Introduction to Exercise Physiology & Sports Performance

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Lecture - 27

Physiological response to Exercise in Heat and Cold

Good morning, ladies and gentlemen and welcome back to week 6 of this course on exercise physiology and sports performance. This is lecture 2 where we will be dealing with the physiological response to exercise in heat and cold. I will be covering this topic under the following heads: exercise in heat, physiological responses to exercise in heat, limiting factors, exercise in cold, physiological responses to exercise in cold, and conclusion.

We all know that when we exercise in heat, heat production is not a good thing. However, when we exercise in a cold environment, heat production is beneficial as it helps to maintain the normal body temperature. Metabolic heat load places a very large burden on the mechanisms that control body temperature even if you are exercising in a cold environment.

Let us talk about some of the physiological responses to exercises in heat. When you exercise in heat, the increased demands on the cardiovascular system is because there is a normal demand of the cardiovascular system wherein it is supposed to supply oxygen to all the body and body temperature regulation demands will also be added on to the cardiovascular system. The CVS has to transport blood to the working muscles and to the skin for heat transfer to the environment. The cardiovascular changes to meet this dual demand are, increase in the cardiac output by increasing the heart rate and the stroke volume and shunting of blood flow away from the non-essential areas like the gut, the liver, and the kidneys to the skin.

During prolonged running on a hot day, exercise increases both metabolic heat production and the demand for blood flow and oxygen delivery to the working muscles. This excess heat can be dissipated only if blood flow increases to the skin. In response to the elevated core temperature and the higher skin temperature, these sympathetic nervous system signals which are sent from the POH to the skin arterioles cause these blood vessels to dilate delivering more metabolic heat to the body surface.

The sympathetic nervous system signals the heart to increase the heart rate and causes the left ventricle to pump more forcefully. However, the ability to increase the stroke volume is limited as blood pools in the periphery and there is less venous return. We must have seen several times a long-distance runner completes a race and suddenly stops after finishing the race and then collapses. This is because there is pooling of blood in the extremities and something called the peripheral heart or the calf muscle pump stops working which does not allow the blood to come back to the heart so that is why he goes into a shock state and collapses. This is very commonly seen in long-distance athletes who suddenly stop after finishing a race. To maintain the cardiac output under such circumstances, the heart rate gradually creeps upward to help compensate for the decrease in stroke volume.

There are some limiting factors to the exercise in heat. At some point, the cardiovascular system can no longer compensate for the increased demands of continuing endurance exercise and also efficiently regulating the body's heat. This overload of the cardiac system or interference with heat dissipation can drastically impair the performance and increase the risk of overheating or it may do both.

Exercise in the heat becomes limited when heart rate approaches maximum especially in untrained or non-heat acclimated exercises. There is something called a critical temperature theory which proposes that regardless of the rate at which the core temperature increases, the brain will send signals to stop the exercise when some critical temperature is reached usually between 104 to 105.8 degrees Fahrenheit.

Let's talk about the role of sweating and body fluid balance. On hot summer days, the temperature of the environment exceeds both the skin and the deep body temperatures. This makes evaporation far more important for heat loss because radiation, convection, and conduction are now avenues for heat gain from the environment. Increased dependence on evaporation means there is an increased demand for sweating. During heavy exercise in hot conditions, the body can lose more than 1 litre of sweat per hour per square meter of body surface. An average size female athlete between 50 to 75 kilos might lose 1.62 litres of sweat or about 2.5 to 3.2 percent of body weight each hour. If a high rate of sweating is maintained for a prolonged time, it ultimately reduces the blood volume, increases the heart rate and decreases cardiac output thereby reducing performance. In several long-distance runners, sweat losses can approach 6 to 10 percent of body weight. Such severe dehydration can limit subsequent sweating and make the individual susceptible to heat-related illnesses.

Loss of electrolyte and water in the sweat triggers the release of both aldosterone and antidiuretic hormone. Aldosterone is responsible for maintaining sodium concentrations in the blood and ADH maintains the fluid balance. Aldosterone is released in response to decreased blood sodium content, reduced blood volume, or if the blood pressure is lowered. During exercise in the heat, aldosterone limits sodium excretion from the kidneys. Basically, it holds back sodium in the body. The body retains water and sodium in preparation for additional exposures to the heat and in preparation for subsequent sweat losses. Exercise and body water loss will also stimulate the posterior pituitary gland to release ADH which stimulates water reabsorption from the kidneys and this will help to retain the fluid inside the body. Thus, the body attempts to compensate for the loss of electrolytes and water during the periods of heat stress and heavy sweating by reducing their loss in the urine.

Let's now talk about exercise in cold. Humans are tropical animals with physiological adjustments to heat stress. However, when they encounter cold environments, they need to have a behavioral adjustment like putting on more clothing or seeking warm shelter. Certain occupations, military operations, winter sports, etc., require people to work in cold conditions which may limit performance. Cold stress is defined as any environmental condition causing a loss of body heat that threatens homeostasis. The hypothalamus has a set point of around 98.6 degrees Fahrenheit. Low skin or body temperature provides feedback to the thermoregulatory center to activate mechanisms like peripheral vasoconstriction, that means the blood flow to the periphery is stopped, non-shivering thermogenesis without shivering when heat is produced by the body and shivering thermogenesis to conserve body heat and increase heat production. Behavioral responses may also be required such as huddling or putting on more clothes to help insulate our body from the environment.

Heat conservation and production. Peripheral vasoconstriction occurs as a result of the sympathetic stimulation of smooth muscle layers of the arterioles in the skin. This constricts the arterioles, reduces the blood flow to the skin and minimizes heat loss. Non-shivering thermogenesis, that means stimulation of metabolism by the sympathetic nervous system causes a rise in metabolic rate increasing the heat production. Shivering, which is a rapid cycle of involuntary contraction and relaxation of the skeletal muscles, causes a four-to-five-fold increase in the body's heat production rate.

There are some physiological responses to exercise in the cold. Fatigue and lower exercise intensity reduces the metabolic heat production due to low energy reserves and reduced muscle activity. The resulting decrease in core temperature causes the individual to become even more fatigued and less capable of generating heat. It also reduces small muscle function due to the cold, which causes loss of manual dexterity and diminishes fine motor skills. Basically, reduces the small muscle functions in the upper limb and the lower limb and reduces the fine motor skills.

Prolonged exercise increases the mobilization and oxidation of free fatty acids as a fuel source. Basically, the body starts to burn fat as a fuel when there is prolonged exercise. Cold exposure triggers vasoconstriction in the vessel supplying the fatty subcutaneous tissues, which is a major storage site for lipids or free fatty acids. Because of this vasoconstriction, free fatty acid mobilization is reduced and free fatty acid levels in the blood do not increase. Blood glucose also plays an important role in both cold tolerance and exercise endurance. Hypoglycemia suppresses shivering. Blood glucose concentrations are maintained during cold exposure, but muscle glycogen is used at a higher rate during the cold.

What did we learn from this lecture? Heat production in the body is beneficial during exercise in cold, but is detrimental during exercise in heat. The body compensates for heat production during exercise in several ways. Exercise and heat have limitations due to cardiac output, sweat loss, and rise in body temperature. Sweating has a role to play in body fluid balance and temperature regulation. Exercise in cold needs behavioral changes. Thermoregulatory mechanisms may prove inadequate during prolonged exercise in extreme weather conditions.

These are the references which I have used to prepare this lecture. I strongly urge you to go through them. Thank you for your time and patience, ladies and gentlemen. We will be glad to answer any questions or queries or comments. Do let us know on the email below. Thank you very much for listening, ladies and gentlemen. Thank you and Jai Hind.