Introduction to Exercise Physiology & Sports Performance

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Lecture - 26

Body temperature regulation

Good morning, ladies and gentlemen and welcome back to the course on Excise Physiology and Sports Performance. This is week 6 and today we will be taking on lecture 1. So, this is week 6 and we will be covering two important topics that is environmental considerations in exercise and exercise at altitude. So, we will be covering all the aspects of body temperature regulation, exercise in heat, exercise in cold, how the body adapts to exercise in heat and cold, what are the compensatory mechanisms, what are the adaptations which occur and how can we improve sporting performance in these weather conditions. We also look at altitude, the effects of altitude on the body and the effects of altitude on sports performance.

So, I shall be covering this topic under the following headings, introduction, heat production, transfer of body heat, thermoregulation, thermostat and receptors and the conclusion. So, when we talk about stress in the body, we should know that exercise is also a stress and if that stress is complicated by environmental thermal conditions that is also another stress. So, stresses of physical exertion are complicated by environmental thermal conditions. When you are performing in extreme heat or cold it places a heavy burden on the thermoregulatory mechanisms which struggle to cope with and to compensate.

Human body can adapt to such stresses, but it requires continuous exposure over time. If the exposure is short term over days to weeks it is called acclimation and if the exposure is gained over months to years, it is called acclimatization. We all know humans are homeothermic that means the internal body temperature is regulated to keep it as close to a set value as possible even when changes outside in the environment are there. That means even if it is cold or even if it is hot the human body remains at one particular temperature. The body temperature is a careful balance between heat production and heat loss. If there is prolonged heavy exercise, if you have fever or there are extreme conditions of heat or cold then only body temperatures deviate from the normal baseline range.

When we talk about heat production in the body where does it come from? Approximately 25 percent of the ATP production is used for the normal physiological functions of the body. The rest 75 percent is converted to heat. During moderate to heavy intensity aerobic activity heat production is more than heat loss and the body stores this excess heat and the internal body temperature increases. The ability to maintain a constant temperature depends on the balance between metabolic heat production and the heat gain and the heat losses the body is subjected to.

How is the body heat transferred to and fro from the environment? It is a very fine thin line. It is a fine balance which is there. For the body to transfer heat to the environment the heat produced in the body moves from the core to the shell where it has access to the outside

environment. The shell means the skin. Heat is delivered to the body surface by the arterial blood and by conduction through the subcutaneous tissue.

Heat from the skin can be transferred to the environment by any of four mechanisms conduction, convection, radiation and evaporation. Conduction, it is basically the transfer of heat from one solid material to another through direct contact. Heat can be lost from the body if the skin is in contact with a cold object and if the skin is in contact with a hot object heat will be gained by the body. If the contact is prolonged heat from the skin surface can be transferred to the blood as it flows through the skin and then it is transferred to the core raising core temperature. During exercise, conduction is usually a negligible source of heat exchange because the body surface area in contact with small objects is generally small.

Convection involves transferring heat by the motion of a gas or a liquid across the heated surface. When the body is still and there is little air movement a thin unstirred boundary air layer surrounds the body. As air moves around us passing over the skin heat is exchanged with the air molecules. The greater the rate of movement of air or liquid such as water the greater the rate of heat exchange by convection. If air temperature is cooler than the skin temperature convection permits the transfer of heat from the skin to the air. If air temperature is higher than skin temperature heat is gained by the body through convection. Convection constantly removes the metabolic heat we generate as long as the air temperature is lower than the skin temperature. In cold water the amount of heat dissipated from the body to the water by convection can be nearly 26 times greater than in cold air.

Radiation and convection are the primary methods for eliminating the body's excess heat at rest. At room temperature the nude body loses about 60 percent of its excess heat by radiation in the form of infrared rays. The skin constantly radiates heat in all directions to objects around it, but it can also receive radiant heat from surrounding objects that are warmer. A tremendous amount of radiant heat is received from exposure to the sun.

Conduction convection and radiation are considered avenues of dry heat exchange. Resistance to dry heat exchange is called insulation and the ideal insulator is a layer of still air and which can be achieved by trapping layers of air within the fibers such as down fiberglass or layers of clothing etcetera. During exercise dissipation of heat to the environment is done by wearing thin light colored clothing to remit the radiant heat absorption that allows for maximally exposed skin surface area.

Evaporation. Evaporation is the primary avenue for heat dissipation during exercise. It is very important for people who are exercising. Evaporation accounts for about 80 percent of the total heat loss during exercise and around 20 percent at rest. As the core body temperature increases sweat production increases dramatically. As sweat reaches the skin it is converted from a liquid to a vapor and heat from the skin is lost in the process. This is called the latent heat of vaporization and it helps to remove heat from the body. Thus, sweat evaporation becomes increasingly important as the body temperature increases.

Evaporation of 1 litre of sweat in an hour results in the loss of 2,428 kilojoules of heat. Unevaporated sweat contributes nothing to body cooling and simply represents a wasteful loss of body water. Clothing adds resistance to sweat evaporation. That is why clothing that fits loosely and comprises fabrics which can wick the sweat away from the skin enhances evaporative cooling.

Humidity and heat loss. The water vapor pressure of the air expressed as relative humidity plays a major role in evaporative heat loss. High air humidity decreases its capacity to accept more water because the pressure gradient between the skin and the air is decreased. High humidity limits sweat evaporation and heat loss while low humidity improves sweat evaporation and heat loss. If sweating is prolonged without inadequate fluid replacement dehydration can occur.

Thermal regulation. The internal body temperature at rest is regulated at approximately 98.6 degrees Fahrenheit. During exercise a person can reach core temperatures exceeding 104-degree Fahrenheit and a temperature of 107.6-degree Fahrenheit is often achieved in the active muscles. The muscle energy systems become more chemically efficient if there is a small increase in muscle temperature, but if the temperatures go above 40 degrees centigrade, it can adversely affect the central nervous system.

The body's thermostat. There are some sensory receptors called thermoreceptors which detect changes in the temperature and relay this information to the body's thermostat which is located in a region of the brain called the preoptic anterior hypothalamus. This region activates mechanisms that regulate the heating or cooling of the body and like a home thermostat the thermostat has a predetermined temperature or set point. The smallest deviation from the set point signals this thermoregulatory centre to readjust the body temperature.

The receptors. Thermoreceptors are located in the skin and the central nervous system. The peripheral skin receptors monitor the skin temperature which varies with changes in the temperature around a person. Because the skin temperature changes long before core temperature these receptors serve as an early warning system for impending thermal challenges.

When the hypothalamic thermostat senses temperatures above or below normal signals are sent through the sympathetic nervous system to four sets of effectors. The skin arterioles, the eccrine sweat glands, the skeletal muscles and the endocrine glands.

So, what do they do? The skin arterioles. When the skin or core temperature changes the POAH sends signals to the smooth muscles in the walls of the arterioles that supply the skin causing them to dilate or constrict. If there is skin vasoconstriction heat is conserved by minimizing dry heat exchange. If there is skin vasodilatation that means the blood vessels of the skin open up, increases the skin blood flow which aids in heat dissipation through conduction, convection and by radiation. Fine tuning of skin blood flow is the mechanism by which minute to minute adjustments can be made in the heat exchange and heat balance.

Eccrine sweat glands. If skin or core temperature is elevated sufficiently the pOH sends impulses to the eccrine sweat glands resulting in an active secretion of sweat. These sweat glands are 10 times more responsive to increases in core temperature than to increases in skin temperature. The evaporation of this moisture removes heat from the skin surface.

Skeletal muscle. Skeletal muscle is called into action when a person needs to generate more body heat. In a cold environment, thermoreceptors in the skin or core send signals to the hypothalamus which activates the brain centres that control muscle tone. These centres stimulate shivering which is ideal for generating heat to maintain or increase the body temperature due to heat production.

Endocrine glands. Several hormones cause the cells to increase their metabolic rates. This increase in the metabolism affects the heat balance because it increases heat production. Cooling the body stimulates the release of thyroxine which can elevate the metabolic rate throughout the body by more than 100 percent. Epinephrine and norepinephrine mimic and enhance the activity of the sympathetic nervous system and directly affect the metabolic rate of virtually all the body cells.

So, what did we learn from this lecture? Humans are homeothermic with resting temperature range between 97 to 100 degrees Fahrenheit, despite the changes in environmental temperatures. Body heat is transferred by conduction, convection, radiation and evaporation. At rest most heat is lost via radiation and convection, but during exercise evaporation becomes the most important avenue of heat loss. Higher humidity decreases the evaporative heat loss.

The PAOH is the primary thermoregulatory center and acts as a thermostat, monitoring temperature and accelerating heat loss or causing heat production as needed. Peripheral skin receptors and central brain receptors provide temperature information to the PAOH. Central thermoreceptors are far more sensitive to temperature change than the peripheral receptors.

Effectors stimulated by the hypothalamus through the sympathetic nervous system can alter the body temperature. Smooth muscle in the skin arterioles can dilate to move blood to the skin for heat transfer or constrict to retain heat deep in the body. Metabolic heat production can also be stimulated by the actions of hormones such as thyroxine and the catecholamines.

These are the references which have been used for preparing this lecture. I would strongly urge you to go through them and improve your knowledge much more than what we could have communicated to you in this short lecture.

I thank you for your time and patience ladies and gentlemen. We will be glad to answer any questions or queries or comments which you may send to us by email. Thank you for your attention ladies and gentlemen. Thank you and Jai Hind.