Introduction to Exercise Physiology & Sports Performance
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Lecture - 19
Exercise in Children and Adolescents - Part 1

A parent comes to you asking, I used to be an active sports person and I had practiced in school games as well as junior level competitions in basketball. He wants his son who is 6 years old to undergo basketball training only, so that he can specialize early in basketball. As a coach or a trainer or an advisor, what would you think of in this particular case? What is unique about exercise in children and adolescents? What about growth, development and maturation? Do they have a role to play in exercise training? And what will be your advice, considering these aspects? If you are looking for answers to these questions, you are in the right place.

Welcome to this NPTEL offered course on introduction to exercise physiology and sports performance. You are here for this module on exercise, adolescence; and I am Wing Commander Dr. Chandrasekara Guru. I am a sports medicine physician with the Armed Forces Medical Services. You shall be learning during this course, as we discussed, about growth, development and maturation, physiological systems in young athlete that is children and adolescents. Early sports specialization, what is unique about it and what is the current concept about this particular early specialization. What is the response of the body to exercises specific and unique to this age group, and how do you apply these concepts in your day to day practice of exercise and sports training? Moving ahead, in the general population, children and adolescents, if you see there is a marked increase in the obesity level.

Day by day, the physical activity level has gone down and if you see as per the 2020 data, about 81% between the age group of 11 and 17 years just not even cross one hour of moderate to vigorous physical activity in a day. That is the kind of scenario which we have with the general population. What about the sports population? Sports population is on the other extreme of the spectrum, wherein you are now seeing more and more participation in sports training as they are very young, both in children and adolescents. This has been increasing day by day, and especially the specific sports based specialization, what you call as early specialization in sports has seen an increase as early as 6 years of age, in a specific type of sports. Moreover, this specific group is more important, because they often present to you a health condition which is for the first time.

So you need to be aware about certain conditions which are more common in this group so that at the first time only, or at second repeated presentation you are able to at least catch hold of

these conditions and take preventive measures, and do correct referral to the physician. So thus, this knowledge and awareness about the specific scientific concepts in this age group is very very essential. As we go ahead, we need to define what age group defines a particular phase of development. So, as the child grows and reaches the stage of adulthood, we have different phases. So based on the chronological age we can say; an infant is one who is less than 1 year of age, starting more than 1 year till puberty.

Puberty is the onset of sexual maturation or the sexual changes that happen in the body because of the hormonal changes that happen. So, this forms under the group of childhood, preschool and elementary. As soon as the individual reaches puberty, till the time when the individual actually reaches the adult stage or adult, complete adult stage is called as adolescent. This varies in case of both males and females. In the case of male kids it lasts starting from 10 years and can end up to 22 years, when they completely mature as an adult.

What about females? In females it starts slightly earlier, probably at around 8 and then thereafter they reach adult size by about 19 years of age. So again, it is important to understand what is the difference between growth, development and maturation because these are the words and the concepts that we keep on hearing in this particular topic. So as a child grows and matures to a stage of adult, it undergoes various phases. So initially there is increase in the size as depicted in the picture where you see a small kid becoming a large human. So that increase in size is what you called growth.

The growth is not just increase in size, you also have different type of cells, different type of tissues, different type of organs which differentiate from a single cell which undergoes what you call as the zygote. From there, it keeps on differentiating over a period of time during the process of growth and it gets differentiated into specific organ systems. So this particular process of differentiation is what you call development. What do you mean by maturation then? So the differentiation or the development of these tissues attain a final functional state and that is when you call the individual as an adult, when the complete physiological and functional achievement has been done in a particular organ system. So, that is what you called as maturation.

But then again, as I said the differentiation of the cells into different tissues and the organs and the organ system, they do not happen simultaneously at the same time. So they all have different time of maturation. So that is when it is important to understand that the chronological age, what you mean by calculated from the date of birth and every year where you celebrate your birthday, that is completely different from how you mature as your skeletal age or your bone and the skeletal system matures. So that is depicted as the skeletal age and which is again completely different from how your sexual organs and the organ system matures. So, the chronological age is not always equal to the skeletal age and it is also not equal to the sexual maturation stage.

Why I am only focusing on these three aspects, because they have major connotations in terms of planning your exercise training and the participation in sports in this particular age group, until they reach the stage of complete functional completion or maturation. So in this aspect as well, we have two different groups of people called early maturers and late maturers. Say, I will quote an example where you have a group of kids in a classroom, you can find that not everyone in the classroom you know reaches the stage of maturity, whatever the maturity I am saying, skeletal maturity or sexual maturity do not happen at the same time. So, every individual has a different kind of hormonal milieu and the internal body state based on which the maturity happens. So, few of them may mature early for that particular chronological age and few of them may mature late as per the chronological age.

So it is very important to understand the connotation that it carries in the exercise training in this particular age group which we will discuss as we get into the topic. So what is this difference between the chronological age and the maturation? So, if you see as I said it is not equal, the physical maturity and the chronological age is not always equal and hence it is important to understand that there is risk of injury in the individuals when we make them participate based on the chronological age. So just now I said, that few of them may mature early, few of them may mature late. So if we kind of enroll them based on the chronological age and impart the same kind of exercise training, you may find that few groups of people will be getting positive adaptation in a better way to the exercise training that you are giving. However, few of them may go into negative adaptation, or may not adapt to your training, and may not show any kind of good response in your training.

However, they may also be predisposed to development of certain injuries; and based on the fairness of participation it is totally unfair to have different groups of people who are physically you know the physical maturities at different spectrums. More so, when it is seen that scientifically those people who enter into sports with early specialization based on the chronological age end up you know end up in terms of burnout and mental health risk as they grow up over a period of time, because of the early specialization into the sports. So, when you consider early versus late, there is a concept which is coming up which is called bio-banding based on the physical attributes. So you have a group of people of the same chronological age. However, in the same group you identify the group of people who have similar kind of physical attributes in terms of their height or weight or other aspects, as per the growth of the individual as well as the development of the various tissues in the organ system.

So based on this, you have a group of people who are actually fitting into the same kind of physical attribute and they are banded as a one group. So that's called a bio-banding concept. Now the physical maturity always may not match the physiological maturity also. So that is again an important aspect. So based on the physiological maturity only, the individual will also kind of learn the skill or the technique of the sport.

So these also may not match. So, it is important to kind of monitor the physical maturity, the physiological maturity of a particular system which is important for that particular sport as well as the technical skill, the mental maturity is important to grasp the concept of the technique that is required for that particular sport. So, if an individual has good physical and physiological maturity but then lacks the mental maturity to kind of understand the information and process it and to replicate it in its training, it may not actually give the good outcome that is expected. So, it is important that there should be some approximation between the three aspects of maturity, the physical maturity, the physiological maturity as well as the mental maturity. And the sports participation presently is moving towards more of a long-term athlete development model; wherein you see the athlete as a longitudinal development during the growth and development of the athlete per se.

So your exercise training should match these physical, sexual and mental developments. So accordingly then you can plan your exercise training, so that the individual also is able to have better positive adaptation to the exercise stimulus that you are providing during your exercise training. This is a new concept which has been trending over, I would say, over a period of few years. Let us now focus on various physical and physiological parameters that one needs to know or needs to focus on when you are having or training a group of children and adolescents. So, the most important or the commonly used parameter is, demographic parameter is your, rather than anthropometric parameter is your height and weight.

So let us see about height. Height, which is about 50% increase in height is achieved by 2 years of age. So there is an increase in the length of the body. It's called length until a certain period of time thereafter it is termed as the height. So this 50% of the increase in height happens up to 2 years of age.

Thereafter, it becomes kind of stable and once it reaches a kind of growth spurt, there is an increase in the height of the child. So it again varies based on the gender for males and females depending on the hormonal change that happens and that's how you have something called peak height velocity. So there is an increase in the rate of growth, and there is an increase in the height. So this particular rate of increase in height is maximum at a certain age and that is called the peak height velocity, and that is almost generally evident 6 months before the onset of puberty. So, 6 months before the onset of puberty, the individual will show a drastic increase in height.

So that particular time the height change is significant. So, in girls it is generally seen at around 12 years, and in boys it is about 14 years of age. And thereafter, the height kind of stabilizes and gradually the individual reaches the stage of the height of an adult. In girls, it is at about 16 years, and in boys it is about at the age of 18 years. So what is the carry-on message from this

point is that there is a definite increase in the, significant increase in the rate of height.

So if you do not map that increase, you will not be able to identify this phase. So hence, it is important that 3 monthly they should be monitoring the height by the coach or the trainer. Then this height is plotted so that you will get a note that the curve gradually increases during a particular period of time. So that is the time where you know that the individual is undergoing pubertal changes. So that is the time when you can change your training program based on the requirement.

So that is important to monitor. The second thing which we discussed was about the weight. So, weight again changes with the increase in the muscle mass as well as increase in the strength. And it also has similar to height, it also has a peak weight velocity. This is again 6 to 12 months after the peak height velocity. So, this generally happens because of changes that happen during puberty, because of the increase in the growth hormone as well as the other sex hormones, because of which there is also an increase in the influence on the muscle mass.

So muscle mass increases after the puberty change, and because of which you will find that there is a peak weight velocity during this age group of girls between 12.5 years or so and boys be around 14.5 years. So in males it kind of happens slightly later. The puberty changes happen slightly later as compared to the girls.

And this particular thing is very important, because if the child is kind of introduced to strength training, this is the time period where you can introduce all those strength training related, resistance training related programs. So this is the time when the peak strength velocity is also coinciding with the peak weight velocity, and it is very important. So again similar to height, it is important that you also measure the weight of the individual. So, if you do not have any other advanced equipment to measure the various parameters, you just need a tape and a weighing machine, which is very very basic equipment that is required for exercise training, or in a gym where you can measure the height and weight every three months and monitor the progress.

Moving ahead, we discussed about height and weight. Now we also see about the body composition. The body composition is that the composition of the body into fat and fat-free mass or you call it muscle. The fat-free mass includes so many other components of the body also. In detail, this will be discussed in a separate module. So with respect to the muscle, if you see, there is an increase in the muscle mass with the increase in the weight which we discussed in the previous slide.

There is about 25% muscle mass at birth, which gradually goes up to 40 to 45% of the total body composition by the time you reach adulthood. This peak muscle development happens, again it coincides with your peak weight velocity. So, when you know that weight is increasing, the rate is significant, you can indirectly assume that the muscle mass is also increasing. So in

girls, it is around 16 to 20 years, and in boys it is about 18 to 25 years. And this time the increase in the muscle mass mainly because of the hypertrophy.

So you would have been introduced to this terms, hypertrophy and hyperplasia during the module on skeletal muscle physiology. So the hypertrophy is just the increase in the size of the muscle. So, the muscle mass increases by increasing the size of the muscle fibers. There is also an increase in muscle length. You know why? Because you also have a concomitant increase in height.

So when the individual's height increases skeletal bone increases, so muscles are attached to the ends of the bones. So you will also have increase in the muscle length, which causes increase, you know, kind of accompanied by increase in bone length. And this is also accompanied by an increase in the number of sarcomeres, which is the basic component of the muscle. So it is important that this particular phase is coinciding with your peak anaerobic performance. So if your child athlete is involved in more of strength training and anaerobic related sports, then this is the time when you have to target the strength training and power kind of training to increase the performance.

And, if you also notice this is the time period when there is an increase in the percentage of muscle mass, where you will find most of the world records that happen in these type of anaerobic sports. Say we have the world best performance by Usain Bolt, which is again in sprint which is a very phenomenal kind of achievement that happened during this particular age group. He did this at the age of 22 years. Moving on to the other component of the body is fat. So how does the fat kind of growth and development happen? The deposition of fat cells is initiated early in the fetal development.

As the fetus grows in size within the womb itself, the fat deposition starts. And this fat cell size increases as the individual increases in age. And at about 10 to 12 percent of the body composition is fat when the individual is born, and it increases up to 15 to 25 percent depending on the gender as the individual reaches the adult stage. So what is this gender difference because of? The gender difference is mainly attributed to the hormonal changes that happen during the puberty. So, because of the effect of the sex hormones in females it is more of estrogen which causes more kind of fatty deposition.

And fat deposition is also again distributed as per the sex related changes. So more fat deposition happens in the back, lower back as well as in the thighs and also in the breast tissues. So there is an increase in the fat component in females as compared to males. And various factors that determine the fat accumulation are, in both the sexes are the hereditary thing, which is genetically determined and then the exercise habit. The more exercise you do, accordingly the fat accumulation varies.

Now, an important concept or important factor that determines how much fat that is accumulated is your diet. So that determines the amount of intake. So the diet grossly determines the, because hereditary is not modifiable. However the modifiable factors are diet and exercise habits right. So the diet is an important component that determines your fat accumulation.

So this is important to understand for those of you who deal with general population, with childhood obesity or adolescent obesity where the target area for fat control or fat management which should be body weight management, should be at the level of diet more so compared to your other factors. So, this is because I have discussed about the hormonal difference and the estrogen causing the different kind of regional distribution of fat. The next important component of the body is the bone. So the bone is again like any other tissue starts development right from the fetus. It initially starts as a cartilage and gradually kind of ossifies.

So, the process by which the cartilage gets converted or matured to a bone is called ossification deposition of various minerals to become more of a bony structure. The line of cartilage where the growth happens is called the growth plate. The different bones have different fusion of this growth plate happens at different levels, different times of growth. So based on which you can say kind of estimate the skeletal age of a person. Based on the fusion of a particular bone, you can estimate what is the skeletal age of that particular individual.

So that is now is used in the skeletal age estimation especially in sports to identify what is the approximate age and correlate it with the chronological age, to avoid any kind of age frauding. So that is generally done using an x-ray or an MRI of the wrist. So there are so many other methods that are used to estimate skeletal age. This for your information and knowledge and commonly used thing is your x-ray or MRI of your wrist. And the fusion of say at 12 years it is the fusion of the Pisiform bone of your wrist, and at 14 years if the metacarpal bones are fused the individual will be around somewhere around 14 years of age.

So in the wrist itself, when you see the fusion of lower end of radius, the radius is the outer bone of your forearm and the lower end of it is at the wrist level. So, if this particular bone is fused in your x-ray then the radiologist tentatively gives an opinion that this individual has crossed 17 years of age. So accordingly, you can correlate this skeletal age with the chronological age that the individual has submitted using an age or birth certificate. So that is how it is being used. And when you see the difference between the girls and boys, girls attain skeletal maturity early, and this again because of the hormonal difference, mainly the estrogen.

It signals the growth rate to close earlier. So that is the reason why you have females getting kind of the bone fusion happens early in females.

What about the nervous system? Because the nervous system is again an important component as we have studied during the neurophysiology module of this particular introduction to exercise physiology. Nervous system is important for all your conduction. So wherein, you have neural adaptation that happens in your nerves. And it is more so important in certain sports which is more of information processing which happens and this is in sports involving balance, agility and coordination.

So this improves with the individual increase in the age of the individual. And that is mainly because there is something called myelin which is the covering of the axon of the nerve cell. So if you remember from your neurophysiology, every nerve cell has a cell body and an axon, and just to remind you about this. So the cell body and the axon, the axon is again covered by a sheath of, you can say a type of fat and that is called the myelin sheath. And this process of laying over of myelin is called as myelination.

So certain nerve cells are myelinated some are not. So, those cells which are myelinated they also have certain kind of nodes in between that are called as nodes of Ranvier. So why this is important because they undergo something called as saltatory conduction. Then we saw that the nerve signal or the action potential electric impulse is transmitted through the nerve right from proximal to the distal or distal to proximal. So this particular electric signal, if it is myelinated, jumps from one junction to the other junction because of the presence of myelin.

So the conduction of this impulse is faster. So this can happen because the nodes of Ranvier are present. So now this happens as the individual grows the myelination also is happening along with the maturation stage. So when the individual does not have complete laying over of myelin the conduction will not be as efficient as if it is not myelinated. So, it is important that with age the nervous system also improves, and thereafter your conduction of the electrical impulses in the nervous system also improves.

Thereby your response is faster. So fully nervous system maturity is important for fine tuning and coordination of the skill. So this is what we discussed earlier. It is also important that the individual should have that maturity in the nervous system to also technically follow the particular sports. So that can happen with this. So it is important that a nervous system should mature for both your increase in strength as well as for your speed and other agility related workouts. So, what is the general recommendation as per the age, based on the development that happens growth and development in the sports participation.

So in less than six years: the individual can be allowed to take part in natural forms of movements, more in terms of games and play, so that all types of motor qualities are addressed without any kind of specific focus on a particular system. Now, between six to eight years of age the coordination of movement starts to develop. So, you can introduce the drills related to

coordination and movement. And again, there is not any specific load on the skeletal system, but then it should be part of their fun and games. And, between eight to ten years of age as the nervous system starts developing, you can introduce drills pertaining to agility and speed, and also with respect to the movement dynamics how the individual learns to kind of develop the techniques in this particular type of sport.

As the individual grows from ten to thirteen years of age, because now there is improvement in the physical maturity as well as the hormonal milieu causing sexual maturation. So this is the time period when we can focus on developing endurance and strength, depending on the sports the individual is going to pursue. And again thirteen to fifteen years of life, there is about complete development in terms of the cardiovascular and the other systems that are related with the endurance training. So it is more of a full range of endurance training. When the individual goes to more than fifteen years full range of strength and the static strength related exercise can be introduced.

So what is the concept about early sports specialization? So it more so has happened because of the commercialization of the sports mainly in the kind of it has kind of resulted in a lot of revenue generation mainly in football and baseball, and these are the sports where you have early kind of specialization. And you have examples of famous sports celebrities like Lionel Messi and LeBron James. So, it happens because of the early selection and scouting and the recruitment by these clubs, because of the commercialized nature of the sport. And there is also fear of missing out, which is because of which the sports start scouting early in this stage of life. So that you get the talented individual at an early time, and start developing their skill.

And they also have this concept of the ten thousand hour rule where they say that if you practice more than ten thousand hours in that particular sport, you gain that specialization better. So thereafter you can gain that required skill. However, with the early sports specialization happening, there are certain concerns which have come up in various studies; wherein, the child can go into social isolation because of over involvement in the sports. Over dependence may be an important concern that can come up, because of the early sports specialization involvement in one particular type of sports the individual can go into burnout. They are also seeing the other psychological aspects of manipulation is also common in these athletes.

There is also a risk of increased overuse injury in these people, because of the concomitant growth also which is happening. Including the length of the bone, the change in the size and the length of the muscle, various other organ systems are developing. So there may be chances of overuse injury in this group of people. It is also seen in certain sports where it compromises the growth and maturation. There may be postponement of the puberty age group in girls who are in early participation in certain sports.

So that is an important concern that happens because of early sports specialization. So to tackle this concern that is happening in the child athlete, in 2015 the International Olympic Committee has come up with certain guidelines and recommendations, wherein these should be limited to the kind of unstructured and free play should be there to improve the motor skill development as I said during the age group of 6 to 10 years of age. Thereafter, you have to have a self-regulation exposure so that the individual can reduce the risk of overuse injury. And, it is also important to encourage participation in variety of sports so that the individual mentally can identify what is the keenness towards a particular sport and choose that particular sport as the individual or the child grows. However early participation is favored in certain sports where flexibility is an important aspect like gymnastics, swimming, diving and figure skating.

So the current evidence says that as in case of elite and sub elite increases the performance also improves when the athletes specialize late in their teams, as compared to the individual who take early specialization of a particular sport. So performance is also better if the individual evidence shows that this the participation of or specialization of an individual in sports towards the late teams as the individual mature based on the maturity has a better performance aspect as well. So it is more logical that the early specialization of sport should be discouraged. To summarize in this part 1, we discussed the growth, development and maturation, what is the difference in them? How is it varying between the chronological age, the skeletal maturity and the sexual maturity? And we discussed various physical and physiological systems in terms of height, weight, muscle, fat, bone, nervous system.

We discussed participation based on age versus weight based participation and also the concept of bio-banding. We discussed the long term athlete development compared to the early sports specialization and the concepts that are related with the early sports specialization and the current recommendations. So, those of you who are interested for in depth further studies you can refer to the standard textbooks as I have flashed here. Thank you.