Introduction to Exercise Physiology & Sports Performance
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Lecture - 18
Endocrine responses to Exercise - Part 3

Welcome to this NPTEL course on introduction to exercise physiology and sports performance. So this module on endocrine system and exercise. This will be the last and final session of this module. I am Dr. Chandrasekara Guru. I am a sports medicine physician with the Armed Forces Medical Services.

So we are learning about the endocrine glands of the body, the basic concepts namely the functions, mechanism of action, classification of hormones, the hormone response to exercise and the hormones function in regulating the exercise metabolism have been discussed in part 1 and part 2. In this final part 3, we will discuss certain case scenarios and with respect to the hormone and their function in exercise and sports. Let us revise the concepts that we have gone through in the previous two parts.

So, we saw about the various endocrine glands, the basic concepts, the different classification of hormones based on the chemical structure, the mechanism of action of these hormones, how the hormone receptor complex functions and we also discussed about the various endocrine glands and the hormones that are produced, the target organs as well as the major functions. In part 2 of this module, we discussed about the effect of or the response of these hormones to exercise, as well as the importance in carrying forward the knowledge in your practical day to day application in exercise training. We discussed growth hormone and its importance in exercise, how it varies with respect to exercise, and how the knowledge can be utilized to promote anabolic effect of growth hormone, induce the skeletal and non skeletal effects. We studied about catecholamines which is secreted from the adrenal medulla, the relation with sympathetic nervous system, how they respond, what is their role and function during exercise. And, we discussed about the hormones produced from the adrenal cortex namely the mineralocorticoids and the glucocorticoids in the androgens. We discussed the importance of the electrolyte and water balance that is regulated by the aldosterone during exercise, the effect of cortisol namely the stress hormone and how it varies with diurnal variation and its importance and various function and what are the factors that you know regulate the production of cortisol during exercise, what are the various functions of androgens, the testosterone, estrogen and progesterone as well as the dehydroepiandrosterone produced in the adrenal cortex, and what is their role in terms of you know promoting muscle growth and increasing performance during exercise.

We also discussed in detail about the hormones of the pancreas, namely the insulin and glucagon. Insulin tries to increase or decrease the blood glucose level, and glucagon as an antagonistic effect to increase the blood glucose level causing catabolism. So the opposing effects have been discussed in part 2 of this module. We also discussed about the functions of insulin, and what are the various effects that it has on various tissues, the liver, muscle as well as the adipose tissues. We also discussed a few case scenarios with respect to the you know application of the information on endocrine and hormones in your day to day exercise training and framing of exercise regimens. So with this background in this session we will discuss various case scenarios and we will try to apply the knowledge that we have gained in the previous two parts of this module.

So case 1 is Arun, who is a marathon runner, with respect to growth hormone response to endurance training. What must be the intensity at which Arun must train for a favorable growth hormone release? So you know about growth hormone, how it is released, what its function is, the type of exercise training that you need to incorporate in this endurance training as a marathon runner in order to have a favorable growth hormone release. So from the scenario we know that it is an endurance activity. So, various studies have shown that specifically in endurance activity with constant load, the growth hormone levels tend not to increase, and it almost stays parallel to the levels of blood lactate and the catecholamines. So conversely you can assume that when you increase the level of blood lactate by means of training, or by increasing the catecholamine levels in the blood there has been an increase in the levels of growth hormone as well.

So, this information can be incorporated in your practice. So how do you increase the lactate blood lactate level in the blood? It is by training at lactate threshold or beyond lactate threshold. So this would help the individual aid in increasing the blood lactate concentration, and training at such intensities is also found to increase the growth hormone levels. In addition if you also train at maximum intensity, you are also triggering the anaerobic bioenergetic pathway, so that release results in increase in the catecholamine release, which again also favors increase in the growth hormone levels post activity. So this information is important for you to understand and incorporate this in your day to day training.

So in this case Arun has to incorporate lactate threshold training as well as maximum intensity training in his training sessions or periodization in order to have better growth hormone response.

Let us move on to the second case. So here is Vishwa who has joined your gym and has been doing resistance training since last two months. He is regular and has gained good muscle strength as well as size. So what hormone effects would have contributed to this progress in

strength? I am sure you would have incorporated this you know concepts in your practice and hence you would have seen good muscle strength and size.

So what are the hormone effects which would have contributed to this progress? I will give you a moment of time to you know think over. Continue. So when you start resistance training initially, it stimulates the hormonal change, and because of the hormonal change there is increase in or better neuromuscular response to the training, and this results in increased muscle strength. However with ongoing training with progressive overload principle this increased in the testosterone as well as growth hormone. So we know testosterone favors muscle growth, growth hormone also has anabolic effect on the skeletal and non skeletal tissues.

So because of which, there is an increase in the muscle force production, as well as increase in the size of the muscles by means of hypertrophy. So this is the reason why you have an increase in muscle strength as well as size in this case. Heavy resistance training incorporated with even one session has been found to increase testosterone levels. So, it is important that you incorporate at least one or two sessions in a week with heavy resistance training in the weekly program; so that you trigger the secretion of testosterone and growth hormone. More or less, maximum intensity also increases the catecholamines, and together these result in increase in the force production of the muscle.

So that is about that part of it. In the same individual, what type of resistant training in terms of the FITT principle. FITT is nothing but frequency, intensity, type and timing principle, which is required to achieve the favorable hormonal milieu. So it is shown that in resistance training when you incorporate resistance training of large muscle group namely the gluteus, the quadriceps by means of doing a deadlift or a power clean or a squats. So large muscle groups are involved, and your resistance should be maximum beyond 85% of one repetition maximum.

And the third important aspect is, when the volume of exercise is moderate to high. What I mean in this is that you need to have multiple sets of such heavy resistance training. However, you give good adequate interval between the sets, but not between the repetitions. So such kind of resistance training incorporating such principles of FITT principle in your resistance training is found to increase the hormonal which favors muscle size as well as growth.

Let us move on to another case, case 3. She is Miss Kavya, she is 24 years old female. She is a trained half marathon runner, and she has trained over last 10 weeks for this half marathon. A study was done as a research in which they estimated a plasma insulin level and glucagon values during the marathon. And it was found that it was at par with their pre-exercise resting level. So with whatever knowledge you had, what could be the reason for relatively low levels despite an exercise state.

So we have discussed that most of the hormones as the exercise progress, tend to increase. However, in this case, you have seen that the measured plasma insulin and glucagon are almost similar to the resting state. So what is the reason for this individual was trained for an half marathon? Let us see what the reason is. So with exercise training, there is increased insulin sensitivity, which we have discussed previously and this increased insulin sensitivity is there in both muscle as well as in the liver. And this causes a better hormone receptor affinity, which results in, you know, better desired action at a very low concentration itself.

So basically because of increased insulin sensitivity, the low level of insulin itself is able to trigger the receptor, form a strong and increased affinity hormone receptor complex, which delivers the desired action which would have been done by more level of hormone which is available in the blood. So, that is an important adaptation that happens with endurance training for a period of time. Secondly, the endurance training per se, you also have better fat mobilization because of the adaptation that happens in the hormones, catabolic hormones. So they mobilize the fat, and they result in catabolism of the fat, which is lipolysis, which results in an alternate source of energy fuel for the endurance training. So thereby, the need for insulin is low to maintain the blood glucose level, because here for a prolonged period of time during the submaximal state, it is the fat which gives 50% of the energy source as fuel.

Also, during exercise as such exercise causes increase in the release of catecholamines, which again inhibits the action of insulin or secretion of insulin. So, these are the probable reasons why the level of insulin was almost equivalent to the resting state level in this particular individual, who has undergone exercise training over a period of time for a long distance run.

Moving ahead with another case, it is quite an interesting case. She is Vidya and she is a regular cyclist. She goes for long cycling events, and she says that even missing one day is not there in her schedule. So why she says so? Because she says cycling calms her mind and gives her better clarity, reduces the confusion. She says that, at the end of the session when she completes, she feels a good high or kick after the cycling session. So that is why she does not want to miss the session, she wants to continuously take part in a cycling session. And it is also supposed to relieve her stress. That is one of the main reasons that she again performs cycling without even missing a day.

So with all these inputs, what do you think is the hormone that is involved? Yes, there is a specific group of hormones, which are kind of endogenous opioid peptides. They resemble the action of opioids, and these are called endorphins. They are produced by the body, and they increase about five times when you do a physical activity or exercise from the resting level. And these endorphins are found to increase the pain tolerance. You can tolerate more pain, it means, the appetite is better controlled, and it also reduces the anxiety level, stress level, anger and also confusion.

Further, it is found to increase with increase in moderate level of intense aerobic activity. When you do resistance training for a longer duration with a light resistance, I mean to say the resistance that you will have will be around 40 to 60% of weight resistance, and performed over a longer duration with long rest intervals. So this almost turned out to be a circuit training kind of a thing, which almost triggers an aerobic metabolism as well. And such kind of activity is found to increase the release of endorphins. And endorphins, because of their effect on the central nervous system, the calming effect they have on your mind, you will find trained athletes, elite athletes, you know, frequently involving the activity for the sheer high that they gain from that activity per se.

So that is even called for runners as runners high. So, that is what is the effect of endorphins. So Vidya in this case is also experiencing these kinds of, you know, good emotional as well as mood related outcomes because of the release of endorphins. And this is one of the reasons why it is also attributed to the, you know, positive outcomes in mental health with the effect of exercise. Let us discuss something about the metabolism of glucose.

Here we have Ankur, he goes for a five kilometer run. What do you think of how glucose metabolism is regulated? So in this case at rest, Glucagon is which is present in the body by its action of catabolic activity, it causes glycogenolysis, because of which you have an increase in the blood glucose level. When you start doing the exercise, there is an increase in the secretion of glucagon. So you need, you know, glucose for your continuous nutritional supply and energy supply. So glucagon along with catecholamines, catecholamines as we know, are the first set of hormones to be released because of the sympathetic stimulation.

So catecholamines and glucagon again act on the liver as well as the muscle, and they initiate the process of glycogenolysis and start glycolysis thereby yielding the increase in the blood glucose. Now as the exercise activity progresses, when the individual reaches about half an hour into the activity, there is an increase in the secretion of cortisol. So we know that cortisol has a permissive action; wherein it exaggerates the action of glucagon and catecholamines. So they are already available in the blood with the release of cortisol, the action is further compounded, which further results in a catabolic effect where the alternate source of fuel that is protein is catabolized. So protein is broken and that results in glucose undergoes gluconeogenesis to get into the glucose pathway to form increased carbohydrate as a source.

Subsequently, the growth hormone which is again secreted at 30 to 45 minutes of the activity, further increases the mobilization of free fatty acids with this anti insulin effect, which we have seen. So as a direct action growth hormone has on the adipose tissue to increase the free fatty acids, and thereby it spares the carbohydrates. So because of which, there is increased availability of carbohydrate for the immediate reserve. Subsequently, with the intensity

increasing there is increased release of catecholamines. So we have discussed that as a intensity increases towards the maximum there is increase in the catecholamines which are released, which results in increased utilization of muscle glycogen to give anaerobic energy.

It also acts on the liver to increase the glucose level, and thereafter, increases the blood glucose. This glucose which is formed in the liver is released onto the blood and this is used by the muscle, uptake is done by the muscle to replenish the utilized glycogen stores in the muscle. Subsequently as the glucose level in the liver comes down, this further triggers further secretion of glucagon and cortisol, which increases gluconeogenesis through the other sources like fat as well as through the protein. So thus, as the intensity and the duration progresses, the hormones have a catabolic effect by kind of using the glycogen stores first from the liver, and the muscle and continuously replenishing them. Meanwhile, when the stores get depleted, carbohydrate stores get depleted, the hormones namely the cortisol and the glucagon acts at the lipid store as well as at the proteins; and they are broken down to get converted into the blood glucose and which again is utilized by the muscle to provide the necessary energy.

So, that is how various hormones during the process of the exercise contribute to maintain the carbohydrate level, to give constant energy to the activity.

Let us discuss the last case in this session that is we have with us Mr. Rahul who is an ultra distance runner. When he runs for long durations, he utilizes fat as a major source of fuel in the submaximal range. So with whatever knowledge you have gained, what do you think is the influence of you know endocrine hormones on the fat catabolism sparing the carbohydrates.

So during the long duration run in the endurance activity you have free fatty acids as the main source of energy; and these are broken down from the stored fat by the action of a hormone called lipase; and most of the hormones act at this level to increase the rate of lipolysis. So thus the rate of lipolysis is stimulated by decreasing the level of insulin; why, because insulin is an anabolic hormone. So insulin level if it is low it favors catabolism. Second thing is the availability of increased levels of catecholamines. So catecholamines are the immediate hormones, which are released after an exercise activity, and they subsequently increase as the exercise progresses.

So catecholamines are essential to cause lipolysis. Thereafter comes your cortisol and growth hormone as the exercise progresses beyond 45 minutes to 1 hour. So during that time, you have the effect of cortisol and growth hormone contributing to the fat metabolism, and the yielding energy to the activity.

So from the discussion of this module on endocrine system and exercise the key takeaways that you need to consider, is that endocrine along with the nervous system collectively called as the

neuroendocrine system, is the main communication system. Both the nervous system and the endocrine system acts as a communication as well as an integration system between the internal inputs as well as from the external stimulus.

The other aspect is that, though there are multiple endocrine glands there is one true master gland that is the hypothalamus. So, hypothalamus is the one which integrates this nervous system. What you want to kind of do? the voluntary requirement, the learning and memory aspect of it, the emotion and the mood aspect of it are all integrated with the endocrine system. So this happens because of the hypothalamus. So at the hypothalamus the integration of these two different systems happens, and thereafter a common pathway happens because of the various release of hormones; and it also controls the feedback mechanism and regulation of these aspects as well. And the feedback mechanism is a very closely knit system; wherein, each and every minor change in the levels of either the neural response or the humoral response, that is level of blood molecules in the blood or the hormonal response, by either of these three mechanisms the feedback is closely titrated.

So thereby you have a very specific effect through the target organ. So the hormone, even though it is secreted in the blood at a very distant or remote place, it still finds its way to the target site; that is mainly because of the availability of certain specific receptor and the target sites. And, because of their interaction not only the hormone level, the availability of the number of receptors as well as the interaction that happens between the hormone and the receptor like a lock and key mechanism; that triggers this system of or system of you know chemical reactions or activities within the cell, which results in the desired effect. The desired effect may be to increase certain proteins, or it modulates certain enzyme activity, or by influencing the secretary function of the cell. So, these are various ways by which the hormone functions to execute the required desired action. More importantly, as a practitioner what you need to incorporate in your day to day exercise training and prescription protocol is that, the availability of right nutrition as well as the exercise training principles namely the periodization, the FITT principle with a variety of training, progressive overload; all these principles with a background of adequate right nutrition can provide a good environment for right hormonal milieu.

So what I mean by the right hormonal milieu is that, a favorable condition for anabolic effect to take place and catabolism to be at the minimum. So because of which, you can promote a better muscle growth and response to the exercise using the endocrine system. So I think these are the main takeaways of this module. Those of you who are interested in further going and reading in depth you are directed to these standard textbooks of exercise physiology and strength training and conditioning by NSCA. Thank you.