Introduction to Exercise Physiology & Sports Performance
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Lecture - 20
Exercise in Children and Adolescents - Part 2

Welcome, welcome to this course offered by NPTEL on introduction to exercise physiology and sports performance part 2 of exercise in children and adolescents. I am Wing Commander Dr. Chandrasekara Guru. I am a sports medicine physician from the Armed Forces Medical Services.

So you will be learning in this particular module about growth, development and maturation, physiological systems in young athletes, early sports specialization, their concerns, what is the current recommendation about them.

This we have covered during part 1. So, in part 2 we will be discussing the response to exercise and how you apply them in your day to day practice. So to revise what we covered in the earlier part, so we saw about the difference between growth, development, maturation, their definition and their differences. What is the age category and the relation between the chronological age, the skeletal maturity and the sexual maturity.

We saw about the different changes that happen with respect to height, how it is correlated with the physiological development, weight and what is the correlation or peak weight velocity and the peak strength velocity is related with weight. We saw the body composition aspect with respect to muscle and fat. We also saw the growth and maturation aspect that happens in terms of the bone and nervous system. And, we discussed about the general criteria that one needs to adopt in terms of aligning the sports participation with the development and what is the long term machine development model and also we discussed about the early sports specialization, what is the concern and what is the current International Olympic Committee 2015 guideline on early sports specialization. So with this background, let us proceed with part 2 on physiological response to exercise.

So all physiological systems improve till maturity is what we discussed, but then they don't kind of have the same kind of growth and maturation, and they also reach a kind of level of plateauing after a certain period. So, this starts to decline as the individual grows. So the physiological response results in certain important qualities that are related with the sports performance. They are strength, cardio-respiratory system, aerobic capacity, anaerobic capacity

and endocrine responses. So in the following subsequent slides, we shall be discussing how the physiological response to exercise happens in the children and adolescents because of the growth and development.

So, coming to strength, strength pre-pubertal, there is no difference between male and female. It is almost the same, and they gradually increase and reach a level. As the individual, because of which the application is that you can have mixed gender sports participation until this particular stage where male and female have not attained puberty. So until this time, most of the change that happens in strength development is almost the same in both genders. At sexual maturity when puberty happens, the thing differs.

So the boys have increased 15% of lower limb strength and if you see the males, they have two times the upper body strength of the females. So, you cannot have mixed gender competitions because they are unfair in terms of the physiological development process. So it is logical as well as scientific to have gender specific competition. So not only gender specific, instead of age specific, gender specific, you should have more of a weight specific competition to have a fair play between the participants. That is an important aspect about strength, and growth and development.

Let us see a case where a community coach comes to you and he enquires whether you can start resistance training in a group of children that he is giving training, age group of 10 to 12 years of both male and female. So how do you advise this? What do you advise to this particular individual? So it is yes, because we saw in the previous lecture, by about pre-pubertal or when the peak velocity happens, there is an increase in the peak strength velocity as well. So this is the time when you have an increase in the peak weight velocity as well. So monitor, you can start a resistance training in pre-pubertal children as well so that to increase the strength, and this is more so because of the improvement in the neural mechanism during this stage and increase in the motor coordination and the motor unit activation. So, more of a neural based adaptation happens during this phase.

So hence, resistance training can be done. However, there may not be much of an increase in muscle size. So the weight should be accordingly managed or the load should be accordingly managed. Whereas, in the case of children who reach the pubertal group where both the muscle size also increases. So, there you can also increase the load so that there is concomitant increase in the muscle size as well leading to better increase in the strength.

So that is important to consider. So what is the myth about strength in this age group? Resistance training or weight training will stunt the growth or height of the individual. This is actually a myth, because current evidence states there is no apparent effect on height or stunting because of the inclusion of resistant training or weight training in the adolescent age group. In

fact, resistant training is beneficial because you have better neural adaptation this time and the injury risk is also not seen and they in fact may offer protection because of improving the muscle strength especially the muscles that cross the joints get strengthened. So the chance of injuries are lesser when you incorporate resistant training in the adolescent age group.

So the recommendation per se is, not that you go overboard and increase phenomenally. Rather it should be a conservative approach, but then it is not that you should completely abstain yourself from resistant training. That is the current recommendation.

So what about the cardiorespiratory system? When we see about the cardiorespiratory system response in terms of when the individual is at rest or submaximal exercise, the blood pressure is comparatively low as you compare with an adult. This is mainly because body size is low.

So when the body size is low and also the peripheral resistance. So when we have discussed during our modules on the cardiovascular system, the blood pressure is determined by the resistance offered at the periphery. So, because of decreased body size as well as because of decreased peripheral resistance, the BP is generally lower in the children and adolescent group. Moreover the heart size because the body size is low so obviously the heart size is also smaller. Smaller heart size will be able to pump only lesser amount of blood.

So that causes a decrease in the stroke volume, as well because of which to compensate for the increase in the blood supply that is required for the same kind of activity where an adult and a child are doing. Say if you want to compare then in this case how the cardiac output is maintained so that it can be maintained only by increasing the heart rate. So we have seen in our previous module on cardiovascular system cardiac output is a product of stroke volume and heart rate. So by virtue of being a small heart, the child will not be able to increase the stroke volume but then the heart rate can be increased to maintain the cardiac output. So in children you will have better or increase in heart rate.

Why is it important? Because the same kind of heart rate based load monitoring that you do in adults cannot be applicable or may not be applicable in children. So, here we will have to use a different methodology to assess the intensity of the load that you prescribe in your exercise training. More so, body size is more and the cardiac output is low. Obviously this results in this because of this increase in the cardiac output as well decrease in the body size you also have a compensatory increase in the arteriovenous difference that is the amount of oxygen which is used by the peripheral muscle and the remaining amount is carried by the veins. So, the amount of oxygen that is carried by the vein is so low that most of the oxygen is utilized at the peripheral muscle itself.

So then by which you are able to, the child is able to maintain the oxygen delivery to the tissues. So that is called the VO2 max. What is VO2 max? VO2 max is the maximal oxygen

consumption which we have already looked at during our class in the cardiovascular system. Wherein it is a product of cardiac output and the arteriovenous oxygen difference. So where cardiac output can be maintained by increasing heart rate but still the oxygen delivery can be increased by in children because of increasing the arteriovenous difference in the oxygen carrying capacity.

So the better muscle perfusion which happens in children is mainly because of decreased total peripheral resistance and increased arteriovenous difference in the oxygen carrying capacity. So, that is the response that happens in the cardiovascular system. What happens with respect to the maximal exercise? So, we saw that in maximal exercise you will have an increase in the heart rate to the maximum level. So, as compared to the others we have earlier seen that the cardiac output is maintained by increasing the heart rate so because of which you will have more increase in the maximal heart rate as compared to the adults in children. And this maximal heart rate as the individual grows and attains adult stage it gradually drops down by 0.5 to 1 beat per minute every year as a child grows. So, this is mainly because of the decreased sensitivity that happens in the cardiac beta receptors in the cardiac muscle. The maximal oxygen consumption also decreases as compared to adults. This mainly happens with increase in age and maturity. What about the capacity, the aerobic capacity? The aerobic capacity, the absolute capacity that is mentioned as liters per minute or the other term is the maximal oxygen consumption, right.

So that increases with age and maturity status of the individual. As the organ system matures, the absolute aerobic capacity also increases. But mind you this is only the absolute value. What about the relative value? What is the difference between absolute and relative? Absolute is, when it is expressed as the complete consumption for the entire body. When you want to further understand the difference in the relative aspect with respect to the weight, you can use the total oxygen consumption per kg body weight.

So what is that value per kg body weight? And if you want to further get to know exactly what is the oxygen consumption per kg lean body mass or the muscle mass, that gives you an exact idea about the distribution of aerobic capacity, or the actual aerobic capacity response to the exercise. So, the relative aerobic capacity here in terms of kg, after puberty there is increase in the fat mass in girls because of the estrogen effect right. So we know that oxygen is delivered to the muscle. So wherever there is an increase in muscle mass there will be an increase in the oxygen consumption. In girls because of the increase in the fat mass it is relatively lower, as compared to the boys.

This is as simple as simple logic. So the muscle mass is more in boys or rather the entire body composition you will see the fat composition is lower in boys so you have a better aerobic capacity in boys as compared to the girls. And the peak aerobic capacity is proportional to your peak height velocity. So as a coach or a trainer, when you monitor the height every three months,

you get to know the peak height velocity and this is the time when you know that the individual can improve the aerobic capacity further. So, if the individual is involved in a sport like football where aerobic capacity is a major role then you can impart the aerobic kind of training to the child athlete.

So, that will improve the adaptations in the cardiovascular as well as the respiratory system. With respect to the early maturers and late maturers ,if you see the absolute aerobic capacity is more in early maturers because if I mature early at an earlier age obviously I will be at a better advantage with terms of absolute aerobic capacity. So if the individual is participating in football, if the individual is an early maturer then the performance will be better in that particular sport as compared to a late maturer. So that is the difference if you have the same group of people with same age in a sport, an early maturer will have a better advantage as compared to a late maturer. So the next important quality for performance is your anaerobic capacity.

So anaerobic capacity increases as the individual grow and mature, and mainly the sexual maturity is correlated with it and it is determined by the muscle increase in the muscle size the muscle glycogen stores, because we know that from the module from bioenergetics anaerobic capacity is completely dependent on the glycogen and the ATP PCR. So if these stores are available in large quantities the performance will be better. Also, the enzyme activity which is related to the utilization of these stores is also better developed during the sexual maturity stage. So, the peak anaerobic capacity if you see it is in case of females it is early 20s, and males it is about late 20s. So, as similar to the relative absolute and relative values in VO2max we also have similar absolute and relative values in anaerobic capacity as well.

So as individual age and matures unlike the anaerobic capacity, here it is mainly due to the increase in the peripheral factors; and glycolytic capacity this because in the peripheral factors you will have better glycolytic capacity motor coordination and neuromuscular control as the neural and the skeletal skeletal system matures over a period of increase in the growth and development. So the other important organ system which is essential for the exercise responses in children and adolescents is the endocrine responses. As we do exercise, we know that we have seen in the chapter on endocrine responses to exercises wherein, exercise per se can stimulate hormones, because of which there is mobilization of both fat as well as carbohydrates and this per se also stimulates growth and maturation. So, when you involve or introduce high intensity exercise in children and adolescents, because of this high intensity you it is seen that there is an increase in the secretion of growth hormone, which also varies with the daily cyclic release and in turn can also improve the growth and maturation of the individual. So this is one instance where your inclusion of such activities in your exercise training can promote better growth and maturation in the child athlete.

So what about the insulin and catecholamine response? So in children the response is different

as compared to the adult. The glucose control is different in children and muscle glycogen is low as well as the liver glycogen is also immature. So the majority of the time you will have chances of relative hypoglycemia in the beginning of the activity, and thereafter the fat metabolism chips in during the exercise. So compared to adults, the fat metabolism is high in children because of the lack of proper maturity in the terms of glucose metabolism, and the glucose oxidation if you see more than the endogenous the body is can better utilize the exogenous glucose. So when you take glucose from outside during an activity, that glucose is better utilized as compared to the endogenous glucose oxidation in children. So these points will help to accordingly use your exercise training and frame the exercise training programs.

So let us see a case. There is a volleyball coach who has been training his young players and he comes and asks you "I've been training young boys and girls of 10 to 14 years old. I generally monitor their height every three months. Six of my young players have shown signs of growth spurt. So is it advisable that I give you know plyometric jumping training since they are growing? Will it increase the chance of them getting you know injured?" So, this is a genuine doubt a coach has because you have there in the face of growing and as plyometric training is known to have better you know improvement in terms of the jump performance and other anaerobic performance. So as a coach I am worried whether I should introduce such training to my young child athlete or not. So I will give a minute for you to just ponder over the particular question.

So the answer depends here if you analyze this particular case, the height is measured three months here. So now this is very good wherein you can monitor the peak height velocity. Similarly this coach is also monitoring the weight every three monthly. So approximately, six months prior to the puberty you have the peak height velocity; and studies have also shown that bonding exercises or plyometric exercises which are short term but high impact when they are included in the training program they found to increase the bone mineral density and also found to reduce the fracture risk, if they are continued till maturity.

So based on the scientific evidence you can advise in this case that the coach can include certain bonding exercises, plyometric training. However the the load should be kept to a shorter aspect with high impact for a short period of time, and and that should be continued or interspersed in the microcycle or the macrocycle as the individual grows and then reaches the level of maturity, and they are found to have reduction in the risk of bone injuries as well. Let us see another case. You train a young athlete in your gym okay, and he complains of difficulty in breathing during the exercise. What are the common possibilities that you must consider as a gym trainer? So, he is a young athlete, and he is complaining to you of breathing difficulty during exercise. So as we discussed earlier, unique things about children of this age group is that they may present for the first time a problem for you.

So common causes of breathlessness in children on exertion. Dyspnea is called breathlessness.

It's probably because the individual's aerobic capacity is not so good, but then you're given a high intensity training program so that's why the individual is not able to breathe. That must be the first concern. If not so, you have given a good training program, but still the individual is having breathing difficulty, probably some pathological condition, some underlying disease should be there. So this disease might be because of say a bronchial asthma representing for the first time, or some vocal cord problem. So you have the larynx which has vocal cord which approximates and sometimes it blocks the airway movement.

So these are the two conditions that one has to keep in mind and if you find that probably these may be conditions then you will have to consult a physician for further evaluation and management. So how do you rule this out? So during exercise if the breathlessness happens probably because of poor fitness level, and you know how you have to improve the intensity of the exercise. So based on that you will get to know but if the breathing problem happens at the end or after the exercise, probably it may be guiding you towards bronchial asthma or exercise induced bronchoconstriction, and further the physician may do a spirometry to rule out this. With intense exercise and high stress competition, probably because of the psychological component as well, the individual has gone into a vocal cord issue, because of which we are having this problem. So in such cases the spirometry reports may be normal.

Just to give you an idea how health conditions can also be tackled with some basic ideas about the scientific concepts. Another important unique aspect in exercise in children and adolescents is the thermal stress. Thermal stress is nothing but heat stress basically. So the body surface is more because of their smaller size, and this is in fact advantageous if they are kind of training in a normal environment where it is not excessively hot or excessively cold, where they can easily dissipate their heat which is produced during exercise. However, if they are practicing in hot weather they also gain more temperature from the external environment, so thereby they increase the body temperature as well, and moreover the spread rate is also lower in children.

So this may result in increased heat stress. So it is important that if you are taking the individual actually to a hot weather place the rate of acclimatization is low; so you need to give time for the acclimatization to happen. And always, you should watch out for thermal stress while exercising in hot weather. In cold weather, it is the same thing because of the heat exchange. So the cold external ambient weather is cold then the individual can see easily can decrease the core body temperature. So they may go into hypothermia. So in this case it is important that adequate clothing in layers is taken care of before starting the exercise program.

So, the special consideration that one needs to see in children is the certain medical conditions present for the first time in children. So it is always important that, as a trainer or coach it is important for before taking or advising any exercise training program, a pre-participation medical must be done by a consultant or physician. So congenital heart disease are more common in children to present for the first time bronchial asthma as we discussed in a case is

more common type 1 diabetes is an insulin dependent or a type 1 diabetes is more common or it present commonly in children. So it is important that pre-participation medical must be done before prescribing any kind of exercise and if individual has a medical condition then accordingly the condition has to be catered in your exercise program; and these people have to be regularly followed up and to be monitored by the physician so that they do not end up in a grave situation.

One more important aspect that I would like to stress upon in this module of exercise in children and adolescents is the concussion in child athletes. So we know that concussion is a very grave thing that can result in a fatal incident also if not properly monitored in an adult. It's the same kind of an effect it has on children as well. We know that it is a traumatic brain injury which is caused either by a direct or indirect blow to the head, neck or body during the sports and exercise related activity. So generally you do not find any abnormality in the standard structural abnormality, so most of the time we have the neuroimaging which is normal but still it is important to assess them using certain guidelines that we have.

So the International Olympic Committee has come up with the sixth consensus statement as latest as 2022 published in BJSM, where they have given a broad guideline about the concussion in athletes, where the Child SCAT-6 has come up for athletes between 8 to 12 years; and more than 13 years, normal adult SCAT-6 guideline can be used. The unique thing in child athletes is that the recovery is prolonged so the RTP guidelines are different from the adult so that one needs to understand when you are handling a case of a concussed young athlete.

So, to summarize physiological responses to exercise varies based on the growth and development and maturation of different physiological system; and based on that you have different system responding differently accordingly as a trainer or a coach have to implement such training programs during the different phases of growth. The importance of aerobic capacity and aerobic capacity, and what is the age when you need to monitor and institute into the program which we have discussed. Special considerations we have seen about the thermal stress in children, the importance of concussion, you know unique things that happen in children because of the prolonged recovery and the need for a separate RTP also we have discussed in this module. So the takeaway from this module of exercise in children and adolescents is the growth and maturation varies so chronologically is not always equivalent to your maturation age. The early specialization is only recommended in certain sports where flexibility is an important aspect.

Fair play would mean that including gender specific weight based criteria in the bio-banded athletes, based on the maturation, and as a coach or a trainer, it is important to impart long-term athlete development model; so that the physical and mental well-being of the child is also taken care of; so that the individual can enjoy the sport. and a very important consideration because a few of the health conditions can present for the first time in children. It is always important to

have a pre-participation medical done by a sports physician or a general physician before you know prescribing and exercise training or imparting any training to the athlete. For those of you who are interested in further in-depth learning following your references and additional reading are quoted here. Thank you.