needed.

Heat Exhaustion Treatment

- Cooling and rehydration are the cornerstones for treating heat exhaustion. The affected individual should stop their activity and then move from the hot environment to a cooler environment. The person may be placed in the shade or taken to an air conditioned environment (don't forget that cars have air conditioning). Clothes may be removed to help with air circulation across the body. Misting the skin with cool water also helps by stimulating evaporation and cooling the body.

- Rehydration is the next important step in treating heat exhaustion. This may be a challenge if the person begins to suffer from nausea and vomiting. Small sips of water, a mouthful at a time, might be tolerated even if some vomiting persists. Water, sports drink and other electrolyte replacement drinks are reasonable options.

- If oral rehydration fails or if symptoms persist, intravenous fluids may be required to replace the water loss because of the excessive sweating. Hydration continues until the patient begins to urinate, a signal that the kidneys have sensed that there is enough fluid in the body, and it no longer retains fluid.

- Muscles cramps and pain may be treated with over-the-counter medications like ibuprofen and acetaminophen.

Complications of Heat Exhaustion

Heat exhaustion is one part of the spectrum of heat-related illness, and symptoms should be reversible with treatment. However, some affected individuals do not recognize their symptoms and if they are not removed from the hot environment, cooled and rehydrated, the heat-related illness can progress to heat stroke, a life-threatening condition.

Individuals who have suffered from heat exhaustion are more prone to experience another episode and should be cautious when working or exercising in hot conditions.

Heat Exhaustion Prevention

Understanding one's environment is perhaps the most important step in preventing heat-related illness. If possible, strenuous activities should not be performed in excessively hot or humid environments. However, people often have to work in the heat of the day, or indoors in hot situations and need to make the effort to protect their bodies. These can include frequent breaks taken in a cooler area, adequate fluid intake, and slowing the pace of work to decrease heat generation within the body.

A person at risk for heat exhaustion should watch their urine output to monitor their hydration status. If the body is dehydrated, the kidneys will hold onto water, and make concentrated, strong smelling urine. If enough water is present, the urine will turn clear.

Acclimating to conditions allows the body to perform in situations that would otherwise be difficult. The body will make physiologic changes allowing it to cool more efficiently, if it has gradual exposure to hot conditions. Moving from a cool to very hot environment quickly increases the risk of developing heat related-illness symptoms.

Hyperthermia

Hyperthermia is an elevated body temperature due to failed thermoregulation. Hyperthermia occurs when the body produces or absorbs more heat than it can dissipate. When the elevated body temperatures are sufficiently high, hyperthermia is a medical emergency and requires immediate treatment to prevent disability or death.

The most common causes are heat stroke and adverse reactions to drugs. Heat stroke is an acute condition of hyperthermia that is caused by prolonged exposure to excessive heat or heat and humidity. The heat-regulating mechanisms of the body eventually become overwhelmed and unable to effectively deal with the heat, causing the body temperature to climb uncontrollably. Hyperthermia is a relatively rare side effect of many drugs, particularly those that affect the central nervous system. Malignant hyperthermia is a rare complication of some types of general anesthesia.

Hyperthermia can be created artificially by drugs or medical devices. Hyperthermia therapy may be used to treat some kinds of cancer and other conditions, most commonly in conjunction with radiotherapy.

Hyperthermia differs from fever in the mechanism that causes the elevated body temperatures: a fever is caused by a change in the body’s temperature set-point.

The opposite of hyperthermia is hypothermia, which occurs when an organism’s temperature drops below that required for normal metabolism. Hypothermia is caused by prolonged exposure to low temperatures and is also a medical emergency requiring immediate treatment.

Classification of Hyperthermia

Hyperthermia is defined as a temperature greater than 37.5–38.3 °C (100–101 °F), depending on the reference, that occurs without a change in the body’s temperature set-point.

The normal human body temperature in a healthy adult can be as high as 37.7 °C (99.9 °F) in the late afternoon. Hyperthermia requires an elevation from the temperature that would otherwise be expected. Such elevations range from mild to extreme; body temperatures above 40 °C (104 °F) can be life-threatening.

Signs and Symptoms of Hyperthermia

Hot, dry skin is a typical sign of hyperthermia. The skin may become red and hot as blood vessels dilate in an attempt to increase heat dissipation, sometimes leading to swollen lips. An inability to cool the body through perspiration causes the skin to feel dry.

Other signs and symptoms vary depending on the cause. The dehydration associated with heat stroke can produce nausea, vomiting, headaches, and low blood pressure. This can lead to fainting or dizziness, especially if the person stands suddenly.

In the case of severe heat stroke, the person may become confused or hostile, and may seem intoxicated. Heart rate and respiration rate will increase (tachycardia and tachypnea) as blood pressure drops and the heart attempts to supply enough oxygen to the body. The decrease in blood pressure can then cause blood vessels to contract, resulting in a pale or bluish skin color in advanced cases of heat stroke. Some people, especially young children, may have seizures. Eventually, as body organs begin to fail, unconsciousness and death will result.

Causes of Hyperthermia

Drugs

Some drugs cause excessive internal heat production, even in normal temperature environments. The rate of drug-induced hyperthermia is higher where use of these drugs is higher.

Many psychotropic medications, such as selective serotonin reuptake inhibitors (SSRIs), monoamine oxidize inhibitors (MAOIs), and tricyclic antidepressants, can cause hyperthermia. Serotonin syndrome often presents following exposure to multiple drugs. Similarly, neuroleptic malignant syndrome is an uncommon reaction to neuroleptic agents. These syndromes are differentiated by the other associated symptoms, such as tremor in serotonin syndrome and “lead-pipe” muscle rigidity in neuroleptic malignant syndrome.

Many illicit drugs, including amphetamines, cocaine, PCP, LSD, and MDMA can produce hyperthermia as an adverse effect.

Malignant hyperthermia is a rare reaction to common anesthetic agents (such as halothane) or a reaction to the paralytic agent succinylcholine. Malignant hyperthermia is a genetic condition, and can be fatal.

Personal protective equipment

People working in industry, the military and first responders must wear Personal Protective Equipment (PPE) to protect themselves from hazardous threats such as chemical agents, gases, fire, small arms and even Improvised Explosive Devices (IEDs). This PPE can include a range of hazmat suits, firefighting turnout gear, body armor and bomb suits, among many other forms. Depending on its design, PPE often ‘encapsulates’ the wearer from a threat and creates what is known as a microclimate, due to an increase in thermal resistance and decrease in vapor permeability.

As a person performs physical work, the body's natural method of thermoregulation (i.e., sweating) becomes ineffective. This is compounded by increased work rates, high ambient temperatures and humidity levels, and direct exposure to the sun. The net effect is that protection from one or more environmental threats inadvertently brings on the threat of heat stress.

Others

Others possible, but rare, causes of hyperthermia are thyrotoxicosis and the presence of a tumor on the adrenal gland, called a pheochromocytoma, both of which can cause increased heat production. Damage to the central nervous system, such as from a brain hemorrhage, status epilepticus, and other kinds of damage to the hypothalamus can also cause hyperthermia.

Hyperthermia Diagnosis

Hyperthermia is generally diagnosed in the presence of an unexpectedly high body temperature and a history that suggests hyperthermia instead of a fever. Most commonly this means that the elevated temperature has appeared in a person who was working in a hot, humid environment (heat stroke) or who was taking a drug for which hyperthermia is a known side effect (drug-induced hyperthermia).

The presence of other signs and symptoms related to hyperthermia syndromes, such as the extra pyramidal symptoms that are characteristic of neuroleptic malignant syndrome, and the absence of signs and symptoms more commonly related to infection-related fevers, are also considered in making the diagnosis.

If fever-reducing drugs lower the body temperature, even if the temperature does not return entirely to normal, then hyperthermia is excluded.

Prevention of Hyperthermia

In cases where heat stress is caused by physical exertion, hot environments or wearing protective equipment it can be prevented or mitigated by taking frequent rest breaks, staying hydrated and carefully monitoring body temperature. However, in situations demanding prolonged exposure to a hot environment or wearing protective equipment, a personal cooling system is required as a matter of health and safety. A variety of active or passive technologies personal cooling systems exist which can be categorized by their power sources and whether they are man or vehicle-mounted.

Due to the broad variety of operating conditions, a personal cooling system must meet specific requirements, such as the rate and duration of cooling, need for physical mobility and autonomy, access to power, and conformance with health & safety regulations. For example, active liquid systems operate on the basis of chilling water and circulating it through a garment that cools the skin surface area that it covers through conduction. This type of system has proven successful in certain Military, Law Enforcement and Industrial applications.

Bomb disposal technicians wearing bomb suits to protect against an Improvised Explosive Device (IED) use a small, ice-based chiller unit strapped to their leg with a Liquid Circulating Garment, usually a vest, worn over their torso to maintain their core temperature at safe levels. By contrast, soldiers traveling in combat vehicles can face microclimate temperatures in excess of 150 degrees Fahrenheit and require a multiple-user vehicle-powered cooling system with rapid connection capabilities. Requirements for Hazmat teams, the medical community and workers in heavy-industry will vary further.

Treatment of Hyperthermia

Treatment for hyperthermia depends on its cause, as the underlying cause must be corrected. Mild hyperthermia caused by exertion on a hot day might be adequately treated through self-care measures, such as drinking water and resting in a cool place. Hyperthermia that results from drug exposures is frequently treated by cessation of that drug, and occasionally by other drugs to counteract them. Fever-reducing drugs such as paracetamol and aspirin have no value in treating hyperthermia.

When the body temperature is significantly elevated, mechanical methods of cooling are used to remove heat from the body and to restore the body's ability to regulate its own temperatures. Passive cooling techniques, such as resting in a cool, shady area and removing clothing can be applied immediately. Active cooling methods, such as sponging the head, neck, and trunk with cool water, remove heat from the body and thereby speed the body's return to normal temperatures. Drinking water and turning a fan or dehumidifying air conditioning unit on the affected person may improve the effectiveness of the body's evaporative cooling mechanisms (sweating).

Sitting in a bathtub of tepid or cool water (immersion method) can remove a significant amount of heat in a relatively short period of time. However, immersion in very cold water is counterproductive, as it causes vasoconstriction in the skin and thereby prevents heat from escaping the body core.

In exertional heat stroke, studies have shown that although there are practical limitations, cool water immersion is the most effective cooling technique and the biggest predictor of outcome is degree and duration of hyperthermia. No superior cooling method has been found for nonexertional heat stroke.

When the body temperature reaches about 40 C, or if the affected person is unconscious or showing signs of confusion, hyperthermia is considered a medical emergency that requires treatment in a proper medical facility. In a hospital, more aggressive cooling measures are available, including intravenous hydration, gastric lavage with iced saline, and even hemodialysis to cool the blood.

Thermal Regulation and the Human Body

1. Human Body Temperature

The human body's core temperature varies from day to day, and from time to time, but these fluctuations are small, usually no more than 1.0ºC. Humans are homoeothermic and body temperature is regulated at about 37ºC +/- 1ºC. The thermoregulatory center in the hypothalamus plays a very active role in keeping body temperature in the normal range.

External (*climatic*) and internal (*metabolic*) heat sources influence body temperature. Heavy exercise, illness, and not only hot and humid but also cold and windy environments alter body temperature outside the normal range. Ambient temperature, humidity, air movement, and radiant heat from the sun, as well as warm and cold surfaces, contribute to climatic heat stress. Metabolic heat is produced by exercise.

Body temperature reflects a careful balance between heat production and heat loss. There is a continuous heat exchange between the body and the environment. Bi-directional routes for heat exchange are: **convection, conduction, and radiation**. There are also two uni-directional routes: metabolic heat increases the thermal load; evaporation decreases the load.

When the net heat storage is positive, body temperature will rise and when net heat storage is negative, it will go down.

2. Climatic Heat Stress

Air temperature alone is not an accurate index of climatic heat stress. Temperature and other important factors, including radiant energy, wind velocity and humidity, contribute to climatic heat stress. To determine the overall effect of these factors, a combination of measurements must be made. The Wet Bulb Globe Temperature (WBGT) index has been introduced to assess climatic heat stress. It consists of three thermometers: dry bulb, which measures air temperature; wet bulb, which measures relative humidity; and black globe, a measure of solar radiation. The difference between the wet and dry bulb temperatures indicates the environment's capacity for cooling by evaporation.

3. Metabolic Heat Stress

A large part of the energy that the body generates is degraded to heat. All body tissues produce heat that can be used to maintain body core temperature. When heat production exceeds the body's heat loss, body temperature rises. Intense exercise may increase the metabolic energy expenditure 20–25 times over resting levels.

No more than 25% of this energy is utilized for muscular movement — the remainder is heat, which the body must dissipate. Metabolic heat is transferred by convection from working muscles to the blood stream, and thence to the body's core. Without adaptive mechanisms, even moderate exercise would elevate body temperature by 1ºC every 5–6 minutes; thus, exercise would be limited to no more than 20–30 minutes before heat stress fatigue or life-threatening hyperthermia intervened.

In fact, the body is able to respond to a heat load through a variety of physiologic mechanisms: sweat rate, body and skin blood flow shifts, cardiac output, respiratory rate, and a sensation of heat intensity. Well-trained endurance athletes can sustain a core temperature of 39º–41ºC for prolonged periods.

The muscles' energy systems become more chemically effective with a small rise in muscle temperature. However, a critical thermal maximum is reached at 42ºC (108ºF), so there is a limited safety margin at intense levels of exercise. Heavier athletes run a higher risk of overheating than lighter athletes when exercising at the same rate.

A. Physiologic Responses

Core temperature is sensed by the hypothalamic thermoregulatory center. This center then sets off a number of circulatory adjustments in an effort to dissipate heat. Primarily this involves increasing cardiac output and redistributing blood from the visceral organs to the working muscles and skin.

During heat stress, skin blood flow may be up to 20-fold higher than at resting level. Sweat glands become more active for increasing evaporative heat loss.

B. Four mechanisms are responsible for heat exchange at the skin surface:

i. Conduction has a minimal effect on body heat transfer, as it depends upon direct contact between skin and a cooler object. Conduction could be utilized by immersion in water to cool or warm the body.

ii. Convection is responsible for transferring heat from working muscles and the skin surface. The circulatory system transports the heat generated in the active muscles to the surface of the body. The air around the body is in constant motion and it sweeps away the warmed air molecules on the skin surface.

It is dependent upon (a) the temperature differential between skin and the environment; and (b) the heat transfer coefficient, which varies with available body surface area and wind velocity. Minimal body fat and loose-fitting clothing enhance an athlete's convection potential.

Conduction and convection constantly remove body heat when air temperature is lower than skin temperature. Inversely, convection and conduction cause heat gain in a very hot environment.

iii. Radiation, including solar radiation and radiant heat from tracks, roads, and surrounding structures, can be a major contributor to an athlete's heat load. At rest, radiation is the primary method for discharging the body's excess heat. The heat is given off in the form of infrared rays. Radiation heat loss or gain depends upon the temperature gradient between the skin and the environment.

iv. Evaporation is the most important heat dissipation mechanism in warm environments. Though it accounts for only 20% of body heat loss at rest, more than 80% of body heat loss is achieved by evaporation when environmental temperature exceeds 20ºC (68ºF). Fit athletes can produce up to 30 ml of sweat per minute, but not all of this is available for heat elimination. Evaporative rate is determined by air velocity and the water vapor pressure gradient between the skin and the environment. This latter is determined by the **relative humidity** of the air. High humidity limits sweat evaporation and therefore, heat loss. Each liter of effective evaporated sweat removes 580 Kcal from the body. Evaporation plays a very important role in dissipating heat during exercise.

4. Acclimatization to Heat and Maximizing Heat Loss

Partial adaptation to heat stress occurs even with training at moderate temperatures, but full acclimatization can be achieved only with repeated bouts of exercise in the heat. At least five to ten days of training in the heat are required for full acclimatization. This should begin by training at a reduced intensity (60–70% of the usual load), so as to avoid heat-related disorders.
There are numerous adaptations that occur as a result of acclimatization to exercise in the heat:

a. Sweat rate in the skin areas exposed to heat is higher, thus enhancing evaporative capacity. An increased production of aldosterone can strongly stimulate the sweat glands and cause them to reabsorb more sodium and chloride.

b. Earlier onset of sweating leads to a lower skin temperature, improved core-skin temperature gradient, and less demand for blood flow to the skin. This latter provides improved muscle blood flow and oxygen supply.

c. Plasma volume is increased, due to an increased production of aldosterone and antidiuretic hormone (ADH). Aldosterone causes sodium and chloride retention by the renal and sweat tubules, and ADH increases renal water retention. Hence, there is a decrease in sweat sodium and chloride, but not potassium. More sodium is retained, which promotes water retention. Plasma and interstitial fluid volumes can increase 10–20%.

d. Body core temperature can be kept lower, as heat dissipation is more efficient.

e. Heart rate is lower at any given work load, as the core temperature is lower, plasma volume is higher, skin blood flow distribution is decreased, and there is improved stroke volume.

f. The perception of heat stress is reduced.

g. Onset of fatigue is delayed, as the rate of muscle glycogen utilization is decreased.

Men and women acclimatize equally well. Training in a hot, humid environment is more stressful than training in hot, dry conditions.

5. Cold Exposure Thermo-regulation and Minimizing Heat Loss

The body's hypothalamic set-point for temperature regulation is about 37ºC +/- 1ºC. A decrease in skin or core temperature signals the thermoregulatory center in the posterior hypothalamus to set off a number of mechanisms to increase heat production. These include:

a. Shivering: The involuntary muscular contractions in response to cold. This can cause a 4–5 fold increase in heat production. Shivering results in decreased muscular coordination and impairs performance.

b. Non-shivering thermo genesis: The sympathetic nervous system releases epinephrine and nor-epinephrine in response to cold exposure, causing anaerobic glycolysis and a release of free fatty acids from fat stores. This mechanism occurs in young children because of their rich brown fat.

c. Increased thyroxin production: Hypothalamic thyrotropin-releasing hormone (TRH) rises, stimulating TSH release and ultimately elevated thyroxin production to increase general metabolic rate.

d. Peripheral vaso-constriction: The sympathetic nervous system stimulates skin's smooth muscle contraction, thus shunting blood away from the skin and into deeper tissues.

The balance between heat loss and heat production is controlled by a number of factors. Generally, the greater the gradient between skin and environmental temperature, the greater the heat loss. However, a great number of anatomic and environmental factors affect the rate and degree of heat loss. For example, body size and body composition influence heat loss. Subcutaneous fat acts as an insulator. Smaller athletes such as children have a higher surface area/mass ratio, and may sustain greater heat loss. Clothing helps reduce heat loss.

The degree of heat loss also depends on air movement (convection), humidity, evaporation (sweating), and temperature. Wind velocity exacerbates heat losses from convection, radiation, and evaporation. This is known as the Wind Chill Effect.

Exercise in the cold can affect muscle function. Muscle functions best at a temperature of 40ºC. Cooling alters the nervous system and the muscle fiber's recruitment pattern. Muscle shortening velocity and power decrease when the temperature is lowered. Muscle glycogen utilization is higher during exercise in the cold. Epinephrine and nor-epinephrine secretion increases markedly. However, FFA may not rise as much as in a normal environment, as blood flow to subcutaneous fat areas is lower, and less FFA are mobilized.

So long as clothing is adequate and metabolic rate remains high, the body temperature and function can be maintained. However, as fatigue develops and exercise intensity (i.e., race pace) slows, heat production declines and hypothermia may develop.

Effects of Extreme Cold

The most famous cold related illnesses are:

1) Frostbite

2) Hypothermia

Frostbite and hypothermia are both cold-related emergencies. Frostbite occurs when tissues freeze. This condition happens when you are exposed to temperatures below the freezing point of skin. Hypothermia is the condition of developing an abnormally low body temperature.

Everyone is susceptible, even people who have been living in cold climates for most of their lives. Some groups of people at greatest risk for frostbite and hypothermia include people:

- who spend a great deal of time outdoors, such as the homeless, hikers, hunters, etc.;
- under the influence of alcohol;
- who are elderly without adequate heating, food, and shelter;
- who are exhausted or excessively dehydrated;
- who are mentally ill?

Frostbite

Frostbite occurs when there is freezing of body tissue, and it is the most serious of the cold weather-related injuries. Frostbite usually affects the hands, feet, nose, and ears, though other areas of the body may also be affected. This type of injury results from decreased blood flow and heat delivery to body tissues resulting in damaging ice crystal formation, which ultimately leads to cell death. Upon re-warming of the affected tissue, vascular damage and complex cellular metabolic abnormalities lead to tissue death. Damage to tissue is most pronounced when there is prolonged cold weather exposure, the affected area slowly freezes, and the subsequent re-warming process is slow. Repeated thawing and refreezing of the affected tissue is particularly damaging, and should be avoided.

Frostbite injuries can be classified as either superficial or deep, depending on the tissue depth of injury. **Superficial frostbite injuries** involve the skin and subcutaneous tissues, while **deep frostbite injuries** extend beyond the subcutaneous tissues and involve the tendons, muscles, nerves, and even bone. Superficial frostbite injuries have a better prognosis than deep frostbite injuries.

Frostbite Causes

Your body works to stay alive first, and to stay functioning second.

- In conditions of prolonged cold exposure, your body sends signals to the blood vessels in your arms and legs telling them to constrict (narrow). By slowing blood flow to the skin, your body is able to send more blood to the vital organs, supplying them with critical nutrients, while also preventing a further decrease in internal body temperature by exposing less blood to the outside cold.

- As this process continues and your extremities (the parts farthest from your heart) become colder and colder, a condition called the hunter's response is initiated. Your blood vessels are dilated (widened) for a period of time and then constricted again. Periods of dilatation are cycled with times of constriction in order to preserve as much function in your extremities as possible. However, when your brain senses that you are in danger of hypothermia (when your body temperature drops significantly below 98.6 F), it permanently constricts these blood vessels in order to prevent them from returning cold blood to the internal organs. When this happens, frostbite has begun.

- Frostbite is caused by two different means: cell death at the time of exposure and further cell deterioration and death because of a lack of oxygen.

    - In the first, ice crystals form in the space outside of the cells. Water is lost from the cell's interior, and dehydration promotes the destruction of the cell.

    - In the second, the damaged lining of the blood vessels is the main culprit. As blood flow returns to the extremities upon re-warming, it finds that the blood vessels themselves are injured, also by the cold. Holes appear in vessel walls and blood leaks out into the tissues. Flow is impeded and turbulent and small clots form in the smallest vessels of the extremities. Because of these blood flow problems, complicated interactions occur, and inflammation causes further tissue damage. This injury is the primary determinant of the amount of tissue damage that occurs in the end.

    - It is rare for the inside of the cells themselves to be frozen. This phenomenon is only seen in very rapid freezing injuries, such as those produced by frozen metals.

Signs and Symptoms of Frostbite

The signs and symptoms of frostbite depend on the extent and depth of tissue injury. Individuals with superficial frostbite may experience the following signs and symptoms to the affected area:

- pain,
- burning,
- tingling,
- numbness,
- pale colored skin,
- clear-colored skin blisters may develop, and
- firm-feeling skin with soft underlying tissue which can move over bony ridges.

As the degree of injury progresses (1st to 3rd) to involve deeper tissue structures, the signs and symptoms of deep frostbite can develop, this may include the following:

- complete loss of sensation,
- pale, yellowish, bluish, gray, or mottled skin color,
- formation of blood-filled skin blisters, and
- firm-feeling skin and underlying tissue, with the affected area feeling hard and solid.

With advanced frostbite injuries, the affected area can subsequently appear blackened and gangrene can develop, placing the affected individual at high-risk for infection.

Frostbite Diagnosis

The doctor will take a history in order to gather information on the events of the exposure and the medical condition prior to the cold injury.

- The doctor will take note of the vital signs, including temperature, pulse, blood pressure, and respiratory rate in order to exclude or treat any immediate life threats such as hypothermia or severe infection.

- X-rays may be performed, but they probably will be deferred until weeks later when they are more useful to the treatment team.

- The doctor will collect data in order to classify the injury as superficial or deep and the prognosis as favorable or poor.

    - A good prognosis is heralded by intact sensation, normal skin color, blisters with clear fluid, the ability to deform the skin with pressure, and the skin becoming pink when thawed.

    - Blisters with dark fluid, skin turning dark blue when thawed, and an inability to indent the skin with pressure indicate a poor prognosis.

Frostbite Treatment

- Keep the affected body part elevated in order to reduce swelling.

- Move to a warm area to prevent further heat loss. Avoid walking on frostbitten feet as this can lead to further damage.

- Note that many people with frostbite may be experiencing hypothermia. Saving their lives is more important than preserving a finger or foot.

- Remove all wet clothing and constrictive jewelry because they may further block blood flow.

- Give the person warm, nonalcoholic, non-caffeinated fluids to drink.

- Apply a dry, sterile bandage, place cotton between any involved fingers or toes (to prevent rubbing), and take the person to a medical facility as soon as possible.

- Never re-warm an affected area if there is any chance it may freeze again. This thaw-refreeze cycle is very harmful and leads to disastrous results.

- Also, avoid a gradual thaw either in the field or in the transport vehicle. The most effective method is to re-warm the area quickly. Therefore, keep the injured part away from sources of heat until you arrive at a treatment facility where proper re-warming can take place.

- Do not rub the frozen area with snow (or anything else). The friction created by this technique will only cause further tissue damage.

- Above all, keep in mind that the final amount of tissue destruction is proportional to the time it remains frozen, not to the absolute temperature to which it was exposed. Therefore, rapid transport to a hospital is very important.

Frostbite Prevention

The first step in preventing frostbite is knowing whether you are at increased risk for the injury.

- Most cases of frostbite are seen in alcoholics, people with psychiatric illness, car accidents or car breakdowns in bad weather, and recreational drug misuse.

- All of these conditions share the problem of cold exposure and either the unwillingness or inability of a person to remove himself or herself from this threat.

- Tobacco smokers and people with diseases of the blood vessels (such as those with diabetes) also are at increased risk because they have an already decreased amount of blood flow to their arms and legs.

- Homelessness, fatigue, dehydration, improper clothing, and high altitude are additional risk factors.

Although people don't always know or acknowledge these dangers, many of the dangers can be reduced or prevented.

- Dress for the weather.

- Layers are best, and mittens are better than gloves (keeps your warm fingers together while warming each other).

- Wear two pairs of socks with the inner layer made of synthetic fiber, such as polypropylene, to wick water away from the skin and the outer layer made of wool for increased insulation.

- Shoes should be waterproof.

- Cover your head, face, nose, and ears at all times.
- Clothes should fit loosely to avoid a decrease in blood flow to the arms and legs.
- Always travel with a friend in case help is needed.
- Avoid smoking and alcohol.

The very old, very young, those who are not in good physical condition and people with diabetes and anyone with vessel disease should take extra precautions.

Be especially wary of wet and windy conditions. The “feels like” temperature (wind chill) is actually much lower than the stated air temperature.

Hypothermia

The body maintains a relatively stable temperature whereby heat production is balanced by heat loss. Normally, the core body temperature (when measured rectally) is 98.6 degrees F or 37 degrees C. When the outside environment gets too cold or the body’s heat production decreases, hypothermia occurs (hypo = less + thermia = temperature). **Hypothermia is defined as having a core body temperature less than 95 degrees F or 35 degrees C.**

Body temperature is controlled in the part of the brain called the hypothalamus, which is responsible for recognizing alterations in the body temperature and responding appropriately. The body produces heat through the metabolic processes in cells that support vital body functions. Most heat is lost at the skin surface by convection, conduction, radiation, and evaporation. If the environment gets colder, the body may need to generate more heat by shivering (increasing muscle activity that promotes heat formation). But if heat loss is greater than the body's ability to make more, then the body's core temperature will fall.

As the temperature falls, the body shunts blood away from the skin and exposure to the elements. Blood flow is increased to the vital organs of the body including the heart, lungs, kidney, and brain. The heart and brain are most sensitive to cold, and the electrical activity in these organs slows in response to cold. If the body temperature continues to decrease, organs begin to fail, and eventually death will occur.

Medical Uses of Hypothermia

Cooling patients as part of their medical care is called induced or therapeutic hypothermia. While there is potential benefit of this practice for many conditions, at present, medical hypothermia is most often used in patients who have been resuscitated from cardiac arrest.

Medical scientists have shown that in patients who survived episodes of cardiac arrest due to ventricular fibrillation or ventricular tachycardia, cooling the body to 93.2 F (34 C) for 12-24 hours was associated with better survival rates and better neurologic outcomes.

Causes of Hypothermia

Hypothermia most often occurs because of prolonged exposure to cold weather. Inadequate clothing for conditions may not provide enough insulation for the body to prevent heat loss. Immersion in water hastens hypothermia, and just a few minutes in cold water may be fatal.

Risk Factors for Hypothermia

There are numerous factors that increase the risk of hypothermia:

- **Age:** The very young and very old may be less able to generate heat. The elderly with underlying medical conditions such as hypothyroidism or Parkinson's disease that limit the ability of the body to regulate temperature are less able to generate heat. Infants don't generate heat as efficiently, and with their relatively large head size compared to the body, they are at risk for increased heat loss by radiation.

- **Mental status:** Impaired judgment and mental function can lead to cold exposure. Patients with Alzheimer’s disease are prone to wander and become exposed to the elements.

- **Substance abuse:** Alcohol and drug abuse increase the risk of hypothermia in two ways. First, impaired judgment can lead to cold exposure. Additionally, alcohol and similar drugs can dilate blood vessels near the skin (vasodilation) and decrease the efficiency of the shivering mechanism, both of which decrease the body’s ability to compensate for cold exposure.

- **Medical conditions:** Underlying medical conditions can also lead to accidental hypothermia.

- Patients with hormonal abnormalities (thyroid, adrenal, pituitary), and those with peripheral neuropathy (due to diabetes or other conditions) or may be less able to feel the cold and generate a shivering response.

- Patients with spinal cord injuries, similarly, may not be able to adequately shiver.

- Patients who have suffered strokes or brain tumors may have impaired thermal regulation centers in the brain.

- Overwhelming infection and sepsis may both present with a lowered temperature instead of fever. People with diabetes who have very low blood sugar can appear unconscious and very cold.

- **Medications:** Some medications can increase the risk of hypothermia by limiting the shivering mechanism including some psychiatric medications.

Signs and Symptoms of Hypothermia

The body starts to slow as the temperature drops. Aside from the cold that is felt and the shivering that may occur, mental function is most affected initially. A particular danger of hypothermia is that it develops gradually, and since it affects thinking and reasoning, it may go unnoticed.

- Initial hunger and nausea will give way to apathy as the core body temperature drops.
- This is followed by confusion, lethargy, slurred speech, loss of consciousness, and coma.
- Often the affected person will lie down, fall asleep, and die. In some cases, the patient will paradoxically remove their clothes just before this occurs.

The decrease in brain function occurs in direct relationship to the decrease in body temperature (the colder the body, the less the brain function). Brain function stops at a core temperature of 68 F (20 C).

The heart is subject to abnormal electrical rhythms as hypothermia progresses. Ventricular fibrillation, a disorganized rhythm in which the heart is unable to pump, may occur at core temperatures below 82.4 F (28 C). This is one type of cardiac arrest.

Hypothermia Symptoms by Body Temperature			
Celsius	**Fahrenheit**	**Description**	**Symptoms**
37	98.6	No hypothermia	No hypothermia
Below 35	95	Definition of hypothermia	N/A
32 to 35	89.6 to 95	Mild hypothermia	Shivering Lethargy, apathy, confusion Rapid heart rate
28 to 32	82.4 to 89.6	Moderate hypothermia	Shivering stops Increased confusion or delirium Slowing heart rate; may be come irregular
Below 28	Below 82.4	Severe hypothermia	Coma Ventricular fibrillation May appear deceased
20	68		Brain activity stops

Hypothermia Diagnosis

Usually the diagnosis of hypothermia is evident because of circumstances. The patient is found outside in the cold, and either the patient or a companion can explain the situation. Sometimes, it is less apparent, especially if the patient is found indoors and is confused.

The body core temperature needs to be measured; this may be done with a special rectal thermometer that is designed for very low readings or with a bladder catheter equipped with a temperature probe. Oral or ear temperatures are not accurate in very cold patients.

Aside from diagnosing hypothermia, the underlying cause needs to be ascertained. While some causes may be readily apparent, there may be confounding factors. Intoxicated patients may have fallen and sustained a head injury. The elderly patient may have diabetes and have a low blood sugar. While it is important to treat the low temperature, the individual medical history of the patient needs to be considered and appropriate diagnostic tests performed to rule out any associated injuries or conditions.

Hypothermia Treatment

Care for the hypothermic patient begins when the person is found.

- First aid should be initiated.
- The patient should be removed from the cold environment and placed in a warm shelter away from the wind. Wet clothing should be removed and replaced with a warm, dry covering including head covering.
- Emergency medical services should be activated as soon as possible.
- The patient’s breathing should be monitored, and if it becomes dangerously slow or stops, CPR should be initiated.
- Rough handling or jerking of the patient should be minimized if the person is lethargic or unconscious. This may cause an irritable heart to develop electrical abnormalities such as ventricular fibrillation.
- Re-warming should be started by applying warm compresses to the chest, neck, and groin. Hot water should not be used. Because there may be associated frostbite, direct heat should not be applied to the body. Instead, warm blankets and body to body contact may be needed as a first aid measure.
- The severity of hypothermia and the patient's mental status and ability to function will determine what further treatment is necessary. Passive re-warming with warm clothing in a warm environment may be all that is required for a conscious person who is shivering.
- Active re-warming may be considered for those who are colder, showing signs of confusion, or have other medical conditions that need attention. Warmed intravenous fluids, warming blankets, and warmed humidified air may be provided in the hospital.
- More aggressive core re-warming may include infusing warm fluids into the stomach or bladder, irrigating warm solutions into the chest or abdominal cavity, and in some situations, placing the patient on dialysis or heart bypass to re-warm the body.

Each of the above options needs to be specifically tailored to the patient's situation and presentation.

One axiom that continues to be followed in emergency medical care is that a patient is not dead until they are "warm and dead." Vital signs like breathing, heartbeat, and blood pressure may be difficult to detect in a severely hypothermic patient, and often efforts are made to try prolonged resuscitation until the patient is warmed. Occasional stories are reported in the press about patients, especially children, who have been resuscitated from severe hypothermia due to immersion in cold water.

Call a Doctor for Hypothermia

In parts of the country where a cold environment is a way of life, many people have minor exposures to the elements and do not need to seek medical care.

Because the brain is so sensitive to cold, medical care should be accessed if the mental status of the patient is affected. This is manifested by a wide range of behaviors, from the person who is mildly confused to the patient who is comatose. As well, it is important to remember that there may be an underlying medical condition that led to the hypothermia that may need to be addressed.

Hypothermia Prevention

While medical emergencies can occur in association with hypothermia (for example, people with diabetes who develop very low blood sugar), most cases of hypothermia are preventable with good planning and good judgment.

- Wear appropriate clothing for the weather.
- Prepare for the worst when enjoying an outdoor activity if cold weather is a possibility. If choosing to drink alcohol, make certain there is a sober person who will be responsible for your safety.
- For the elderly and the poor who may not have adequate home heating in the winter, communities should insure that safe housing is available. Shut-ins should have routine social service or family contacts.

High Altitude

Training or exercise at altitude may help athletes gain a competitive edge at sea level; altitude exposure also presents problems to athletes and these could possibly cancel out benefits.

All athletes seek a competitive advantage. Although the benefits of some interventions (like training for example) are clear, most strategies are less well proven. Altitude is no exception to this. Training at high altitude has been used by competitive athletes as a means of improving their potential. Additionally, altitude training is usually expensive and loaded with logistical problems.

High Altitude effects on Exercise

Altitude also has serious effects on someone not in shape for the experience. The air is thinner, which means the oxygen pressure is lower at high altitudes. The heart must work harder by beating faster to meet the body's oxygen needs. Sudden changes in altitude and workload can be life-threatening.

Distress symptoms during exercise include shortness of breath, rapid breathing, faster heart rate, poor athletic performance, and early fatigue. Slow your pace if climbing or hiking up to higher ground. Avoid hard workouts for a few days upon arrival at a higher altitude.

Other problems may include headache, agitation, nausea and vomiting, a general ill feeling, loss of hunger, and an inability to sleep. The body needs time to adjust to a high altitude. It does so by making more red blood cells to carry more oxygen. It takes about 2 to 3 weeks for the body to fully adjust to moderate altitude. Return to a lower altitude if the symptoms do not go away.

Rare but serious problems may occur when progressing too fast from your normal altitude to a higher one. Watch for extreme shortness of breath, rapid breathing and pulse and weakness. Chest pain, severe headache and confusion may require immediate medical care.

Fit people are less likely to feel the effects of higher altitudes. Train lightly when first relocating to higher altitudes. Allow your body several days to adapt to the new altitude. Take time to rest and drink plenty of fluids. Return to a lower altitude if symptoms occur and do not improve. Medical care may be needed at that time.

Effects on Training at Altitude

Many athletes live at altitude, and others elect to train there in hopes of enhancing their performance at lower elevations. However, maximal aerobic capacity and sub-maximal aerobic training pace decrease at altitude, especially above 2500–3000 m. Prolonged stays at altitude may be detrimental to high-intensity endurance performance, so altitude training should be interspersed with periods near sea level.

A programme of altitude exposure (hypoxia) interspersed with periods of near-sea-level exposure to permit intense training, when carried out for 3–4 weeks, enhances sea-level performance. This is most likely due to an erythropoietin-induced increase in red cell mass and aerobic capacity.

Benefits of High Altitude

High altitude could theoretically improve an athlete's capacity to exercise. Exposing the body to high altitude causes it to acclimatize to the lower level of oxygen available in the atmosphere. Many of the changes that occur with acclimatization improve the delivery of oxygen to the muscles -the theory being that more oxygen will lead to better performance.

For any type of exercise lasting longer than a few minutes, the body must use oxygen to generate energy. Without it, muscles simply seize up and can become damaged. This type of exercise is called aerobic exercise, meaning with oxygen.

The body naturally produces a hormone called erythropoietin (EPO) which stimulates the production of red blood cells which carry oxygen to the muscles. Up to a point, the more blood cells you have, the more oxygen you can deliver to your muscles. There are also a number of other changes that happen during acclimatization which may help athletic performance, including an increase in the number of small blood vessels, an increase in buffering capacity (ability to manage the buildup of waste acid) and changes in the microscopic structure and function of the muscles themselves.

Problems of High Altitude

However, acclimatization to high altitude is not simple, and there are a number of other effects that could cancel out the above benefits. For example the increase in red blood cells comes at a cost - having too many blood cells makes the blood thicker and can make blood flow sluggish. This makes it harder for your heart to pump round the body, and can actually decrease the amount of oxygen getting to where it is needed.

At very high altitudes (greater than 5000m), weight loss is unavoidable because your body actually consumes your muscles in order to provide energy. There is even a risk that the body's resistant system will become weakened, leading to an increased risk of infections, and there may be adverse changes in the chemical make-up of the muscles. Additionally, the body cannot exercise as intensely at altitude. This results in reduced training intensity, which can reduce performance in some sports. At very high altitudes, further problems are encountered: loss of hunger, inhibition of muscle repair processes and excessive work of breathing. On top of this, there is the problem of altitude illnesses, which can dramatically reduce the capacity to be active at altitude, or foreshorten the exposure to high altitude altogether.

High Altitude Techniques

Various techniques have been devised in order to expose the athlete to the beneficial effects of high altitude whilst not reducing their ability to train effectively. These have been labeled 'Live High – Train High, 'Live Low – Train High' and 'Live High – Train Low'. The typical altitudes used are around 2000-2500m, which in itself reduces the risk of some of the unhelpful effects of altitude exposure. The 'low' altitudes may not actually be at sea level but could be 1250m, for example. However, the difference between the two altitudes is significant enough to have an effect on training.

Live High – Train High

Maximum exposure to altitude. Evidence of a positive effect at sea level is controversial, and there is less support for this method amongst experts.

Live Low – Train High

The idea behind this regime is that the athlete is exercising in a low oxygen environment, whilst resting in a normal oxygen environment. There have been some interesting findings suggesting that this technique might work, but there are no good studies showing that the technique makes any difference to the ultimate competitive performance of the athlete at sea-level. Additionally, training intensity is reduced so some athletes may find that they actually lose fitness using this regime.

Live High – Train Low

The theory behind this regime is that the body will acclimatize to altitude by living there, whilst training intensity can be maintained by training at (or near) sea level.

Hence, the beneficial effects of altitude exposure are harnessed whilst some of the negative ones are avoided. However, residence at altitude must be for more than 12 hours per day and for at least 3 weeks. With this technique, improvements in sea-level performance have been shown in events lasting between 8 and 20 minutes. And interestingly, athletes of all abilities are thought to benefit.

Breathing at High Altitude

Everyone breathes faster and deeper (hyperventilates) at high altitude – it is necessary to do this in order to survive. The function of the lungs is to expose blood to fresh air, and breathing faster essentially increases the flow of fresh air past the blood. This means that whenever an oxygen molecule is taken away by the blood, it is quickly replaced by a fresh one. This means that there is always more oxygen available to be taken up into the blood.

Carbon Di Oxide (CO_2) is constantly produced by the body and the lungs remove it by allowing it to diffuse into the fresh air in the lungs. Increasing the flow of fresh air through the lungs, by hyperventilating, increases the rate at which CO_2 is lost. This happens for the same reason that wet laundry dries faster in a strong wind: the wind blows away the water vapour, so there is space for more water to evaporate. You can see how hyperventilating changes the level of carbon dioxide in the blood using the altitude oxygen calculator. Simply increase the number of breaths taken per minute. These processes have important effects on the binding of oxygen to haemoglobin in the blood.

High Altitude Effects on Sport Performance

Athletes will typically experience two different types of effects upon their ability to perform at high-altitude venues. The first is physiological, determined by the body's reaction to a thin, less-oxygenated atmosphere. The second effect is impacts that are sport-specific but equally pronounced: how the physical components of a particular sport are altered in high altitude performance.

High altitude is the description given any locale where the athlete begins to experience the limitations that a reduced oxygen intake place upon the body. Scientists generally classify elevations of 6,500 ft (2,000 m) as high altitude because of the pronounced difference in oxygen content; the effect of altitude may be experienced at lower elevations. The human body has a built-in mechanism to counter the effects of low oxygen in the immediate atmosphere. When the body senses that it is not receiving its accustomed level of oxygen, it determines that it must produce a greater number of erythrocytes (red blood cells), which carry oxygen to the bloodstream. The increase of transportation capability means that the body will be optimizing the amount of available oxygen.

The process by which erythrocytes are increased commences with the release of a hormone in the kidneys known as erythropoietin (EPO), which acts as a trigger to the production of erythrocytes centered in the bone marrow of the long bones of the body, primarily the femur (thigh). The acclimatization of the body to an oxygen-reduced environment is not instantaneous; high altitude adaptations begin immediately. An athlete will be as much as 75% accustomed to the thin air within 7-10 days of exposure to the conditions, with full acclimatization within 15-20 days.

High altitude training is a proven effective performance-enhancing tool, as the ability of an athlete to utilize greater amounts of oxygen will naturally support improved capabilities. The physiological benefits of high altitude training continue for between one to three months after the return of the athlete to sea-level training conditions.

The physics of high altitude sports performance and the advantages derived by the competitors in such venues are as varied as they are emphatic. The 1968 Olympics held in Mexico City were the first games staged at a high altitude (7,349 ft [2,300 m]), and the number of world records set was indicative of the impact of the thinner air on performance. American Bob Beamon set a long jump event record of 29 ft 2 inch (9.3 m), which shattered the then-existing standard by over 2 ft (.6 m), in a discipline where records are almost always broken in increments of fractions of an inch. Lee Evans of the United States set a world record of 43.86 seconds in the 400 m race, a mark that stood for almost 20 years. Records fell in almost every track event from the 100 m to the 1500 m; the longer distances posed difficulties for the athletes that were not entirely accustomed to the high altitude effects.

Intense research conducted in the wake of the world record onslaught at Mexico City confirmed that the reduced wind resistance and drag upon the competitors' bodies in the thin air permitted the athletes to move with greater efficiency. So long as the event did not involve prolonged duress to the aerobic energy system and its dependency upon maximal amounts of oxygen, an athlete could expect better performances in higher altitude. Not only does the moving body encounter reduced air resistance, any objects thrown, such as a discus or javelin, would tend to travel further as well.

The effects of high altitude are well known in different professional team sports. The visiting soccer team to venues such as Mexico City and La Paz, Bolivia (where the stadium attitude of over 11,000 ft [3,400 m], is the highest in international soccer), will likely not be able to perform at a maximum level unless it has trained at altitude. To a lesser but measurable degree, Denver, Colorado's Mile High Stadium, situated at 5,500 ft above sea level (1,700 m), has been regarded as a difficult competitive environment for visiting American football teams since it was opened.

Altitude is a significant performance factor in the game of baseball, especially with respect to how far a batted ball will carry in the thinner air. The professional baseball stadium in Denver is known as a hitter's park for this reason, as are a number of National Collegiate Athletic Association (NCAA) venues in the western United States that are constructed at elevations greater than 5,000 ft (1,550 m). Research conducted at various times has concluded that a baseball will travel between 3% and 7% further in air at these altitudes than a similarly struck ball at sea level, assuming that the temperature is constant. An object will travel further in warmer, less dense air than it will in cold air.

In the sports of both American football and rugby, a ball can be kicked further in thinner high altitudes than at sea level. American football coaches and their specialist field goal kickers will be inclined

Factors effecting Performance at High Altitude

A. Environmental Conditions at Altitude

B. Physiological Responses to Altitude

C. Adaptations to Chronic Altitude

D. Preparation for Competition at Altitude

Altitude adversely affects performance in aerobic events (i.e., those lasting more than two minutes), because the partial pressure of oxygen decreases as barometric pressure falls. This leads to a decline in pulmonary diffusion of oxygen into the blood. A measurable effect on maximal oxygen uptake (VO2 max) can be seen at elevations as low as 1524 m (5000 ft).

A. Environmental Conditions at High Altitude

1. Atmospheric Pressure

Atmospheric pressure decreases as altitude increases, but the percentage of gases in the air remains constant. Air always contains 20.93% oxygen, 0.03% carbon dioxide, and 79.04% nitrogen. The pressure that oxygen molecules exert (PO2) is directly related to the atmospheric pressure (Pb). This change in the partial pressure of oxygen directly affects the transfer of oxygen between the lungs and the blood, and between the blood and the tissues.
Table: Changes in the partial pressure of oxygen with increasing altitude.

Altitude	**Atmospheric Pressure (Pb) (mm)**	**Partial Pressure of Oxygen (PO2) (mm)**
0(sea level)	760	159.2
1000	674	141.2
2000	596	124.9
3000	526	110.2

2. Air Temperature

Air temperature decreases about 1º C for every 150 m of ascent. This lower temperature also reduces the relative humidity of the air, and increases water losses by evaporation from the skin and the lungs. The increased respiratory rate and loss of respiratory water in dry air can lead rapidly to dehydration, especially during exercise.

3. Solar Radiation

Solar radiation increases at altitude, as less ultraviolet light is blocked by the reduced atmosphere and the lower water vapour pressure.

B. Physiological Responses to High Altitude

1. Respiratory Responses

a. Ventilation

As the partial pressure (PO_2) of oxygen decreases, more air must be taken in to provide adequate tissue oxygenation. This increase in ventilation reduces the amount of alveolar and blood carbon dioxide, leading to respiratory alkalosis. The kidney compensates by excreting more bicarbonate ion, decreasing the blood's buffering capacity and reducing the alkalosis (compensated respiratory alkalosis).

b. Pulmonary Oxygen Diffusion

Oxygen diffusion across the alveolar-capillary membrane is dependent upon alveolar PO_2. This decreases as altitude increases, leading to a decrease in oxy-hemoglobin saturation. At sea level hemoglobin is 98% saturated, but this falls to 92% at 2400 m (8000 ft).

c. Muscle Oxygen Gas Exchange

The pressure gradient between blood and muscle oxygen concentration is 74mm Hg at sea level (94mm–20mm). This gradient is the major factor responsible for driving tissue oxygenation. At 2400 m the arterial PO_2 is about 60mm Hg, while tissue PO_2 remains at 20mm Hg, a gradient of only 40mm Hg, or a decrease of nearly 50%.

2. Cardiovascular Responses

a. Blood Volume

Plasma volume decreases soon after altitude exposure, and levels off after a few weeks. This leads to an increased red cell concentration (hematocrit), aiding oxygen delivery to tissues. Plasma volume is gradually restored, and erythropoietin from the kidney stimulates red cell production.

b. Cardiac Output

Cardiac output must increase at altitude to compensate for the reduced PO_2 and decreased oxygen delivery to tissues. Initially this is accomplished by an increase in heart rate, as stroke volume is lower due to the decreased plasma volume. After a few days, tissue oxygen extraction improves (increased a-v O_2 difference) and this reduces the cardiac demands. At maximal workloads, maximal stroke volume, heart rate, and tissue oxygen diffusion are reduced, thus total maximal VO_2 and aerobic work are diminished.

3. Metabolic Adaptations

As oxidative pathways are limited at altitude, there is a shift toward anaerobic energy sources. At any given work level, lactic acid production is higher than at sea level. However, at maximal workloads lactic acid is lower, possibly because work levels are too low to maximally activate all energy systems.

4. Maximal Oxygen Uptake

Maximal oxygen uptake measures the ability of the body to take in, transport, and utilize oxygen. It decreases as altitude increases, but does not begin to fall until atmospheric PO_2 drops below 125 mm Hg. This occurs at an altitude of about 1600 m (5250 ft). VO_2 maximum is related to the decline in the barometric pressure and the partial pressure of oxygen (PO_2). VO_2 maximum decreases 11% for each 1000 metres above the 1600 metre level.

C. Adaptations to Chronic High Altitude

1. Blood

Erythropoietin stimulates red cell production, and eventually a higher hemoglobin and hematocrit. Adequate dietary iron is essential to meet this demand for increased erythropoietin.

2. Muscle

Muscle cross-sectional area may decrease with chronic altitude exposure, though capillary density increases to deliver blood to the tissues. At very high altitudes (over 2500 m), levels of muscle enzymes decline, so that muscles are less able to generate ATP aerobically or anaerobically.

3. Cardio-respiratory

Ventilation is stimulated by the hypoxia of altitude. This causes carbon dioxide removal and respiratory alkalosis. Bicarbonate is excreted and remains low, decreasing buffering capacity.

Muscle oxygen uptake decreases at altitude, and improves little with prolonged exposure. This may be due to the profound hypoxia that occurs during exercise at altitude and the consequent inability to train at an adequate intensity and volume.

D. Preparation for Competition at High Altitude

Many major competitions, including the Olympic Games (1968) and the World Championships (1997) are conducted at altitude. While this provides an advantage for sprinters, hurdlers, and jumpers, endurance events of 800 metres and longer are adversely affected. Therefore, a period of adaptation to altitude is essential in preparation for competition, if one lives at sea level. There is still much to be learned about optimal preparation, but a few principles seem to be well accepted:

1. The adaptation period at altitude should be at least 3 or 4 weeks prior to the start of competition.

2. Athletes should be in good general health, free of medical and orthopedic problems, and not iron deficient prior to beginning altitude training. Iron supplementation should be used if ferritin levels are low.

3. Training volume, intensity, nutrition, and health should be carefully monitored during the training and competition processes.

    a. During the first week, aerobic adaptation should be stressed. Training volume should be moderate, about 75–80% of sea-level loads.

    b. Intensity should increase in the second week, with mixed aerobic and anaerobic sessions.

    c. During week three, emphasis is on maintaining speed, with aerobic work at the highest levels possible. Intensity of runs may be maintained by increasing rest time between interval runs.

    d. Week four is for tapering and recovery prior to the start of competition.

Acclimatization at High Altitude

Acclimatization to altitude involves breathing faster & more deeply and the heart pumping more blood to the brain & muscles. If you go to high altitude quickly, your body has to adapt to the thinner air and the lack of oxygen. Two important things happen almost immediately.

You breathe faster and more deeply to maximize the amount of oxygen that can get into the blood from the lungs and your heart pumps more blood to increase the supply of oxygen to your brain and muscles.

You can demonstrate how important breathing harder is by using our high altitude oxygen calculator. Some people include breathlessness during exercise as a component of altitude sickness, but this is misleading. Breathing harder is a normal response to the shortage of oxygen but it does have other effects on the body.

The sensation of breathlessness usually indicates that the lungs are having difficulty in supplying the body's demand for oxygen. Therefore, if a climber is walking too fast for his lungs to keep up, he feels breathless and slows down. However, breathlessness at rest indicates that the lungs are having difficulty in supplying even the small amount of oxygen that the body needs when it is resting. This is an ominous sign at high altitude and may indicate the development of high altitude pulmonary oedema (HAPE). Any climber who is breathless at rest at high altitude should descend to a safer altitude as soon as possible. If you have had HAPE, please register with the online HAPE database.