Introduction to Exercise Physiology & Sports Performance

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Lecture - 25

Adaptations to aerobic and anaerobic training - Part 3

Welcome back to this part 3 of the present module on adaptations to aerobic and anaerobic training. I am Wing Commander Chandrasekara Guru. I am the sports medicine specialist at Armed Forces Medical Services. And you will be learning about these aspects and we have already covered about the aerobic training adaptations. And in this part 3, let's focus on the anaerobic training adaptations that happens in the physiological system.

So, to revise, in the previous part we covered about the muscular adaptations to aerobic training, the metabolic adaptations that can be assessed again to aerobic training, various neural and endocrine adaptations that happens in the physiological system because of the aerobic training methods. We also discussed about the change in the body composition that happens because of the aerobic training methods, wherein you have predominant decrease in the fat percent as compared to the fat free mass percentage. We also saw that limitation, what is the various hypothesis that is available, the utilization hypothesis and the cardiovascular hypothesis, wherein more and more research is accumulating in terms of cardiovascular limitation or aerobic performance. We also discussed about various factors that influence the adaptations that happens because of the aerobic training methods. And we discussed few case scenarios, wherein the fatigue ability in a non-endurance sports athlete and fatigue ability in an endurance sports athlete, what is the approach, what are the various possibilities and how as a exercise specialist and trainer, how you will have to approach these clients of yours who have such problems. So, having known about the aerobic training methods and their various adaptations, let us move on to the anaerobic training methods.

So, to recapitulate, exercise training can be broadly divided as aerobic and anaerobic. The anaerobic training is mainly focused on the adaptations involving the neural system and the that is the nervous system and the muscular system. So, you also target to trigger the various energy systems and the pathways towards the anaerobic bioenergetics that is your ATP PCR energy source and the anaerobic glycolytic system, which gives you immediate ATP for the exercise activity. So, this results in increasing the sports performance that is

specific for the anaerobic sports and that is improved in terms of muscular strength, power, muscle endurance, body composition and the motor performance as such in terms of the movement and the skill and the economy aspect of it.

So, the adaptations that happens with respect to the anaerobic and the resistance training are again predominantly it is important to trigger the nervous system and the muscular system. So, the neuromuscular system forms the most important adaptation that happens because of the anaerobic training. You also similar to the aerobic you also have adaptations that happens at the level of the energy systems and as well as the endocrine adaptations.

So, seeing going through these adaptations that happens neural adaptation is the first one to happen as you compare with the muscular adaptation, when a sedentary or an untrained individual is kind of exposed to resistance or anaerobic training. So, the various adaptations that happens in the nervous system, we have already you know kind of add a glimpse into the neurophysiology and its relation with exercise in one of the modules. So, those of you who are new to this particular module, I would again urge you to go through the neurophysiology and exercise module to understand the terminologies that I shall be covering in this particular neural adaptation. So, most of the things I have covered in that. So, you will have to go through that to understand this in a better way. So, the adaptations that happens because of the anaerobic training in neural system is the central adaptation motor unit. The motor unit is the primary you know unit that fundamental structural unit that is responsible for the conduction of the electrical impulses to the exercising muscles. So, the adaptations happen at the motor unit level as well. The motor unit the nerve finally, terminates into the muscle and they form something called as a neuromuscular junction. So, there are adaptations that is happening or taking place in the neuromuscular junction as well. And because there are certain kind of reflexes which are involuntary that happens at the level of spinal level itself which we have discussed earlier in the neurophysiology module. And that potentiation is also there with respect to the reflex activities that happens in the spinal level. So, let us delve in detail central adaptations obviously with training you have improvement in the confidence level, improvement in the intent level. So, there is increase in the motor cortex activity at the level of the cerebral cortex per se. So, that enables you to have a better central adaptation in the neural system. And this also is important to recruit maximum number of you know motor units especially the fast twitch motor units. So, if you have gone through that module, you will understand motor units have different recruitment of the motor units depends on the type of activity. And accordingly, the motor units are divided into the fast twitch and the slow twitch. So, for an anaerobic or a resistant activity you need fast twitch motor units to be recruited more. So, that happens because of the central adaptations in the system. What are the adaptations that happens at the level of motor units? So, the rate at which the motor unit fires and the frequency at which it fires both are increased because of the training methodology of anaerobic type. So, you we have discussed about the summation principle. So, this is

enhancement of the summation principle that helps in continually maintaining the muscle contraction. So, that is an important aspect there is an adaptation in terms of the continual firing both in terms of frequency and rate. So, thereby the muscle contraction continues until the activity is done. The other important change is the size principle. So, depending on the training method, because of the anaerobic training method the type of motor units that is being recruited varies as per the demand. So, this is again you know efficiently carried out in the nervous system because of the training methods. The third important thing is selective recruitment. Say for this basically means that the selective stimulation of eye threshold motor units for specific type of movements. So, practicing or imparting training in specific type of movements enables to stimulate the collective recruitment of the motor units to perform that job. So, that helps in maximal effort that is delivered to the muscle per say. And the fourth important aspect is the synchronous activity of firing. So, the firing which is happening at the level of the motor unit is also made synchronized. So, that helps to kind of stimulate the muscle at the right time at the right amount. So, that helps in developing the adequate amount of force that is required to carry out the activity. So, all these changes happen in the level of motor unit.

At the level of say the neuromuscular junction, the neuromuscular junction area per say increases and also the end plate the perimeter length and the area as such also increases. So, there is more chemical mediators that is released in the neuromuscular junction simultaneously there is also increase in the number of receptors at the level of muscular end plate. So, these are the changes that happens at the neuromuscular junction. At the level of the, there are certain reflexes which happens at the spinal level which we had discussed. So, that also get potentiated I would mean this would mean that there is increase in the response of the reflex activity at the level of the muscle spindle and also at the level of the as a stretch reflex. So, this increases the elastic property the involuntary elastic property is increased in the muscle. So, because of this 20 to 55 percent increase in the reflex response there is better neural response and better muscular activation. So, the neural adaptations generally are the one to happen earlier in the early phase of training. Generally, it happens by 6 to 10 weeks of resistance or anaerobic training. After 10 weeks of training, you will have predominant strength gain correlated with the muscle hypertrophy. So, we will see about muscle hypertrophy in the muscular adaptations. And there is also concept called as cross education as a part of the in studies where only in right side when they have done certain activity and trained the nerves there is neural adaptation that has happened on the other side as well. So, that is called as cross education. Just by doing activity in one side the body and the nervous system learns and concomitantly you also have the learning effect transferred to the opposite side as well. So, this kind of adaptation also happens with cross education in the nervous system.

Coming on to the muscular adaptations what are the adaptations that happens at the level of muscle you have the change in the muscle fiber size. The transition happens in terms of

fiber type similar to the aerobic training also you will have change in the muscle architecture per say to produce better force. And enzyme activity happens as well in anaerobic training as well compared to the aerobic also you have change in the substrate level concentration the source of fuel also is you know stored more in muscle which is involved in the activity. So, because of these changes that happens in the muscle or the adaptation that happens in the exercising muscle we have better anaerobic performance in terms of strength, power and muscle endurance. So, these are the five changes or adaptations that happens in the muscle.

The most important change that is relevant or one needs to know in detail is the muscle hypertrophy. So, muscle hypertrophy is nothing but increase in the cross-sectional area of the muscle it is not only that the protein which is involved in the contraction of the muscle these are the contractile proteins I think in depth we would have studied in depth in the skeletal muscle physiology it is been covered under different module. The contractile proteins are actin and myosin. So, not only that contractile proteins are increased it is also the supportive proteins of the framework which is the non-contractile or the structural proteins these are the titin and nebulin. So, these are also increased. So, there is cumulative increase in the protein level and the muscle because of the exercise, the resistance training that is involved. So, what are the pathways? So, those of you who are interested further into knowing what is the cellular level change that has resulted in increase in the muscle size, the resistance training causes stimulation of certain pathways which leads on to protein synthesis. The commonest pathway is the mTOR. So, you will have to just remember mTOR pathway is an important pathway that results in better protein synthesis in the muscles because of which there is increase in the size of the muscle. We need to know what are the factors that favor this protein synthesis when you give resistance or anaerobic training. So, the factors that favor are, in addition to the training, also the availability of nutrients. So, if you give more of a positive protein nutrient rich in which nutrient that is, in terms of carbohydrate and the protein intake that improves the protein synthesis. We will see in detail subsequently also the availability of the amino acids to maintain that positive protein balance in the timing of the nutrient intake when you are taking these nutrients during the resistance training that is again important and the type of mechanical stress we are giving. So, that depends on the FITT parameters that we generally discuss must be frequency intensity type and timing as well as the parameters that is relevant to the resistance training in terms of load and the phase at which the training has to be done and the rest interval which we have discussed in detail during the module in the module of exercise training principles. Then the fifth important aspect is the hydration level of the muscle. So, that is again important also the correct stimulation of the anabolic hormone response. So, all these factors favor a positive protein synthesis which further aid in increasing the size of the skeletal muscle or the exercising muscle is called as hypertrophy. So, the significant hypertrophy to happen in an exercise training or resistance training it takes about 16 weeks. So, 16 weeks is the time you know to actually see

significant level of muscle bulk improvement in or change in the muscle bulk that you would expect in your client if you are giving a resistant training, but again there are various other factors that determine this significant hypertrophy to happen.

So, the other important aspect in muscular adaptation is the muscle fiber type, muscle fiber type here it is more of an anaerobic training. So, you will have to have more recruitment of type 2 in aerobic we discussed that type 1 is of more oxidative. So, you need more type 1 and there is hypertrophy of type 1 whereas in case of anaerobic training will have more of type 2 which are involved and the transmission that happens is from type 2 x to type 2 a. The architecture also changes say for example, this is a picture which I am showing something similar to leaf and certain muscles the muscle fibers are attached like the pennate. So, the angle of pennate is important. So, there is a central rim then you have the muscle fibers attached like the leaf as shown here. So, the angle of pennation also increases when the angle of pennation increases the muscle fibers large number of muscle fibers are actually accommodated in a single entire muscle. So, the production of forces also accordingly increased. So, and not only that the fascicle length also increases. So, that is the change that happens in the muscle architecture at the level of ultra structural level of the muscle you will have changes in terms of the enzymes wherein you will have predominantly anaerobic glycolytic enzymes which are getting activated. You also have better buffering capacity why it is important we have studied in the module of bioenergetics that when the glycogen gets broken down and enters the anaerobic glycolytic pathway you will end up in development of a final you know molecule which is lactate. So, we also discussed which is the reason for fatigue whether lactate is considered or not and we have evidence now saying that lactate is actually an energy source it is not the actual reason, but with lactate you also have accumulation of H + ions. So, the H + ions cause increase in the acidic nature at the level of the muscle which again impairs the further breakdown and further enzymatic activity of various enzymes. So, that H + ions have to be buffered by the body if you want to continue to produce or perform the anaerobic glycolysis to produce energy. So, buffering capacity is very essential to alleviate the effect of H + ion accumulation. So, that is one of the reasons that is one of the adaptations that happens in the ultra-structural level of the muscle also you need to have a more ATP and creatine phosphine substrate which is available in the local muscle. So, that you can release energy faster. So, the substrate level content also increases in the type 2 muscles

Let us discuss a case. So, Mr. Balwant Singh is a gym trainer he has three clients where freshers join the gym, he has been giving the same training to all these three people initial conditioning and thereafter they found that when he assessed they showed improvement and he finds that the gym trainer finds that one among the three is not showing any change in muscle bulk compared to the other two in the first eight weeks of training. So, with whatever knowledge that you have, you know we discussed in the previous slides, what is your opinion and what may be the reason in this particular case wherein with the same type

of training one individual is not showing a change in the bulk. So, let us discuss this particular case. So, these are novice gym goers. In the initial period, we discussed that there is improvement in strength, but that is predominantly contributed by neural adaptations to eight weeks of training. Thereafter, beyond eight to ten weeks of training, the strength gain is attributed to an increase in the muscle hypertrophy because of the protein synthesis, right? But then, significant hypertrophy happens beyond 16 weeks of training. So, here in this case, the individual is still in the, uh, phase of the early phase of training where significant hypertrophy may not have started. So, here in this case, the client is normal, absolutely nothing to worry. You will have to just, uh, be aware about the, uh, the kind of adaptations that could happen to a resistant training workout. So, in this case, you will have to just monitor how he is able to improve his 1RM, which is being assessed, uh, you know, every week or every month to change his load. The thing that one has to focus here is the principle of overloading. So, principle of overloading is essential to have a significant effect, uh, to increase the muscle bulk and secondly, the principle of specificity. So, if the goal is to have muscle bulk, then this principle of specificity has to be incorporated in your training parameters. The training parameters, in terms of the load, in terms of the number of repetitions, and also in terms of the rest intervals. Accordingly, the muscle bulk will vary. So, that needs to be incorporated in the training program. Also, the gym trainer should understand this concept of, or remember, recollect we have discussed during the previous parts with respect to the aerobic training method. Similarly, here also you have something called as high responders and low responders. So, the, the coach here is giving the same type of training, right? So, probably if the improvement is not there in 1RM, then you will have to tweak the kind of, uh,

What are the metabolic adaptations that happen with respect to anaerobic training. So, the anaerobic training metabolic adaptations are targeted towards ATP PCR, and number two is glycolytic system, the anaerobic side of the glycolytic system, right? So, in the ATP PCR, the efforts when the, when the efforts are increased, uh, in kind of physical activity lasting only up to 6 seconds, you will have the triggering of the ATP PCR system. And this is commonly seen in weightlifting and splitting type of activity. Whereas, glycolytic system generally, the training, uh, period is generally 30 seconds to have the stimulation of these particular energy systems. So, this results in stimulation of certain glycolytic enzymes. So, that these systems can immediately get activated and produce ATP for the desired activity. So, the enzymes commonly that are targeted or which gets adapted or which the enzymatic activity is increased in terms of phosphorylase, in terms of phosphofructokinase, and in terms of lactate dehydrogenase. So, these are the three enzymes where the anaerobic training results in, uh, kind of adaptations in these three, uh, anaerobic glycolytic pathway enzymes. Okay. So, the performance increase is generally attributed to the strength gain rather than the energy system adaptation. So, if you consider the difference here with respect to the metabolic adaptation between the aerobic method of training and anaerobic method of training. Aerobic, we said that the aerobic method, uh, definitely targets the

energy metabolism in terms of oxidative system. And that is one of the reasons why you have, uh, better utilization of oxygen to produce ATP, right? So, that is the utilization theory. So, whereas in anaerobic method, the predominant kind of adaptations are happening in the level of neuromuscular thing. So, it is not mainly to attributed to the energy system that is being triggered is mainly attributed to the neuromuscular performances that has neuromuscular adaptations that would result in better anaerobic performance.

Okay. So, what are the changes that happen in the level of connective tissue? Connective tissue is also important in addition to the muscle changes because connective tissue includes your ligaments, tendons, the capsules, also the cartilages as well as the bone. So, these form the structural framework for the muscle to produce force. So, in the connective tissues, you will have with resistance exercise there is an increase in the mechanical loading which again triggers the bone formation, osteogenesis. Okay. And in addition to that, you also have an increase in the bone mineral density because of which you have better distribution of minerals that are responsible to, uh, uh, the bone strength. And the adaptations, uh, to take place in a bone, it takes about 6 months of, uh, resistance training. So, 6 months of resistance training would result in adaptation to take place in the bone. And what type of, uh, resistant training would have more kind of adaptations they are more, uh, when you, we are seen in cases where you have free weights kind of, uh, training own body weight training where multiple joints are involved and the entire, uh, uh, specific group of muscles are involved that causes stress on the specific, the bone. So, so that is important also high impact activities, uh, like say for example, running activity which is bonding in nature that is found to increase the bone strength in the femur. So, similarly this is again specific to the type of activity that is being done. So, if you want to have the bone adaptation at the lower limb then you will have to go for more of predominantly bonding activities of the lower limb. So, if you want to have upper body related thing then it has to be predominantly upper body related activity. So, the principle of overload, principle of specificity and variability are key for bone growth.

The endocrine adaptations are very important in resistance and anaerobic training because the it is seen that with acute exercise of, uh, resistant training you will have increased the level of testosterone growth hormones, uh, insulin like growth factors and the cortisol level. So, all of these are important to have a better protein synthesis. So, when these hormones are increased when you have the training parameters in terms of increased load and decreased rest between the repetitions these are found to stimulate the testosterone and cortisol response. And the changes which happens in the endocrine system is that at the receptor level also you will find increase in the upregulation of the androgen receptors after resistance training. So, this is again influenced by various nutrient factors. So, we saw in the muscular adaptations as well to have a positive protein synthesis nutrient factors play a role. Similarly, nutrient factors play a role in endocrine responses post resistance training.

So, it is important that this needs to be kept in mind and what composition of nutrient or supplement will aid in a better anabolic endocrine response that is with a mix of carbohydrate protein supplement and should be taken before and after workout.

So, what is the relevance of body composition with respect to the anaerobic training. So, with anaerobic training you will have definite decrease in the relative fat present. The predominant change is seen in terms of increase in the muscle bulk or the fat free mass. So, you have a hypertrophy so because of which you will have increase in the fat free mass and because of which there may be initially an increase in the body weight as well. So, one needs to understand that with resistance training initial period there may be the increase in the body weight because of the muscle bulk as well as because of the reduction in the reduced rate of fat burn. So, body weight may not even change also, but however the fitness level may improve. So, assessment is again key. And also, there is change in the level of energy expenditure, as well as the basal metabolic rate. So, the resistant training will help in maintaining a better basal metabolic rate as well.

So, we spoke about the importance of nutrition being a main factor in terms of achieving adaptations in the physiological system due to resistant training, or anaerobic training. So, the nutrition timing is important, as well as the composition. So, we discussed the composition of the nutrient should be a mix of carbohydrate and protein. Why carbohydrate? Carbohydrate will stimulate an insulin response. Insulin we have studied in the module of endocrine and exercise. We know that insulin is an anabolic hormone; it promotes protein synthesis. So, carbohydrate is necessary to stimulate the insulin response and generally, it should be in the composition of 6 percent of carbide, 6 to 7 percentage. And it should be preferably taken in liquid form for faster absorption, and that causes a stimulation of insulin. Along with that, they should be to maintain a positive protein balance, you need to add protein, and this specifically should be rich in amino acids of leucine source. So, leucine amino acid should be rich for you to have a positive protein synthesis in the muscle post resistant training, and the protein also should be rapidly absorbed, should be kind of a fast absorbable protein. So, that is commonly seen in milk. So, the common, the supplement used is the whey protein, which is again a component of milk only, and that is provided in an easily consumable form. And the amount of protein that needs to be taken in an on an average, the recommended is 20 to 25 grams. However, if you go by body weight per se, so for those of those of the individual who are into early and early stage of training, and those are not into high level of workouts then 0.8 gram per kg is sufficient. When if it is more of a sport-specific athlete who are involved in high, you know anaerobic sports depending on the sessions and the load that is imparted to them accordingly the protein to maintain a positive protein balance the dose can improve up to 1 to 1.2 gram per kg body weight. What about the timing? Timing is again crucial, there is something called as metabolic window of opportunity, this will be covered in detail in the sports nutrition and performance, you know course. So, this metabolic window is nothing

but a 45 to 60 minutes time period when the body is highly sensitive to absorb the proteins to undergo fast repairing of the involved muscle proteins. So, obviously when you do exercise you have various protein which gets no overused so that needs to be repaired right. So, the body it is body in this period is in a state of high sensitivity to absorb the nutrients and so that it can replenish and repair the used proteins, right. So, this is the period where you will have to target. So, immediately 45 to 60 minutes of the workout is a time period where you will have to take a fast absorbable protein to maintain a positive protein balance and it is also seen that a protein which is rich in leucine stimulates that mTOR pathway. So, we earlier have seen that mTOR pathway is responsible for protein synthesis, right. So, stimulation of that is essential. So, for that you need to take a protein which is high in leucine. So, when you drink in a liquid form it is absorbed easily along with six percent of glucose, further it is manifold increased because of the anabolic effect of insulin as well. So, with resistant training you have increased protein synthesis and the rate you know maintains for some hours. So, this protein synthesis rate is maintained over few hours. So, during this period it is advisable rather than taking a single meal which is rich in protein it is advisable to have a small frequency of meals during this period post workout. So, that you have adequate amount of positive protein balance to replenish and you know address the protein repair and synthesis process of the body.

So, to summarize anaerobic training and sports performance are completely different from what the aerobic training methods have and the main possible or the main key physiological systems that aid in better anaerobic performance are neural nervous system and the muscular system. In the neural adaptations the adaptations happen at the level of the brain the central adaptations the adaptations happen at the level of your tracks in the descending pathways as well the adaptation happens at the level of reflex pathways as well, adaptation happens at the level of the motor units the neuromuscular junctions and the way they are fired as well. The muscular adaptations are happening at the level of muscle fiber size the transition of the muscle fibers the substrate content that is available in the muscle, also the ultrastructural changes in terms of the enzymes that promote anaerobic glycolysis. We also discussed about the importance of endocrine as well as the connective tissue adaptations that happens in the resistance training and what how as a exercise specialist or a trainer you can modulate the training parameters to induce such adaptations in the bone as well as in the endocrine and in addition to that we also saw how the body composition varies with respect to the anaerobic training and what are the implications of the influence of the nutrient that you intake during or after your resistance training as well.

So, from this uh module on training adaptations to aerobic and anaerobic methods so the takeaway points are the adaptations correspond to the exercise stimulus, so, it is the principle of specificity which is there and you can create the adaptations or promote the adaptation based on the modulation between the training parameters. So, if you are aware

scientifically what kind of training parameter can be used to induce a particular type of adaptation you can accordingly incorporate in your training program. The aerobic training causes adaptations predominantly in the cardiorespiratory system and the energy system whereas the anaerobic training is predominantly the adaptations happens at the level of neuromuscular systems and the endocrine system. So, both the systems can be modulated with the correct nutrient intake and other factors which can be utilized to influence the adaptations that can happen in the physiological system because of the training methods. However, the response will be better with the incorporation of the training principle of progressive overload and specificity so that needs to be always considered and more so when you are training in group it is important to also remember that principle of individuality wherein there is differences between individuals so accordingly the program needs to be customized to have the desired result.

So, for those of you who want to learn in depth about this particular module you can refer to these standard textbooks.

Thank you.