Introduction to Exercise Physiology & Sports Performance
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Lecture - 03
Acute and Chronic response to Exercise

Hi participants, this is Dr. Majumdar, former Dean of Sports Authority of India, Head of Sports Science, New Delhi. And presently I am with IIT Madras, working as Senior Advisor, Sports Science Education and Research. Today I will discuss about the acute and chronic response to exercise. And in this discussion, we will cover, we will try to understand what is acute and chronic load.

We will try to find out what is the definition of acute and chronic exercise. We try to figure it out what are the effects of exercise on brain, muscle, bone, liver, pancreas, gut and adipose tissue. We also try to find out the effect of chronic exercise on brain, muscle, bone, liver, pancreas, guts and adipose tissue. And at last we wanted to see what is the conclusion of the entire this module of this chronic and acute exercise and what are the physiological adaptation and what is the take home message.

So let us explore the particular this topic. So let us try to understand what do you mean by internal load, and external load. When we do exercise, then there are certain kind of stress which are imposed on the physiological system and there are certain parameters which can measure those stress. What are those parameters? The most used is heart rate, then blood lactate, and the RPE or rate of perceived exertion which is known as the box scale of perceived exertion.

So, we will try to figure it out that the importance of that. And say for example, an athlete might rate their perceived exhaustion during training session as 7 in box scale in a 20 point scale is the box scale. So, 7 is rated as a moderate level. Now, from there from internal load which we come to external load. So, external load is the quantum of the athlete, say, for example, how much kg he has lifted.

So that is one of the measure to understand in weight training or weightlifting. Similarly, even what intensity the runners are running, how long he is running. So duration, intensity, is measurable and the poundage is obviously measurable, and that is how we can quantify the external load. For example, an athlete may run 10 kilometers at an average speed of 5 minutes

per kilometer So, the 50 minutes he is running. So, you can measure that 50 minutes the runners running at a 5 kilometer per hour.

So, what is the stress and what are the physiological adaptation do occur when you are, when the load imposed externally on the physiological system. So this is very roughly we can say this is the external load and internal load. You can see that how long he has done the workout and internally what the resting heart rate and what was during the workout, how much the heart rate has gone. So basically this is easy way to understand. Now the performance and injury is very much related because modern day sports is very challenging and demanding and the athlete must be very careful or the coaches and practitioner must be very careful to structure the loading.

And this is, I just wanted to tell you that once the load is very minimum, which is designated as through your acute and chronic work ratio, if it is less than 0.8, this ratio, it is under load, the risk is very minimum. When you are going for overload, the ratio can go up to 0.8 to 1.3. It is a moderate load and once you are, this is the yellow line is a very dangerous line. The coaches must be very critical of, critical to maneuver this particular zone because this is the overreaching zone. that is the sustained overloading. So that is quite critical that is from 1.3 to 1.4 and if you exceed that if the sustained overreaching condition is a very dangerous and it can it can cause injury. So this is by and large I just wanted to convey that overtraining is very dangerous, it can cause many of the injuries. Now when we talk about the acute response, the individual bout of exercise is called acute exercise and the response to that exercise bout are designated as the acute response. When examining the acute response to exercise, we are concerned with the body's immediate response. And sometime during the recovery what are the physiological things happening in the body in the system that also will come to our discussion.

Now when we talk about the chronic response, chronic response is how the body responds over time to the stress of repeated bout of exercise. Sometime referred as the chronic adaptation to adaptation or the training effect of particular say for example endurance training effect or resistance training effect. When one perform regular exercise over a period days and weeks and months, the body sets its adaptation. The physiological adaptation that occur with chronic exposure to exercise or training improve both exercise capacity and the efficiency of the individual. With resistance training, the muscle becomes stronger.

With endurance training or aerobic training, the heart and lungs become more efficient and the endurance capacity of the muscle increases. Now we will talk about the physiological response to acute endurance exercise. When you are doing, say for example, 12 kilometers per hour, you are running on a treadmill for 30 minutes. What will happen to your system? So, that we will discuss here possibly it would be interesting to understand because the resting ventilation is around 8 to 10 liter per minute and when you are running for 10 kilometer or 8 kilometer per hour for longer period of time then the ventilation goes up and stays to a plateau. It can go up to

around say for example 60 to 70 liter per minute or in very sedentary person it can even go little higher 80 to 90 liter per minute.

So increased ventilation is one. The heart pumping function of the heart rate definitely will increase. So it can go from resting heart rate of 60 to 70 or 80. It can go up to 140, 150. And in some cases of untrained person, it can even go higher than that.

Then also the acute response endurance training decreases peripheral vascular resistance because of the vasodilatation of the blood vessel. And this facilitates the recovery of oxygen. This facilitates the delivery of oxygen and nutrients to the working muscle. Now we are talking about when somebody is doing the exercise over a period of time every day or thrice in a week he is doing 30 minutes submaximal exercise, then it increases blood flow and oxygen consumption to all organs especially heart and skeletal muscle. So blood flow increases.

And you will gain, if you are doing for a month or six weeks, you will improve your aerobic fitness. So, the lung volumes which are, there are four lung volumes. The first is the tidal volume, then inspiratory reserve volume, expiratory reserve volume and residual volume. The three lung volumes increase during that kind of exercise and residual volume slightly decrease and the ventilatory capacity also increases due to the remodeling of the lungs and its musculature. Training induced increase in oxygen carrying capacity in the form of an increase in the red blood cell mass.

How to measure that? The oxygen carrying capacity or the oxidative capacity we used to measure through maximum oxygen uptake capacity. So the maximum oxygen uptake capacity pre-trend and the post-trend, you will see there is a marked increase in oxygen carrying capacity or the maximum uptake of the oxygen in the muscle which is called the aerobic capacity or the VO2 of that submaximal exercise. Favorable changes in circulating serum lipid and amino acid profile because it is quite evident that when you do that kind of exercise particularly your HDL level goes up because there is also evident. it is quite evident that there is a dose response of HDL. So, once you are doing that kind of aerobic exercise over the period of time your HDL level will go high and that is why there would be favorable changes of the serum lipid and the amino acid profile particularly leucine and glutamine.

also changes aspartate these are the circulating amino acid and those amino acids even act as a substrate of energy. The blood vessel also adapts structurally by increasing their diameter. So there will be as I told you the vasodilatation the blood vessel increases the dilate and therefore increasing the diameter to make it possible to accommodate the increased total blood delivery capacity. Resting blood pressure can be lowered by exercise and training in hypertensive subject but remain normal for normotensive subject. Well if now we are coming to the response in different organ like brain what will happen? Now for acute exercise what will happen to the

brain? Brain blood flow remains largely unchanged in response to acute exercise.

The blood flow is directed to the area controlling locomotor that is your cerebellum, then reticular formation, then vestibular, that is the midbrain, cardiorespiratory, medulla, pons, then the visual function, occipital lobe of the brain, the blood supply of these area increases. With increasing exercise intensity, blood glucose decreases. and the uptake and utilization of lactate increase because lactate acts as a fuel in the brain as a substrate for giving the energy through reverse oxidative process. So the lactate gives the energy and lactate, therefore it is imperative to mention that utilization of lactate is enhanced in the brain. There are certain endocannabinoids that also increase in peripheral blood.

in an exercise intensity dependent manner which can reduce pain sensation and along with many other functions. Similarly when you are doing the chronic exercise the exercise which are I mean for which the adaptation sets in. So it improve your cognitive performance and delayed and prevented the neurological deformity and neurological condition in human. Brain size and brain blood flow is larger in individual with higher exercise capacity. reorganization of synaptic and receptor level in several area of the brain including those area control satiety that is mainly mainly hypothalamic dorsal and dorsal ventral area of hypothalamus and the anxiety which is a frontal cortex thereby helping the body weight control and prevention of depression.

Now effect of acute exercise on the muscle because muscle is the key area for performance. So the muscle tissue receive almost all 85 to 95 percent of your cardiac output and oxygen delivery during maximal exercise. So So, it increases the metabolism because your muscles require to have the proper nutritive support and the oxygen. So, therefore, the blood flow also increases, the metabolic activity increases. It increases the oxygen consumption because your muscle need to have a higher quantum of oxygen to satisfy the metabolic demand.

The mechanical strain also increase. The cardiac output around 5 liter during rest. It can increase to around 20 to 25 litre in non-trained athlete, non-trained person, but in athletic population it may even go higher. The coronary blood flow also increases because your heart is required to get more blood for performing for longer time. The glucose uptake definitely increased and the lactate metabolism also increased in the muscle because normally the basic lactate level in a pre-trained state of an individual may be around 2 millimole per liter and when you are doing the exercise at an intensity of 8 to 10 kilometer per hour for 30 minutes then it can go up to 8 to 10 millimole per liter and even sometime more because it depends on the level of fitness of the individual.

So the effect of chronic exercise, what will happen to the muscle when you are doing the exercise for a longer period of time, maybe 6 weeks, 8 weeks, 10 weeks you are doing the similar kind of routine, thrice in a week you are doing the exercise. Number one, Endurance

capacity training substantially increases your aerobic respiratory capacity of the skeletal muscle. Why once we are talking about that then it does indicate that your skeletal muscle needs to have a higher quantum of blood flow. It increases the mitochondrial mass. So, the density of mitochondria, the number of mitochondria increase and enzyme concentration and activities of the mitochondrial enzyme which is the oxidative enzyme that also need to increase.

It stimulates angiogenesis that is the synthesis of more capillaries leading to higher muscle capillary density which facilitates the oxygen transport to the mitochondria. Structural and functional and electrical cardiac remodeling is also quite evident in chronic exercise of the muscle because all of us know that the athlete's heart because athlete has the bigger heart that means the cavity size of the heart is more even the left myocardium or the thickness of the myocardium in the left ventricle also increases to some extent. Largely it is evident for strength athletes, but endurance athletes also there would be a marginally increase in the left ventricular mass. Increase maximum cardiac output when your heart become the cavity size is more the pumping the cardiac muscle the hypertrophy occur in the left ventricle then definitely left ventricle is capable of sending more blood that is called the cardiac output because the amount of blood ejected out of the heart in one minute is called cardiac output.

So, cardiac output also increased. So, the maximum cardiac output increased due to increase in cardiac mass, volume and superior diastolic performance. Higher insulin sensitivity and insulin resistance ameliorated by physical activity. So insulin sensitivity to the cell increases, more number of receptors are activated, therefore the sensitivity increases and resistance decreases. So the insulin can be effectively used, the receptor, the GLUT4 uses more inflow of glucose inside the cell. Now we are coming, this is majorly in the muscle, but how it happens in the bone, very, very small way we will like to address that.

The exercise is known for its benefit in strengthening bone, we all agree that. The exercise, the acute exercise increase, increased acute exercise induced and recovery phase blood flow that supplies bone and nutrients. Exercise induced enhanced bone perfusion is also responsible for enhancing efflux of stem cell from the bone marrow and this stem cell is responsible for both pluripotent and commutate, these are responsible for the formation of blood. So that also is quite evident for acute exposure for bone. Then the effect of chronic exercise in bone, what happens? The exercise induced mechanical stress improves the physical characteristics of the bone.

Exercise enhances the mobilization of stem cells, as I already told you before from the bone marrow possibly through the vasodilatation which is caused by the nitric oxide. This is the vasodilator substance. It potentially corrects vascular impairment and attenuates the endothelial progenitor cell release observed in bone marrow in disease states such as diabetes. Now what will happen to the effect of acute exercise in the liver, pancreas and guts? Because these three organs majorly support the metabolic function during exercise. So once this metabolic function is

being supported by these three majorly organs, let us try to find out what is happening there.

The arterial inflow of arteries supplying these organs is decreased during acute exercise because the muscle requires more amount of blood so blood would be diverted from non-vital organ to the vital organ. Here the vital organ is the muscle so blood is diverted to the muscle so the arterial inflow of arteries supplying to these organs decreases. The overall metabolism of this splanchnic organ is unaffected by exercise because it has not much role to play during exercise. The blood flow can be reduced to as low as 20% of its resting value. Sustained high intensity exercise may lead to gut hypoperfusion and gastrointestinal compromise because the blood is diverted to the muscle.

The production of insulin from pancreatic beta cell is blunted mainly by sympathetic stimulation. Increased production of glucagon from pancreatic alpha cell, this allows the maintenance of blood glucose level and effective mobilization of free fatty acids and their utilization during prolonged exercise. And under this particular mobilization of fatty acid, here there is not mass scope but there are some of the hormones which play very important roles like cortisol, epinephrine, norepinephrine. Cortisol plays a major role in the initial part of the exercise but in the sustained exercise there are Other hormones like epinephrine, norepinephrine plays a very even growth hormone that causes the mobilization of free fatty acid for giving the energy during submaximal exercise. Liver utilized lactate and branch and amino acid for gluconeogenesis during exercise.

Now all these organs, what happened from acute exercise to chronic exercise. Improve insulin sensitivity to the muscle. Obviously muscle improve the sensitivity. So muscle will now, as the sensitivity increases, the efficiency for taking the glucose is more now.

So the muscle will work much more efficiently. It will get its energy very easily inside. The improvement in liver, pancreas, and gut insulin sensitivity. also improved, maintains the normal metabolic state of the guts for early absorption of food and handling of pathogens and immunity that is also chronic exercise response of these organ. Increased fatty acid uptake in skeletal muscle but lower uptake in the liver during hyperinsulinemia.

Liver and pancreatic fat cell is lower. decrease renal sympathetic nervous activity in sedentary normotensive men causing low renal vascular resistance. So, the blood can flow more inside the kidney. So, that is also a positive aspect because kidney has got immense role for your for maintenance the balance of internal body temperature. and, you know, water balance. So what happens to the adipose tissue? The lipolysis is, you know, the breakdown of fat.

The breakdown of fat happens through the beta oxidation. The lipolysis in white fat is activated by exercise, during acute exercise. which releases free fatty acid into circulation to be consumed

by other tissues. Adipose tissue blood flow increases from rest to light and moderate intensity exercise. What happened to the adipose tissue when you are doing the chronic exercise? Reduction in fat mass and increase in capillary density due to fat cell reduction.

Increased glucose and free fatty acid uptake in visceral and subcutaneous fat. Browning of white fat is quite evident. The reduction in adipose tissue mass is also evident during chronic exercise. So here the take home message if you see during acute exercise, you can see here that the mainly what happens is the lungs, the heart, increased blood flow, increased blood distribution, increased cardiac output, increased coronary blood flow, oxygen consumption, blood flow distribution. You can see it is quite evident from this figure. Even if you see the hemoconcentration in the blood cell then hemoconcentration also increases more number of blood is employed, the oxygen content increases. Then when we are talking about the arterial dilatation, arterial dilatation increases because it has to accommodate more amount of blood flow so there would be a vasodilatation. The capillary pressure increases and the energy substrate exchange is also increased.

When we talk about the blood distribution, distribution also increases and the venoconstriction, the blood, the reserve is the vein. So venoconstriction means more amount of blood is in the arterial circulation. So if you come to muscle, the metabolism increases in the muscle and the blood flow oxygen extraction and consumption increases. So, oxygen extraction we used to call what is the extraction of oxygen like how much oxygen is been used by the muscle. So, in arterial blood the pO2 level of the arterial blood if we wanted to understand that.

So, arterial concentration of oxygen in the blood is say for example, it is around 20 ml per 100 ml of blood. and the venous end it is around 14 to 15 ml. So, the 5 ml is also only used during resting condition. When you are doing the exercise, arterial content is same, but the venous as definitely as the muscle is using oxygen, in the venous end there is a drop. So the arteriovenous oxygen difference or if you go to difference is widen up.

So the muscle is using the blood much more easily. So blood flow in the bone, I told the mechanical strain increases, release of stem cell is also we have discussed. Then in pancreas, definitely the blood flow is decreased. in pancreas because as I mentioned that there would be from non-vital organ, blood is flowing to the vital organ. Vital organ during exercise is muscle.

So there would be a shift of blood to the muscle. Then liver, obviously this is becoming non-vital organ in acute exercise. So liver blood flow decreases. And metabolism of course, liver can play a role for the metabolic support of the muscle. So, the blood flow is increased in the adipose tissue which is shown here and overall the blood flow to the cutaneous circulation is increased.

So, this is all that is happening for the acute exercise. Vis-a-vis if we see what happens to chronic exercise. Chronic exercise, when you are doing a similar exercise for a longer period of time, what kind of adaptation will occur? So, you can see here that say for example muscle, muscle is the major factor here. So, the resting and exercising blood flow decreases. Resting blood flow decreases because muscle improves its efficiency. So the resting blood flow has come down, the exercising blood flow has come down because it does not require that kind of flow now.

And the maximum flow obviously increases because normally now you may run up to your your when you are doing the acute you are sedentary you are untrained so you can you can go up to say for example 14 kilometer per hour maximum your ability, but now as your capacity improved the neurons capacity improved now you can go up to 18 kilometer per hour. So, your muscle require more quantum of blood so the maximum oxygen extraction increases and maximum blood flow also increase mitochondria increase, capillary is increase in the muscle, then the cavity if you locate to the heart, if you just see the images of the heart and what is cavity size increases, wall thickness increases as I told you, so your cardiac output increases, the blood flow and oxygen consumption is increased and oxygen extraction. blood volume increases, red blood cell increase and hemoglobin concentration decreases. Here it is mentioned decrease. Let us try to figure it out why the hemoglobin concentration here it is decrease because of plasma volume increase during exercise. As the plasma volume increase, so there is a possibility of the hemodilution or the that is called pseudoanemia.

So in that case the hemoglobin will remain same or lightly decrease when because of maybe foot strike. So some of the that is why it has shown some either same or slightly decrease level of circulating substance or the energy substrate it is definitely increase. So these are basically the images which can which you can carry for you to understand the acute and chronic response during exercise.

So these are the references. which I wanted to convey you. These are the books which you can follow for your further studies.