Introduction to Exercise Physiology & Sports Performance

Wg Cdr (Dr.) Chandrasekara Guru

Directorate of Medical Services

Lecture - 21

Exercise Prescription and Training principles - Part 1

Mr. Raju joined your gym just as a fresher. He doesn't have any exposure to using any gym equipment. And he is focused to build his body strength, fitness level and to maintain a good body shape. So, as a gym trainer, you would be thinking what type of exercise will I prescribe? What are the primary motor qualities that I need to focus on in my exercise training program? What principles of training should I incorporate in my exercise prescription? If you are looking for answers to these questions, you are in the right place.

Welcome to this NPTEL course on Introduction to Exercise Physiology and Sports Performance with me Dr. Chandrasekaraguru, Sports Medicine Physician from the Armed Forces Medical Services, for this module on exercise prescription and training principles.

You will be learning in this particular module about motor qualities, basic terminologies related with exercise training, exercise prescription, principles of training, components of exercise prescription and how do you apply in your day-to-day practice in exercise training.

Exercise training is nothing but repeated planned exercises which are performed over a period of time. So, when you have a set of exercise training, it causes positive physiological and physical adaptations. And this particular thing happens because of a structured program, which you call it as exercise prescription. And such an exercise prescription will cause an increase in the exercise capacity and sports performance. But then to have a positive outcome, it is important to incorporate the training principles or the exercise training principles in your exercise program. That is when you will have a positive physiological adaptation and a positive outcome in terms of exercise capacity as well as the sports performance. Hence, it is important to have a right exercise program, with incorporation of exercise training principles.

So, let us focus on these two aspects in this particular module. What is a motor quality? So, any individual is born with an innate natural ability to perform an exercise or a movement. So, let us take an example, classroom of 20 kids, you ask them to participate

in a 50-meter running race, and you find that one of the kids reaches faster, way faster as compared to the rest of the kids in the classroom without undergoing any training he is able to reach and at a faster speed. So, this ability for that individual to perform because of its innate quality is a motor quality. So, this is what you call as natural ability. So, it is by birth the individual has that natural ability to cover up that running race with such speed. The speed is the motor quality where which is naturally inherent in that individual. Now you recruit that particular kid into your training program and you want to further improve his speed upon by having a structured training program. So, here you are teaching the kid to develop a particular technique or skill to improve on the movement pattern. So, this is what you call as nurture. So, you are nurturing the kid to develop a skill. Skill is a learned acquired ability of an individual to perform an exercise optimally to enhance performance. So, when you identify motor quality by nature and you incorporate a proper training program nurturing that innate ability through a properly trained program and develop the skill the individual will have optimal performance. So, motor quality and skill both are equally important.

Then before moving on to the training principle and nexus's prescription it is important to understand different motor qualities which are important for improving the performance abilities. So, based on the energy system, information processing and joint mobility there are five basic motor qualities. Based on the energy system you have; you are aware about the bioenergetics. So, the aerobic or the oxidative system gives rise to endurance. The anaerobic capacity or the anaerobic energy system gives rise to a motor quality called strength. The motor quality where more of information processing is required are speed and coordination. And the motor quality where joint based movements are required is called as flexibility. So, based on the interdependence between these basic five motor qualities you have various other important motor performance abilities. Like, in an endurance sports it is purely of an endurance character where you have aerobic endurance. Whereas in sports which require repeated muscular bouts of activity will encompass a combination of muscle strength as well as the endurance aspect. So, that is called as the muscular endurance. A sport where purely strength is required, say example weightlifting is where you have maximum strength is required. It is purely based on strength. There may be sports where you need to perform an activity in a limited period of time. The ability to perform activity is the fastest. Say for example short put throw or say for example a sprint. So, this is more of a power is required. Say for example jumping sports. So, this is called as power. There are certain sports where you need to have a combination of speed, coordination, flexibility and also at a faster pace.
So, that is called as agility in sports like football where you need to be very agile in terms of change of direction with fastest possible way and good flexibility. So, that is called as agility.

To further consider all the motor qualities are related to sports performance. Let us see the interdependence that happens with the core motor qualities like strength, speed and endurance. So, let us take an example of weightlifting. Weightlifting you know it is determined by lifting the maximum weight. So, this is a sport where it purely depends on the strength as the dominant motor quality whereas endurance and speed play very minimal role in this particular sport. So, the dominant motor quality in weightlifting is strength in weightlifting. Say for example marathon. In marathon runners the main dominant motor quality here you will be easily able to guess it is the endurance.

However, though endurance is, say, 80 to 90 percent the dominant motor quality also needs to work on the strength as well because they need to race at a higher pace or a faster pace during the end of the race which require anaerobic capacity and the muscle strength. So, it also requires the component from strength. However, the dominant motor quality in marathon would be endurance. Say let us say example of sprinting. Sprinting it is we all know it is more of speed the fastest speed at which you cover the distance the shortest possible way is the speed. So, however, it also is dependent on the strength of the muscle because that is dependent on the muscle strength as well. So, speed and strength both have a dominant effect on the performance of sprinting. So, that is how the interdependence of the motor qualities pave way for better sports performance in specific sports. So, as a coach or a trainer it is important to identify what is the primary motor quality that you need to focus in a particular sport for an athlete.

Moving ahead let us see about muscular strength. Strength is the capacity to produce large amounts of force and a muscle group or a muscle can generate. It is now regardless of speed or movement. It is mainly focused on the amount of force that is being generated. When we consider the highest force that that particular group of muscle can you know generate that is called as maximum strength. So, normally in a fitness gym you can assess the capability of an individual to lift a particular weight using particular group of muscle using something called as one repetition maximum. What do you mean by one repetition maximum? It is the maximum weight the individual can lift with only one you know repetition and beyond which you will not be able to lift. So, only once the individual can lift the maximum amount of weight. So, that is called as one repetition maximum for that particular group of muscle. Let us take an example of bench press where the individual whom you train gradually you load the weight hands and individual is able to lift only once a maximum weight of say for example 60 kgs. So, that will be the one repetition maximum of that individual on that day for the bench press or the group of muscle that is involved in doing a bench press. That is one repetition maximum.

Let us further dwell in detail with a case scenario. So, you have Mr. Abbas. He has joined your gym and started you know weight training program as per your advice.

You had put him through a general conditioning program initially as per the standard practice for an 8 weeks period. So, now you would like to design a weight training program whereas he is willing to increase his muscle mass and shape as well. So, before starting to design you would like to measure what is the kind of one repetition maximum of this individual. So, now how will you measure? So, what are the steps involved in measuring a one repetition maximum? So, let us discuss this step wise. So, first as step one what you must do is you should instruct the athlete to warm up.

So, you would do some basic warm up. Warm up the group of muscles that you would like to kind of assess and then using a very light resistance where the knee does not get fatigued. Basic 5 to 10 repetitions. Then you ask the athlete to take rest so that his energy sources get replenished over a period of one minute rest period. Step three would be now you estimate a warm up load.

So, you observed him over the last 8 weeks how much of weight he could lift over a period of time in these 8 weeks. So, you use somewhat about warm up load where you could do 3 to 5 repetitions. So, to the warm up load you add some, if you are assessing for upper body add 5 to 10 kg. If you are assessing for lower body because of the bulkier muscle involved you can add up to 15 to 20 kgs this time. So, ask the individual to complete 3 to 5 repetitions.

Once that is done then you provide him or her a rest of 2-minute rest period. So, now in this 2 minute the energy source replenishes. As a step 5 what you must do is now estimate a conservative load which is close to its maximum. So, you know if the individual is able to lift about say 30 kgs now what you do is you make the individual to lift another 5 to 10 kg. Add 5 to 10 kg to the if it is upper body or 15 to 20 kg if it is lower body. Ask him or her to do 3 repetitions. Then now you have to provide about 2 to 4 minutes rest period. So, gradually you are increasing the rest interval so that you giving more time for the energy source that has been used to replenish back again. So, once the individual is completed that 4 minute of rest period now you make an attempt to increase the load by another 5 to 10 kg if it is upper body weight. If it is lower body weight increase it up to 15 to 20 kgs. Now this load should be an estimate load where you must be able to lift only once and not able to lift more than once. So, that is reached. So, that is the one RM of that individual. That has to be noted. If the athlete was successful then you can also add one more thing and try to do that not able to do then the step 7 would be taken as the one RM. If the athlete is not able to do at all so then what you do is you give again 2 to 4 minutes rest interval reduce that weight which you had at last time and now ask the individual to lift. Now if the individual is able to lift only once that becomes the one RM for that particular group of muscles. So, it is based on the gradual increase wherein the individual

is able to do only one repetition. That is important but proper exercise technique has to be maintained during the entire course of the activity. Moreover, it is within the 3 to 5 testing sets only. So, the warming up period thereafter you have to do about 3 to 5 moderation or iteration after which you would be able to reach a one RM of that particular group of muscle. So, that is how you measure the one RM of the client that you have.

So, let us discuss about power. So, we saw about strength and we saw about what is power. Power is nothing but the strength with respect to time. The rate of performing work is called as power. So, we know that

power= Strength x Speed (at which the individual can perform that particular activity).

So, speed is defined as,

Speed= distance/ time.

So, power = force x distance/ time.

So, most of the sports power is very important component for performance and generally it is measured using algometer but we can also measure it roughly using timing the activity as well. So, one thing you should understand here is it is a combination of strength and speed. The speed quality is more of a natural ability and less of a nurturing thing. So, one needs to understand that if you want to increase power very less amount of change that happens in the speed component but you can drastically improve the power by working on the strength component of the individual. That is more important. So, if you want to increase the power increase the strength with exercise training.

Let us see an exercise. You have two people Mr. Ram and Mr. Lakshman. They are both your client and Mr. Ram lifts 50 kg during a leg press. And that is his one RM and he could also lift about 50 centimeters. He lifts it, he could lift at about 50 centimeters during the leg press at about 0.5 seconds period of time. So, here you have the distance and the time and the force. So, you can calculate the power here. What about Lakshman? Lakshman, he is able to lift 60 kg during the same activity. He lifts at the same distance but then he is able to lift over 2 seconds. So, let us, the exercise is to calculate muscle power in both the cases.

So, let us see the maximum strength is 1RM done during the leg press. Ram could lift 50 kg; Lakshman could lift 60 kgs. So, if you just go by strength, Lakshman is stronger. But then let us see what happens with respect to calculation of power.

Power we know that it is force into distance by time. Power= Force x Distance/Time.

So, if you fill up the same 50 kg is the force that individual could lift into distance is 50 centimeter as given in the question and the time is 0.5 seconds. So, let us reduce it to the SI unit. So, 50 into 50-centimeter, 100 centimeter is equal to 1 meter.

So, 50 centimeter will be 0.5 divided by 0.5 second which gives to 50-kilogram meter per second or watts.

50 kg x 0.5m/0.5s = 50-kilogram meter per second

That is the unit for power. What about Mr. Lakshman? Lakshman lifts 60 kgs, so, force is 60 kg, 50 centimeter is the distance and then 2 seconds. So, converting them into SI unit, you get a value of 15 watts of power.

So, if you could see here, obviously Mr. Ram though he is lifting, you know, less weight or he is possessing less strength as compared to Lakshman, but the speed at which he is doing is good. So, that is why his power is more as compared to Lakshman. So, Mr. Ram is more, could generate more power as compared to Mr.

Lakshman despite, you know, lifting less amount of weight. So, let us imagine a case where if with these two outcomes, you find that Mr. Ram is a striker in a rugby match and Lakshman is a defender. So, Ram would have better power to kind of maneuver the ball in the shortest period of time being a striker. Whereas if you see Lakshman is a defender, so, he has better strength, right? So, he could hold the opponent with his better strength. So, that is how you can interpret the importance of strength and power.

So, let us move ahead with muscle endurance. So, the next important motor quality for performance is muscle endurance. There it is important because muscle endurance determined by the capacity to perform repeated muscle contraction or the capacity to, you know, sustain a contraction over a period of time. So, let us take an example for the first one would be, you know, repeated contraction would be to do multiple sit-ups in a period of time and sports like boxing will be of very important application, where you need to have repeated muscle contraction when you do boxing in different bouts. Now, what about sustained contraction? Take an example of wrestling where a wrestler is trying to generate sustained contraction of muscle to resist the force offered by the opponent. So, there you need muscle endurance or a plank till exhaustion where you are not actually causing any kind of muscle contraction, but that is sustained over a period of time.

So, that is an example of muscle endurance where single contraction over time is used. So, generally, it is represented as a number of repetitions as a percentage of 1RM. So, you

know, you assess the 1RM and then percentage of that is used to, you know, express the muscle endurance. Example would be, say, for 75% of your 1RM is the muscle endurance that you can prescribe to your athlete. So, this can be increased by increasing the muscle strength and also by causing local metabolic adaptations so that there is better oxygen delivery and, you know, cardiovascular adaptations. So, as we discussed earlier, muscle endurance is a combination of strength and endurance. So, you need to have adaptations at both the aspect of the endurance as well as the strength.

Let's look at an exercise. We have again Mr. Ram and Lakshman. They are able to lift certain amount of weight as given in the program. So, Mr. Ram is able to lift 50 kg during a bench press 1RM and he could lift the height of 50 cm in 0.5 seconds. Whereas Mr. Lakshman also lifts same 50 kg during the same activity. However, he is lifting over 2 seconds. So, the number of repetitions is given in the problem it seems. So, let's see what's the problem.

So, here we have 1RM of maximum strength. Both of them have same 50 kgs and as we calculate the power, we found that Mr. Ram has 50 watts and Mr. Lakshman is having only 12.5 watts. However, muscle endurance when you see Mr. Ram was able to do 5 repetitions with 75% of 1RM. There are only 5 repetitions he could do. Whereas Lakshman, even though his power was low, he is able to do 10 repetitions. So, muscle endurance of Mr. Ram is lesser as compared to Lakshman. So, now the question is what should be the focus on exercise training for improving performance. So, if you see Ram has better power. So, obviously the focus should be to improve his muscle endurance.

Whereas Lakshman has muscle better endurance. He is able to do 10 reps. So, he has better muscle endurance whereas his power is low. So, he has to his exercise training should focus on increasing the muscle strength. So, that is power will increase. So, that's how you interpret based on the measurement and how they perform and thereafter you can incorporate them in your exercise training based on the identification of the motor quality and assessing them periodically.

So, let's focus on aerobic power. Aerobic power is the rate of energy released by oxygen dependent mechanisms. So, the maximal aerobic capacity is given as the maximal ability to re-synthesis ATP using aerobic pathway. The synonyms which are used are maximal oxygen consumption or VO2 max. So, the various contributing factors here are the muscle which is going to contract, the respiratory system from where the oxygen is taken from the ambient atmosphere and the cardiovascular function from where the oxygen is delivered to the muscle for the action. However, the primary limitation factor of this aerobic power as we have discussed during a cardiovascular system module is your cardiovascular system.

So, generally cardiovascular system is your limiting factor. So, that's why you will have to focus on cardiovascular system when you are promoting exercise training for endurance sports. And this is generally error tested by using field test or lab test. So, important aspect is that you should make sure that you create positive adaptation in these physiological systems when your expected outcome is for an endurance sport is the aerobic power. Let's see about anaerobic power. Anaerobic power is completely on the other spectrum of the energy system that is your anaerobic energy system that is ATP PCR and glycolytic pathway.

So, whatever training that you are trying to impart it should stimulate this anaerobic pathway and the maximal power generator using the anaerobic system is the maximal anaerobic power. However, we know that it is related with time, right? So, the maximal capacity to produce the anaerobic power with respect to the time is called as the anaerobic power. It is also known as anaerobic capacity. Generally, we use lab method like wingate anaerobic test or field method like say stair climbing test or a standing jump test or a standing broad jump test. So, your exercise training should include programs that will stimulate positive adaptations in this metabolic pathway so that it happens at the level of type 2 muscle fibers, namely the type 2 muscle fibers which are high in content of your anaerobic enzymes as well as the anaerobic fuels. So, that is very important.

So, covering certain basic terminologies that you must know before prescribing an exercise program are or which you commonly use in your exercise description are frequency and intensity. Frequency is the training frequency which refers to the number of trainings that should be conducted per day or per week. So, that becomes the frequency of the training activity that one should perform. Intensity is nothing but the effort that the individual has to put through during the session. That is called as intensity. There are various methods to monitor or prescribe intensity. In case of endurance exercises, you can prescribe in terms of VO2 max as percentage. You can use heart rate as an important field method to prescribe the intensity in endurance activity. Certain coaches also prefer prescribing the intensity in terms of the lactate threshold.

These are objective things which you can prescribe. Sometimes you can also take into account of the subjective feeling of the athlete, how the individual feels exerted during the activity. So, accordingly you can scale them from activity of 0 to or 1 to 10 and then accordingly you can prescribe. You can also prescribe in terms of the running pace. Say for example, pace of covering a kilometer in 6 minutes, 6 minutes per kilometer pace. So, the individual, these are available in your wearables wherein in the watch you can fix that and then accordingly you can have a metronome-based kind of input to the athlete when

the exercise is being performed. If it is a resistant training, you generally prescribe the intensity in terms of the percentage of 1RM or the load. It can also be prescribed in percentage of MET. Generally, in clinical scenarios, the MET equivalents are commonly used in a lab-based scenario generally. So, this is important to understand that whenever you prescribe an exercise, it is prescribed in terms of something called as FITT protocol.

So, whatever you prescribe should have 4 components in your prescription. The first 2 components are frequency intensity which we saw now. Let us see what are the other components of FITT protocol. The other one is the type or mode of exercise. What is the type of exercise that the individual has to perform? So, that is called as the type of the FITT protocol.

It can be in endurance, can be cycling or running or swimming. In case of resistance or anaerobic exercises, it can be free weight, it can be machine weight based or it can be own body weight based. So, you will have to specify what is the mode or type of the exercise that individual has to perform. And the last component of the FITT protocol is the timing or the duration. Exercise duration is the length of the time for the training session. So, that would be your timing of the FITT protocol. That is the last key of the FITT protocol. So, these are the common terminologies when we use in our exercise prescription.

One more thing which I have covered was the rating of perceived exertion. So, the rating of perceived exertion is a subjective scale based on the input of the ethnic person and that can be rated from scale of 1 to 10. And 1 would be a scale of no kind of exertion at all and 10 is more of maximum exertion that individual can do. Generally, a rating of 8 is rated towards a lactate threshold level, which is around 85 percentage of the maximal oxygen consumption, 85 to 90. And 9 and 10 would be towards the near maximal load the individual can actually perform. So, that is a rough idea about the rating of perceived exertion scale.

The other common thing is your metabolic equivalent. This is more used in clinical and lab-based scenarios, wherein 1 metabolic equivalent is equivalent to 3.5 ml per kg per minute of oxygen that is consumed by the tissue.

1 MET = 3.5 ml kg^{-1} min^{-1} Oxygen consumed

So, based on that, you have various MET equivalents, wherein say 1 MET is equal to just as I am lying or sitting quietly, I use about 3. 5 ml per kg that is equivalent to 1 MET. So, if I say that he is doing a activity of 5 METs, it would be equivalent to performing an aerobic dance with low impact. So, that would be a MET equivalent of 5. If I run at a

speed of 8.5 kilometer per hour, so, that will be equivalent to about 9 METs. So, there is a compendium of physical activity which shows the activity and the corresponding MET equivalents, which is basically used in various clinical scenarios and lab-based measurements.

To summarize, so, exercise training is more dependent, is an inclusion of various scientific principles to have positive adaptation and better sports performance. That is dependent on the motor qualities which is present innate and how you develop the other skill to further enhance the motor qualities. The motor qualities which are useful or more important are the muscular strength, power, endurance, anaerobic and aerobic power. And we saw about various basic terminologies like the FITT protocol in exercise prescription and, the use of rating of perceived exertion and, metabolic equivalent. For those of you who are interested further in in depth learning, these are the following, you know for additional reading, sources for additional reading. Thank you.