

Introduction to Exercise Physiology & Sports Performance

Prof. Anup Krishnan

IIT Madras

Lecture – 28

Acclimation to Heat and Cold

Good morning, ladies and gentlemen and welcome back to the course on exercise physiology and sports training. This is week 6 and I will be covering lecture 3. I am Col. Dr. Anup Krishnan and I will be your instructor for this lecture. So today we will be talking about a very important topic that is acclimation to exercise in heat and cold.

We are regularly familiar with the term acclimatization. However, as we will learn acclimation and acclimatization have certain subtle differences and we will call it by the terms which has been referred to as in this reference book. So, I will be covering this topic under the following headings. Introduction, exercise in heat, effects of heat acclimation, achieving and maximizing heat acclimation, factors affecting body heat loss, exercise in cold, cold acclimation and conclusion.

Let us start with exercise in heat. Repeated exercise in the heat causes a series of rapid adaptations that enable us to perform better and safely in hot conditions. Physiological adaptations occurring over days to weeks are termed heat acclimation. I repeat physiological adaptations occurring over days to weeks are termed heat acclimation. A gradual set of adaptations that occur in people who live in hot environments for months to years is called acclimatization.

Repeated bouts of prolonged low intensity exercise in the heat cause rapid improvements in the ability to maintain cardiovascular function and eliminate excess body heat which reduces physiological strain. What it means is very simple. If you continue to exercise in the heat, your cardiovascular system becomes more efficient and your thermo-regulatory systems become more efficient and this will reduce the physiological strain and allow you to exercise better and more efficiently in the heat. This process is called heat acclimation and it involves changes in plasma volume, cardiovascular function, sweating and skin blood flow which will allow subsequent exercise bouts to be performed with a lower core temperature and a lower heart rate response. That means when you exercise and your heat acclimated, you will be able to perform the exercise with a lower core body temperature and a lower heart rate.

The body's heat loss capacity is enhanced by acclimation and hence the core temperature during exercise increases less and the heart rate increases less in response to exercise after heat acclimation. After heat acclimation, more work can be done before adverse symptoms occur or a maximal tolerable core temperature or heart rate is reached. These positive adaptations occur between 9 to 14 days of exercise in the heat.

There are certain effects of heat acclimation which we should know. We should know that well-trained individuals need fewer exposures than untrained individuals to fully acclimate. During the first 2 to 3 days of acclimation, there is an expansion in plasma volume because when the muscles contract, plasma is forced out onto the circulation. The same plasma returns to the blood through the lymph and fluid when it moves into the blood exerts an oncotic pressure and there is an increased fluid moving in along with the protein content. However, this change is temporary and blood volume usually returns to original levels within the next 10 days.

Increased sweating is seen on areas such as the arms and the legs which are the most effective at dissipating body heat. Sweating also starts earlier in an acclimated person which improves the heat tolerance but the sweat that is produced is more dilute and hence it will conserve the sodium. This occurs because the eccrine sweat glands become more sensitive to the effects of circulating aldosterone.

When you want to achieve heat acclimation, there are certain factors which we need to keep in mind. The benefits of heat acclimation as well as the rate at which we acclimate depends upon the environmental condition which is prevalent during each exercise session, the duration of exercise and heat exposure, the exercise intensity. An athlete must exercise in a hot environment to attain full acclimation. Sauna or steam room for long periods each day will not fully prepare the individual for physical exertion in the heat. Please note for heat acclimation, an athlete must be exercising in the hot environment and not just resting for long periods in each day in a sauna or a steam.

How do you maximize heat acclimation? Because the body temperature is elevated and sweating occurs, athletes can gain partial heat tolerance simply by training even in a cooler environment. What it means is if you are exercising regularly, you already have achieved partial heat acclimation. Athletes are hence pre-acclimated to heat and need fewer exercise heat exposures to fully acclimate. To gain maximum benefits, athletes must achieve heat acclimation before the contest or the event. Because heat acclimation will improve performance, reduce the physiological stress and reduce the risk of heat injury.

Let's come to body heat loss in cold. From heat to cold, conduction, convection, radiation and evaporation can dissipate heat to the environment faster than the body produces it in extremely cold environments. Thermal balance depends on a wide variety of factors that affect the balance between the body heat production and heat loss. Larger the thermal gradient between the skin and the cold environment, the greater the heat. A number of anatomical and environmental factors can influence the rate of heat loss.

There are several factors which affect body heat loss, body size and composition. People who have more fat mass conserve heat more efficiently than smaller, leaner individuals in the cold. The rate of heat loss also is affected by the ratio of body surface area to body mass. Larger individuals have a small surface area to mass ratio which makes them less susceptible to hypothermia.

Sex. Women tend to have more body fat than men which gives them an advantage during cold water immersion. Aging people tend to lose overall muscle mass making them more susceptible to hypothermia. Small children have a large surface area to mass ratio compared with the adults leading to greater heat loss and it is more difficult for them to maintain normal body temperature in the cold.

Let's talk about something called Wind Chill Factor. When you have air movement or wind, it increases convective heat loss and therefore increases the rate of cooling. Wind chill is an index based on the cooling effect of wind and there are several charts which show the wind chill equivalent temperatures showing various combinations of air temperature and wind speed. Wind chill is not the temperature of the wind or the air and please note, wind chill does not change the air temperature. True wind chill refers to the cooling power of the environment and as wind chill increases, so does the risk of freezing of the body tissues.

Cold water immersion. The body generally loses heat four times faster in water than in air at the same temperature. Humans generally maintain a constant internal temperature in water at temperatures of up to 32 degrees centigrade and become hypothermic in lower temperatures. Because of the large loss of heat from a body which is immersed in cold water, prolonged exposure to cold water leads to hypothermia and even death.

If the metabolic rate is low as when the person is at rest, then even moderately cool water can cause hypothermia. Exercise in water increases the metabolic rate and offsets some of the heat. Although convection heat losses increase when one is swimming at high speeds, the swimmer's accelerated rate of metabolic heat production compensates for the greater heat transfer. This means that when you are swimming, you are losing more body heat because you are in water but because you are exercising, the rate of metabolic heat production generally compensates for the greater heat loss. That is why for competition and training, water temperatures of around 23 to 27.8 degrees centigrade are appropriate.

People who are regularly exposed to cold environments undergo cold habituation in which the skin vasoconstrictor and shivering responses are blunted and core temperature falls to a greater extent. This occurs because when you expose small areas of skin, often the hands and the feet repeatedly to cold air, the body gets used to the cold temperature and it gets habituated to the cold. However, if the body heat loss is more severe or occurs at a faster rate, total body heat loss may occur.

In cases where metabolic heat production alone can sufficiently minimize heat loss, enhanced non-shivering and shivering thermogenesis develop. This is called metabolic acclimation. Insulative acclimation tends to occur when the increased metabolism is unable to maintain the core temperature and enhanced skin vasoconstriction occurs which increases peripheral insulation and minimizes heat loss.

There are three major physiological adaptations which occur when humans are chronically exposed to cold temperatures. First, cold adaptation results in a reduction in the mean skin temperature at which shivering begins. Persons who are cold acclimated begin to shiver at a lower skin temperature as compared to unacclimated individuals. Cold-acclimated people maintain heat production with less shivering by increasing something called non-shivering thermogenesis due to an increased norepinephrine release which causes the cells to increase metabolic heat production.

Second physiological adjustment that occurs due to cold acclimation is that cold acclimated individuals can maintain a higher mean hand and foot temperature during cold exposure as compared to un-acclimated persons. Cold acclimation results in improved peripheral vasodilatation to increase the blood flow and heat flow to both the hands and feet.

Third physiological adaptation to cold is the improved ability to sleep in cold environments. In contrast, un-acclimated people who try to sleep in cold environments will shiver so much so that sleep is impossible. In contrast, cold acclimated individuals can sleep comfortably in cold environments due to their elevated level of non-shivering thermogenesis. Subjects placed in a cold chamber begin to show signs of cold acclimation after one week.

What did we learn from this lecture? Repeated exposure to heat stress and exercise improves heat acclimation. People start to sweat earlier. Sweating rate increases, reduces the skin temperature, increases the thermal gradient and promotes heat loss. Exercise core temperature and heart rate are reduced with heat acclimation. Increase in the plasma volume improves delivery of blood to active muscles and skin.

Full heat acclimation requires exercise in a hot environment, not merely exposure to heat. The rate of heat acclimation depends on the training status, the conditions of exposure, the duration of the exposure and the rate of internal heat production.

Resting humans exhibit peripheral vasoconstriction upon exposure to cold causing a decrease in the skin blood flow thereby reducing convective heat loss from the skin. Exercise in a cold environment enhances an athlete's ability to lose heat and therefore greatly reduces the chances of cold injury. Cold acclimation results in three physiological adaptations. These adaptations increase heat production and maintains core temperature to keep the individual comfortable during cold exposure.

These are the references which we have used to prepare this lecture. Ladies and gentlemen, I strongly urge you to go through them in the interest of better improving your knowledge and experience.

I have finished, ladies and gentlemen, thank you very much for your time, patience and your listening capacity. We will be glad to answer any questions or queries which you may put on the email depicted on the slide. Thank you very much ladies and gentlemen. Thank you and Jai Hind.