Introduction to Exercise Physiology & Sports Performance
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Lecture - 17
Endocrine responses to Exercise - Part 2

Welcome back to this course on Endocrine System and Exercise. Let us continue with part 2 of this session. I am Dr. Chandrasekara Guru. I am a Sports Medicine Physician from the Armed Forces Medical Services.

And we are learning in this session, about the endocrine glands of the body, the basic concepts which we have covered in part 1. In this part 2 of this session, we will focus on hormone responses to exercises, hormones regulating the exercise metabolism. Let us revise. We saw that endocrine glands are ductless glands. They secrete directly, the hormones into the blood and they act either near or at distant sites, specific target sites forming hormone receptor complex. Thereby they execute their function. We saw about various endocrine glands, the basic concepts, function of hormones, classification based on the chemical structure as steroid and non-steroid, further non-steroid into amino acid derived or peptide derived. We saw about the common mechanism of action, based on the different chemical structure classification. Various endocrine glands, there are the hormones secreted by them, the function and the target organ and action.

The endocrine glands that we discussed were the hypothalamus, the pituitary (anterior and posterior), thyroid gland, pancreas, you know secreting insulin, glucagon and somatostatin, the hormone secreted by adrenal gland, namely cortex and medulla as well as the sex hormones. We also discussed about the feedback mechanism that intricately, you know, regulates the hormone secretion and various functions in the body. Let us move ahead and see what is the relevance of some of the important hormones with respect to exercise in this session.

Growth hormone and exercise. As we know, hypothalamus stimulates the anterior pituitary to release growth hormone. The growth hormone has a direct effect as an anti-insulin function. That means, it acts on the adipose tissue to cause an increase in the triacylglycerol release, that is lipolysis; and it also inhibits the glucose uptake, thereby making it available in the blood. So, this results in sustenance of the physical activity when the individual is performing. It also has some indirect actions. What are the indirect actions? It stimulates the liver and other tissues to secrete somatomedins.

These are nothing but insulin-like growth factors and they have both skeletal and non-skeletal effects. In the skeletal system, they stimulate cartilage formation and promote skeletal growth. And the non-skeletal effects are they promote protein synthesis and cell growth. So, overall they

have an anabolic effect on the skeletal system as well as the non skeletal system. So, these growth hormone secretions, and the somatomedins are intricately regulated by a negative feedback mechanism.

What are the types of exercises that results in increased growth hormone levels endogenously? So, it is found that high intensity activities with reduced rest intervals, these type of workouts results in increased level of growth hormone post exercise. Also, supplement with nutrition which is rich in both carbohydrate and protein before and after workout is also found to increase the growth hormone secretion. So if you are a trainer, this is the takeaway point. If you want an anabolic effect of growth hormone, it is important that you also incorporate high intensity activities or workouts with short rest intervals and also advise your clients to take supplements, preferably liquid in nature during or after workout, which are, you know, composed of both carbohydrate and protein. Moving ahead, what about catecholamines and exercise? Catecholamines as we are discussed in the previous session, the catecholamines are secreted by adrenal medulla.

The hormones are epinephrine and norepinephrine. Stimulation of the sympathetic nervous system also causes stimulation of adrenal medulla to release these hormones in the bloodstream. So, catecholamine levels when you exercise, it increases up to 2 to 6 times, and it increases with the maximum physical activity. And, these increases with increase in duration of the activity as well as the intensity of the activity. What are the factors? As you grow older with age, the increase in the catecholamines increases. Between the genders; in male it is seen that there is increase in the release of catecholamines for a similar kind of intense workout.

When you compare resistance workout with an aerobic workout, especially in maximum resistance workouts, there is an increase in the, you know, secretion of catecholamines. This is because the maximum resistant workout will completely rely on the anaerobic energy source. And in order to promote anaerobic energy release, there is an increase in the sympathetic nervous system. And that also add on to increased secretion of catecholamines in the blood. So that is the reason why resistance, maximum resistance workout results in increase in the catecholamine drive.

So, what is the important application of this knowledge in your day to day practice? Catecholamines are the first set of hormones which are released as and when you start the exercise activity as a response to your exercise. And when you have increase in the production of catecholamines regularly, there may be, you know, an increased chance of sympathetic overtraining syndrome, which may lead to burnout. So it is important that you being a trainer or a sports scientist or a practitioner, need to advise the client to periodize the training. So it must have, you know, recovery fitted in so that you have the reduction in the sympathetic drive and

you give adequate time for recovery of this; both nervous system as well as the adrenal medulla related endocrine release of catecholamines. So this is important if you are a trainer.

Moving on to the next set of hormones that is the mineralocorticoids. Mineralocorticoids are basically produced by the adrenal cortex, that is 95% is the aldosterone. So, the aldosterone acts on the distal tubules of the kidney and they aid in sodium retention. Because of the sodium retention, you also have water retention and thus helps in avoiding dehydration during exercise. Further in exchange, you will have excretion of potassium or hydrogen ions, thereby they also maintain the body pH.

So because of this mineral balance, the nerve transmission which is basically because of the balance between the sodium and the potassium ions is maintained and it is seamless. It also aids in better muscle activity. So, thereby there is better muscle action during exercise. The aldosterone is regulated by another hormone called renin, which we saw in the previous session, which is secreted by the kidney. And this renin production aids in secretion of angiotensin II by the lungs, which again along with aldosterone, you know, it maintains the level of aldosterone or regulates the level of aldosterone.

The aldosterone is seen to progressively increase in the blood as and when the exercise duration and intensity increases. So what is the key point that you need to remember? Aldosterone is important for electrolyte and water balance. And in individuals who are obese, and who have insulin insensitivity, say diabetic, these individuals have increased in the level of aldosterone and they have increased chance of developing high blood pressure. So commonly, this is a syndrome called as metabolic syndrome, where we have obesity, we have diabetes and hypertension and other metabolic derangements, you know, clubbed together.

Moving on with the next hormone that is cortisol, how it influences your exercise. So stimulation of the pituitary, you know, it stimulates the adrenal gland by releasing the ACTH, (adrenocorticotropic hormone). And this, you know, stimulates the adrenal cortex to release glucocorticoids and the main hormone of the glucocorticoid is the cortisol. Cortisol is commonly called as stress hormone or catabolic hormone. Why it is called stress hormone, because it is released during stress with circadian rhythm, that is, the way your internal body clock is aligned with the external day to night variation, that is called as circadian rhythm. So these hormones are produced in a cyclical pattern in a pulsatile way as per the circadian rhythm or the diurnal variation.

So, the cortisol is produced when you are immensely in mental stress, also as a routine in the cyclical fashion as per the circadian rhythm. And this cortisol has quite a varied function. And as I mentioned, it is a catabolic hormone. So we know what a catabolic hormone does to the

energy stores. So basically, it causes liver gluconeogenesis, that is, it enhances production of glucose through other sources apart from the carbohydrate.

It also increases the protein breakdown to form glucose. It increases the lipid breakdown, that is called as lipolysis. So increases the lipolysis. In addition to that, it also decreases the glucose uptake. So because of which, the glucose is available in the bloodstream.

It also influences the immune function of the body. So it has an anti-immune function. So thereby, depresses the immune status of the individual. Moreover, it also influences the brain. It affects the mood of the individual.

So that is why I say when you have stress, you have mood changes, the mood varies. So the mood, memory, learning, they are all affected if you have an increase in the level of cortisol. So increasing in stress may be counterproductive because of this particular influence of cortisol on the brain. Also, an important aspect of cortisol is that when cortisol is released in the blood, it increases the permissiveness of glucagon and epinephrine. So, permissiveness is nothing but a mechanism of action by which a presence of one particular hormone magnifies the actual full effect of the other hormone.

So in this case, cortisol when it is present in the blood, it makes sure that the glucagon and epinephrine acts to its fullest. So that is the permissive action of cortisol. Having known about the various function of this, let us see what are the factors which modulate cortisol production. As the various factors are exercise, duration as well as the intensity. As duration increases or intensity is high, the cortisol production increases.

As we discussed, it also is influenced by the circadian rhythm. So, if you follow a good circadian rhythm which is standard and routine, the production is also cyclical. When this is disrupted, the production can also get disrupted. It has a major influence on cortisol production. Further about the fitness level, when the individual is already trained, the individual is already adapted to this stress.

So accordingly, the level will be modulated. And the last one is the nutritional status. If the individual is in a fasted state, there is an increase in the production of cortisol to basically increase the catabolic activity to provide glucose or energy to the active cells. So the cortisol increases during exercise and it remains high, even after two hours of completion of the activity. This is basically an important function of the cortisol to help in recovery of the individual to provide glucose to the immediate recovery for the active or the exercised muscles.

Further, when you compare between untrained individual and trained individuals; with training, the psychological stress decreases. So in untrained individuals, there is increased psychological

stress. So there is an increase in the production of cortisol levels. Whereas, as you get used to that and you are used to that particular situation or competition, trained individuals have less psychological stress and the cortisol level also will be slightly lesser. And one more aspect is sleep as well as the work shift or work shift occupations.

In both these cases, the circadian rhythm is disrupted and this may cause an increase in the cortisol level. What are the third group of hormones, namely the androgens or the sex hormones which are produced in the adrenal cortex. So, the adrenal cortex produces a third group of hormones called as androgens, which are called as the dehydroepiandrosterone. So these group of hormones are sex hormones collectively called as androgens. The ovaries produce predominantly oestrogen and progesterone.

Testosterone is predominantly produced by the testes; and adrenal cortex produces the dehydroepiandrosterone. So these three or four sex hormones together are called as androgens. As we have seen before, testosterone is responsible for increasing the sperm count as well as the secondary sexual characters and it aids in the improvement in the muscle strength as well as the difference in the phenotypic features with respect to the muscle as well as the appearance in the male and female after puberty. What about oestrogen? Oestrogen is converted again in the periphery from testosterone. So oestrogen is also formed in males as well, but then the quantity is less.

So the oestrogen functions in terms of mineralization of the bones. They also aid in growth plate maturation. They increase the insulin sensitivity, as well as decrease the cardiovascular risk and hence, oestrogen is considered as a protective hormone against cardiovascular diseases. So the resistance exercises, which are moderate as well as a moderate aerobic exercise, are found to increase the level of androgens. So if you are a trainer, you can also increase the level of sex hormones by incorporating resistance exercise and moderate level of aerobic exercise.

Whereas if the individual is, you know, exposed to long duration and, you know, intense aerobic activity over a period of time, there may be a decrease in the level of androgens as well. So this one needs to be considered. Hence the importance of periodization of training to accordingly manage the type and the, you know, intensity as well as the volume of the training activity in the training regimen.

So let us discuss a case. Here is an individual, Mr. Dinesh, 23 years old. He is a gym clientele. He just joined the gym and he wants to increase his muscle bulk. He is lean built and he weighs 70 kgs. His height is 170 cm. So what endocrine considerations with whatever knowledge that you acquired in our discussion will you include before starting the exercise regimen? So you will have to, you know, think over this. We will have to consider most of the key points, practical

aspects that we discussed in the previous session one, as well as the previous slides of this session. So I am giving just a few seconds for you to recollect. So let us progress.

If I were you, I would approach in this way. Say first what I will do is I will calculate the BMI because here in this case, I do not have any of the parameters. So I go with BMI. So I want to know how the individual's body composition is. So with the available weight and height, I calculated the BMI, it appears to be normal.

So less than 25 is considered normal, it is 24.22. So, if you have additional equipment with you to analyze the body composition, it can also give you lean body mass percent or fat body mass percent. So based on which you can exactly know what is the percentage distribution of lean mass as well as the fat mass of this individual. So as per the description, the individual somatotyping wise is lean build and he has a normal range of BMI. The focus would be mainly to increase the muscle bulk, because he is within the normal BMI range. So the focus is basically to improve the hormonal milieu in such a way that it causes anabolic growth of the muscle.

So you need to stimulate the growth hormone, what we know from our previous discussion growth hormone as anabolic activity, insulin as anabolic activity and in addition diet. If you have to have muscle growth, you need to supplement with an additional amount of protein. So you need to have a positive protein balance in your diet. So, I would advise the individual about the metabolic window concept.

So what is a metabolic window? It is seen post activity or a workout. So, for 45 minutes to 1 hour, you will have the entire body cells are receptive to the anabolic hormones, mainly the activity of insulin and growth hormone increases. Wherein there is increased uptake of glucose for the repair process increase protein synthesis for the immediate repair process. So, it is important that you also supplement the availability of glucose and protein in the blood. So, I would advise the individual to take a post workout carbohydrate protein mix preferably liquid so that easy absorption can happen within the 45 minutes period after the workout. Subsequently I will focus on the exercise training aspect of it.

In the initial weeks, I will focus on limited intensity, more focusing on the form so that I improve the neuromuscular adaptation. Subsequently, I would advise an increase in the maximum intensity workouts with short intervals. So these types of activities are found to improve the production of growth hormones, thereby the direct as well as indirect effects of growth hormone can be leveraged. I will also advise the individual to avoid catabolic state. So catabolic states happen because of production of cortisol or the stress hormone.

So, you would advise the individual to have proper sleep, proper nutrition and to avoid stressful conditions. So that is how I would have approached that particular case.

So moving ahead with another important group of hormones produced by pancreas and their influence on exercise or response by the pancreas to exercise. So the pancreas has a specialized group of cells called as islet of Langerhans; and the alpha cells of islet of Langerhans produces what you called as glucagon, and the beta cells of islet of Langerhans produces the hormone insulin. So all they are regulated. So whenever the blood glucose level decreases less than 100 milligram per deciliter immediately it stimulates the alpha cells and it causes secretion of glucagon. When glucagon is released into the blood it acts on the liver. It acts on the liver we all we have already discussed that glucagon is a catabolic hormone. So it causes breaking down of the glycogen to release glucose in the blood, thereby causing a rise in the blood glucose level. So, as the blood glucose level increases and it crosses 100 milligram per deciliter it immediately stimulates the beta cells in the pancreas to produce insulin.

The insulin is immediately secreted into the blood, which again acts on the liver to stop the process of you know glucose formation rather it will cause glucose to get converted into glycogen. So because of which it causes a reduction in the blood glucose level. Simultaneously, it also acts on the various cells of various tissues in the body and increases the uptake of glucose by the cells or the tissues thereby decreasing the blood glucose level. So insulin and glucagon if you have seen here, they are antagonistic.

They have opposite action. When you are in a fed state, immediately after having a meal you will have stimulation of insulin to reduce the blood sugar level. Whereas when you are in fasted state, when you are fasting there will be you know secretion of glucagon to break down the stored energy sources to produce glucose and increase the blood glucose level. Let us focus on insulin in this slide. So, the factors that promote insulin secretion into the blood are as we discussed blood glucose level more than 100 milligram per deciliter. When blood amino acid levels are high, that also increases the secretion of insulin.

So that is why even if you have a protein rich food, it will also help in secreting the insulin for promoting anabolic effect of insulin. Another effect is the GIT secreted hormones. Certain hormones are secreted in the gastrointestinal tract as you take your meal called the glucagon like peptides-1. So this directly acts on the Islets of Langerhans cells to stimulate production of insulin immediately into the blood. So we are aware that vagus, that is the parasympathetic nervous system through the vagus nerve supply the abdominal organs.

The stimulation of the parasympathetic nervous system again causes stimulation of pancreas and by which it again causes secretion of insulin into the blood stream. Whereas stimulation of sympathetic nervous system inhibits the insulin secretion. So when you have an increased

sympathetic nervous system stimulation which happens in exercise there will be inhibition of insulin production. So thereby you will have availability of glucose in the blood for energy source. So the insulin's major function here is to regulate the blood glucose level.

So what is the effect that it has? We were discussing about the anabolic effect. The effect that it has on most of the cells or the tissues is, it increases the glucose uptake except for those cells which are exercising; because we said sympathetic nervous system will be the availability of catecholamines. So this will inhibit the effect of insulin. As such it is required that exercising muscle need glucose. So insulin will not increase glucose uptake in the exercising muscle as well as with respect to brain and liver.

Whenever it increases the amino acid uptake thereby it also favors protein synthesis. It inhibits the protein breakdown. So that is an important anti-catabolic effect or an anabolic effect you can say in the tissues. What it does in the adipose tissue? In the adipose tissue, it causes increased deposition of fatty acid and the triacylglycerol to form a storage form of lipid, and it inhibits the process of lipolysis.

In the case of liver and muscle it increases the glycogen synthesis. Glycogen synthesis is increased, and thereby it also inhibits glycogenolysis, that is breaking down of glycogen is inhibited by insulin. In the liver in addition to increasing glycogen synthesis it also increases the fatty acid and TAG (triacylglycerol) synthesis. So it thereby promotes lipid storage and it inhibits glycogenolysis. So, in the resting muscle and adipose tissue you require insulin for glucose uptake. Whereas in the exercising muscle the glucose dependent transporter is not required it is the uptake by GLUT-4.

So, insulin is not required for exercising muscle to consume the glucose or transport the glucose from blood into the muscle. And that is one of the reasons why regular exercise is found to increase the insulin sensitivity and is an effective tool in improving the insulin resistance, that is type 2 diabetes mellitus.

So let us discuss a case here we have Ms. Kavya she is a young diabetic who takes insulin for blood glucose control. What do you mean by type 1 diabetic mellitus, I just mentioned about type 2. So yes diabetes mellitus happens because of increased level of blood glucose and they have different types. Type 1 would mean that the individual has reduced or no production of insulin because of inflammation which happens in the islet of Langerhans cells.

Generally it is genetic, and it can be triggered due to various environmental conditions and it is generally seen in younger individuals. So these individuals are mainly dependent on insulin as exogenous in insulin as the main treatment modality. So, in such individuals what is the complication that you would expect and how can you prevent it. So it is important that you

know about this particular aspect for you to handle such clients. So, while exercising the blood glucose level may decrease drastically because the glucose is also used as a source of energy and that may lead on to severe hypoglycemia and may even lead on to diabetic hypoglycemic attack or coma.

So hence it is important that insulin dose has to be carefully titrated based on the blood glucose level and the exercise duration and intensity. It has a measure of emergency requirement: oral glucose solution should be available with the individual during workout so that if the individual identifies the symptoms can immediately you know take the oral glucose solution. Further with the advent of the latest technology you have various methodology to monitor the continuous glucose. So these kind of monitoring can also help in better understanding the behavior of insulin with respect to the various exercise the individual is performing; and accordingly the insulin dosage can be you know, iterated. To summarize what we saw about growth hormone handles role in exercise, the various effects of catecholamines on the tissues during the exercise and how it enables you know sustenance of the activity.

We also saw the importance of mineralocorticoids in terms of fluid and electrolyte balance. We discussed the important response of cortisol to exercise, and its release as a response to psychological and mental stress as well, and its role in you know augmenting the effect of the other catabolic hormones as permissiveness. We also discussed the androgens and different types of hormones encompassed in this category of androgens, and their role or you know influence of exercise on you know secretion of the androgens. We also discussed in detail about the effect of insulin and glucagon. There you know feedback antagonistic role as well as the maintenance of blood glucose level and the application of the knowledge in terms of hydrating the dose of insulin in the insulin dependent or type 1 type of diabetic patients. So for those of you who are interested in further in depth you know reading about the concepts which we discussed you can refer to this standard textbooks of exercise physiology and sports performance thanking you. Thank you.