Introduction to Exercise Physiology & Sports Performance

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Lecture – 30

Exercise and Sports performance at Altitude

Good morning, ladies and gentlemen and welcome to lecture 5 of week 6 of this course on exercise physiology and sports training. I am Colonel Dr. Anup Krishnan, your instructor for this week and I will be covering everything about exercise and sports performance at altitude.

I will cover the lecture under the following headlines: Introduction, atmospheric conditions at altitude, body responses to altitude, exercise at altitude, VO2 max at altitude, anaerobic response at altitude, body adaptations, health risks, altitude training and conclusion.

Altitude presents an atmosphere or an environment in which the atmospheric barometric pressure is reduced. If the altitude is 1500 meters or higher, there is a notable physiological impact on exercise performance.

Although, the percentage of gases in the air remain constant regardless of the altitude, the partial pressure of each of these gases reduces with the decreased barometric pressure at higher altitudes. The low partial pressure of oxygen in the air at altitude is the environmental condition with the most profound physiological impact.

Air temperature typically decreases as altitude increases. Cold air can hold little water, so the air at altitude is dry. These increase susceptibility to cold related disorders and dehydration. Because the atmosphere is thinner and drier at altitude, the solar radiation is more intense and if the ground is snow covered, the solar radiation is magnified and there is a condition called snow blindness which is because of solar radiation reflecting from the snow.

Altitude causes hypobaric hypoxia resulting in a decreased partial pressure of oxygen in the inspired air. The pulmonary ventilation will increase, pulmonary diffusion is maintained, but oxygen saturation is slightly impaired. Oxygen transport is also impaired and hemoglobin saturation is reduced. Consequently, the oxygen uptake by the muscle is impaired due to the reduced diffusion gradient.

Low plasma volume initially increases the RBC concentration allowing more oxygen to be transported per unit of blood. The cardiac output increases to compensate for the decreased oxygen content per liter of blood by increasing the heart rate. Impaired cardiac output at maximum work and the decreased pressure gradient severely impairs oxygen delivery to the tissues.

When you ascend to altitude, there is an increase in the metabolic rate by increasing the activity of the sympathetic nervous system. There is an increased reliance on the carbohydrates for fuel. The exaggerated fluid loss and the general loss of appetite at altitude increase the risk of dehydration. Decreased energy intake coupled with the increased energy expenditure of activity at altitude can lead to daily energy deficits and weight loss.

Exercise at altitude has been described by E.G. Norton who gave this account of climbing without oxygen at 8600 meters. He says, “Our pace was wretched. My ambition was to do 20 consecutive paces uphill without a pause to rest and pant, elbow on bent knee. Yet, I never remember achieving it. I could only achieve 13 paces.” We can walk 3, 4, 5 kilometers at sea level normally. But at 8600 meters, this trained mountaineer could not walk more than 13 paces, 13 steps. This is what is the effect of altitude on physical activity.

What happens to VO2 max? Maximum oxygen uptake decreases as altitude increases. However, till the atmospheric PO2 drops below 131 millimeters of mercury, VO2 max does not have any effect. That means till about 1500 meters, VO2 max remains normal and beyond 1500 meters of altitude, VO2 max starts getting dropped. This decrease increases approximately 8 to 11 percent for every 1000 meters increase in altitude above 1500 meters. That means when you go above 1500 meters, every 1000 degrees elevation will see your VO2 max drop by 8 to 11 percent.

What does it imply? It implies that normal people who have VO2 max levels below 50 ml per kg per minute will not be allowed, will not be able to survive without supplemental oxygen at Mount Everest. Endurance athletes who have a high VO2 max at sea level have a competitive advantage at altitude, if everything else is equal. VO2 max declines on arrival at altitude and hence competition at any given pace will be performed at a lower percentage of VO2 max.

What happens to anaerobic activities at altitude? Anaerobic sprint activities are generally not impaired by moderate altitude because the energy is provided by ATP, phosphocreatine and the glycolytic systems. The thinner air at altitude provides less aerodynamic resistance to athletes’ movements and because of these reasons, at the 1968 Olympic games, World Olympic records were set in the 100 meters, 200 meters, 400 meters, 800 meters, long jump, triple jump and 400 meters relay in both men and women category.

What happens to chronic exposure to altitude? How does the body acclimate? When the body, people are exposed to altitudes, their bodies gradually adjust to the lower oxygen partial pressure in the air over months. However, while they acclimate to the conditions at high altitude, they never fully compensate for the hypoxia. Even endurance trained athletes who live at altitude for years never attained the level of performance or the VO2 max values that they may achieve at sea level.

Generally, about three weeks are needed for full acclimatization to even moderate altitude. For each additional 600 meters of altitude increase, another week is needed and but all these beneficial effects are lost within a month of return to sea level.

Increase in pulmonary ventilation, at rest and during exercise is one of the pulmonary adaptations to altitude. Within three or four days at 4000 meters, the increased resting ventilation rate levels off at a value that is approximately 40 percent higher than at sea level. Submaximal exercise ventilator rate also plateaus at around 50 percent higher but it will take a longer time frame. Increases in ventilation during exercise remain elevated at altitude and are more pronounced at higher exercise intensities.

What happens to the blood? During the first two weeks at altitude, the number of circulating erythrocytes increases. Basically, number of RBCs increase. The lack of oxygen stimulates the renal release of erythropoietin which increases for about three days. The increased RBC

number may be evident for three months or more. After a person lives at 4000 meters for about six months, his total blood volume increases by about 10 percent.

Blood hemoglobin concentration tends to increase with increases in elevation. The reduction in plasma volume during acute altitude exposure reduces the total blood volume thus reducing cardiac output. But with acclimatization, as the plasma volume and RBCs increase over several weeks to months, maximal cardiac output increases.

Muscle adaptations. After four to six weeks of chronic hypoxia, muscle fiber cross sectional area reduces. Capillary density increases causing more blood and oxygen to be delivered. Muscles inability to meet high exercise demands at high altitude is due to the reduced mass and reduced ATP generation capacity. Muscles lose some capacity to perform oxidative phosphorylation and generate ATP.

Cardiovascular adaptations at altitude. Aerobic capacity remains unchanged for up to two months at altitude. VO2 max values and running performance were not significantly improved with acclimation in several studies which were conducted. Reduced PO2 max of altitude makes it more difficult for athletes to strain at the same intensity and volume as at sea level.

There are several health risks at altitude. Most common is something called acute mountain cognitive sickness. People who ascend to moderate and high altitudes commonly experience symptoms of AMS. This disorder is characterized by headache, nausea, vomiting, dyspnea and insomnia. The symptoms may begin anywhere between six to 48 hours after arrival at high altitude and are most severe on days two and days three. Though not life threatening, severe altitude sickness can be incapacitating for several days or longer and may progress to one of the other conditions like HAPO.

High altitude pulmonary Oedema. HAPO is the accumulation of fluid in the lungs and is life threatening. It is seen in unacclimatized people who rapidly ascend to altitudes above 2500 meters. It occurs in otherwise healthy people and has been reported more often in children and young adults. The pulmonary vasoconstriction resulting from the hypoxia causes blood clots to form in the lungs causing over perfused tissues and fluid and protein leak from the capillaries.

The fluid accumulation interferes with the air movement into and out of the lungs leading to a shortness of breath, cough, chest tightness and excessive fatigue. Sinuses of the lips, finger nails, mental confusion and loss of consciousness may occur. HAPO is treated via administration of supplemental oxygen and movement of the victim to a lower altitude.

After HAPO, there is something called high altitude cerebral Oedema. It is characterized by mental confusion, lethargy, ataxia, difficulty walking and it may progress to unconsciousness and death. It is reported at altitudes greater than 4300 meters and there is a hypoxia induced leakage of fluids from cerebral capillaries which causes edema and pressure buildup in the intracranial space. Basically, fluid buildup in the brain. Treatment involves administration of supplemental oxygen, hyperbaric chamber and a prompt descent to a lower altitude.

Training under hypoxic conditions. Now we have seen all the effects and benefits and ill effects of altitude. Athletes and coaches and exercise physiologists have believed that training under hypoxic conditions in an altitude chamber or at high altitudes may improve sea level endurance performance. Altitude training evokes substantial tissue hypoxia which is essential for initiating

the conditioning response. Altitude-induced increase in red blood cell mass and hemoglobin content improves oxygen delivery on return to sea level. Evidence suggests that these changes are transient lasting days. That means if you take the athlete to high altitude or you put the athlete in a hypoxic chamber for altitude training, make sure he competes within 3 to 4 days after returning to sea level.

Extended training for optimal performance at altitude requires an elevation between 1500 to 3000 meters. Work capacity is reduced during the initial days at altitude and initially the athlete should reduce the workout intensity to between 60 to 70 percent of sea level intensity and gradually work up to full intensity within 10 to 14 days.

What did we learn in this lecture? Prolonged endurance performance suffers the most at high altitude because oxidative energy production is limited. Maximal oxygen consumption decreases in proportion to the decrease in atmospheric pressure and it begins at around 1500 meters. Anaerobic sprint activities that last 2 minutes or less are generally not impaired at moderate altitude.

Acute mountain sickness causes symptoms such as headaches, nausea, dyspnea and insomnia within 6 to 48 hours after arrival at altitude. Acute altitude sickness can usually be avoided by a slow gradual descent to altitude climbing no more than 300 meters per day at elevations above 300 meters, 3000 meters. High altitude pulmonary and cerebral oedema, HAPO and HACO, are life threatening conditions which can be treated with oxygen administration, hyperbaric bags and descent to lower altitudes. Training at altitudes leads to some improvement in sea level performance. Living at high altitudes and training at low altitudes currently appear to be the best alternative that means live high and train low protocol. Athletes who must compete at altitudes should train between 1500 to 3000 meters for a minimum of 2 weeks prior to competition. However, more is better.

These are the references which were used to prepare this lecture. I strongly urge you to go through them.

I have finished, ladies and gentlemen, and this brings us to the end of week 6. There will be an assignment which you will have to complete and submit in the stipulated period. Thank you, for listening and thank you for your patience. We will be glad to answer any queries or reply to any doubts or emails which you may put up. Thank you, ladies and gentlemen and Jai Hind.