Introduction to Exercise Physiology & Sports Performance

Prof. Anup Krishnan

IIT Madras

Lecture – 37

Performance testing in aerobic sports

Good morning, ladies and gentlemen and welcome to lecture 2 of week 8 of this course on exercise physiology and sports training. Today, we will be discussing a very important topic that is performance testing in aerobic sports. We already had a small introduction to performance testing and today we will talk about how it is applicable in aerobic sports.

I will cover the topic under the following headings. Introduction, measurement of VO2 max, lactate threshold testing, indirect lactate threshold testing, performance predictions, how to do them. We will talk about how to test for something called exercise economy and we will conclude with a take home message.

Exercise testing to determine VO2 max dates back more than 90 years. It is not a recent phenomenon. In fact, the British physiologist A. V. Hill coined the term VO2 max in the year 1923. It is defined as the maximal oxygen uptake that an individual can obtain during exercise using large muscle groups. Basically, what it means is how well can your body take in oxygen, how well can your body transport that oxygen and how well can your muscles utilize that oxygen at maximal exercise intensity. This is simply what is the meaning of VO2 max. There are several tests available to estimate VO2 max but the most accurate or the gold standard is direct laboratory measurement using a breath-by-breath metabolic analyzer.

VO2 max is the test of choice for predicting success in endurance events. Direct measurement of VO2 max is tested by using a motorized treadmill or a cycle ergometer and open circuit spirometry. Basically, any instrument wherein you can increase the load on the exercising athlete can be used for measurement of VO2 max. It may be a treadmill, it may be an ergometer, it may be a rowing ergometer also. You can even do it in a swimming flume. Only condition is your breath-by-breath analyzer should be able to work properly. VO2 max has also been measured during swimming, cross-country skiing, bench stepping, ice skating and rowing. There are new breath-by-breath analyzers which are available nowadays which can be used on field and it connects to a laptop via Bluetooth or Wi-Fi and the athlete can be running on the field and you can use the breath-by-breath analyzer to measure data.

In a heterogeneous group of athletes, that means in a group of athletes with different VO2 max, if you take the VO2 max which is expressed in ml per kg per minute, the person with the highest VO2 max is generally going to be able to run better and run the farthest. Because distance running is largely an aerobic event, those individuals with a higher VO2 max will have an advantage. In a homogeneous group where VO2 max values are similar, the correlation between VO2 max and distance running performance is low. That means when VO2 max values are similar, there are other important variables which are factoring into endurance performance. The exercise tests that mimic the actual sporting event are more reliable. VO2

max is only one in a whole battery of tests that should be used in evaluating the performance capacity of endurance athletes.

There are several tests which are there to determine VO2 max. However, for reliability and validity, the test to determine VO2 max should involve the specific movement used by the athlete in his or her event. If the athlete is a distance runner, VO2 max should be assessed during running. In trained cyclists, the test should be performed on a cycle ergometer. Specific testing procedures have been established for cross-country skiers and swimmers.

How do you test for VO2 max? Now, if you look at this diagram or this figure, you can see the athlete is running on a high-speed treadmill and he has got a mask on his face. Now, this is the breath-by-breath metabolic analyzer and he is also wearing some instruments on his chest and his back on a harness. This is called a K4 or a K5 metabolic analyzer. Now, when you start this test, you start with a submaximal warm-up, lasting 3 to 5 minutes. After the warm-up, you start increasing the exercise intensity. Generally, exercise intensity is increased on a treadmill by increasing the speed of the treadmill. And, you increase the load every 2 to 4 minutes and continue till the subject cannot maintain the speed or the subject says I cannot do it anymore. You can measure several values such as gas exchange, RER, PO2, PCO2, heart rate and VO2 values in real time in a breath-by-breath stage along with several other parameters which can be measured.

The protocol generally lasts for 12 to 15 minutes and the VO2 max test is judged as valid if any two of the following criteria are met. The respiratory exchange ratio reaches 1.15. The heart rate of the subject is within 10% of the maximum predicted heart rate and the VO2 max plateaus despite an increase in the load.

We looked at how to test for VO2 max. Now let's look at another something very important parameter that is endurance performance prediction. Exercise physiologists, coaches and athletes have searched for a single laboratory test that can predict success in endurance events but there is no single laboratory test available. Several tests have been developed in an effort to predict athletic performance.

One of these tests is something called lactate threshold. In these athletes, lactate threshold is a good measure of running fitness. Lactate threshold helps to establish training zones and lactate threshold is a good predictor of competition performance.

The gold standard for lactate threshold estimation is something called direct estimation of blood lactate. The generally protocols for lactate threshold estimation begin with a slow warm up. However, it is recommended that no warm up is given rather than that you start the graded exercise protocol from the treadmill speed of zero because if you warm up the patient or the athlete, the blood lactate levels will start increasing and you will not get a true zero baseline value. What you do is make the athlete run on a treadmill and start increasing the load every two minutes or every four minutes and when you continue to increase the load, at each point when the load is increased, start taking blood samples of lactate and these blood samples are then chemically analyzed for lactate and then you make a graph. We will discuss the graph a bit later.

This is how the test is conducted on a treadmill and a graded exercise protocol is given. Generally, the speed is increased every two minutes. Some principal investigators like to do it every four minutes and at every two minutes you start pricking the athlete and collecting blood. This blood is put into a lactate meter and you get the lactate values.

When you plot this against a graph, when you plot the lactate values in millimole per liter here, here you plot, generally you plot time, you may even plot treadmill speed or you may plot load. At the institute where I used to work called Army Sports Institute, we also used to plot heart rate at the same time in beats per minute. I will discuss why we used to do it because it gives us a lot of good data.

So, if you look at this graph, you will see lactate has been plotted. There are some areas where blood lactate will rise for a minute or so and it will fall back to the baseline again. This is generally called lactate threshold 1 and this is normally not considered for blood lactate estimations. What we consider is LT2 wherein the graph has broken its linearity from the baseline and the increase in blood lactate is more than 1 millimole per liter above the baseline. This is what is generally taken as lactate threshold. Now, if you look at the heart rate graph, at the same time there is a heart rate response to graded exercise and when you plot the heart rate at LT and you drop it 10 millimeters and 10 millimeters above, this will give you this 179 to 188 is your lactate threshold heart rate training zone. So, when you plot the heart rate along with lactate threshold, there are a lot of data which can be used and a lot of data which is useful to the athlete and the coach. Generally, what is done is 2 to 3 sessions of threshold training, that means training at this heart rate is given to the athlete every week and when you test these individuals after 3 to 4 months, you will find that the entire curve shifts to the right thereby signifying an improvement in the lactate threshold.

Now, we have seen that direct estimation of lactate threshold is an invasive procedure wherein you have to take finger pricks of every reading and at least 7 to 8 readings are required before you can get a good graph and that means 7 to 8 finger pricks which is an invasive procedure. So, several indirect lactate threshold estimation methods are available which are non-invasive. They are the Conconi protocol, wherein you plot the heart rate versus a graded exercise protocol and you will find at the lactate threshold, the heart rate dips a bit and then rises again. There are other methods such as time trial method, race trial method, there are even wearable devices which work on near infrared spectroscopy method. There is another method by which you can measure lactate threshold called ventilatory threshold method. It is said that ventilatory threshold corresponds to lactate threshold during endurance training.

A ventilatory threshold by gas exchange is done by a similar test to VO2max analysis basically using a breath-by-breath analyzer. What we do is we graph minute ventilation at each work rate and oxygen uptake in liters per minute. The point at which ventilation rises rapidly is considered the ventilatory threshold. This is one method. The other method is you plot VCO2 by VO2 again by using a metabolic analyzer and the point where the graphs cross is also called ventilatory threshold.

We would like to do something called performance prediction in endurance athletes. It is done by a method called critical power. The concept of critical power is based upon the notion that athletes can maintain a specific exercise intensity without fatigue. So, running speed is plotted on the Y axis and the time is plotted on the X axis. Critical power is defined as the running speed at which the running speed time curve reaches a plateau.

Critical power is done by having the subjects perform a series of 5 to 7 timed exercise trials to exhaustion. It is determined by the point where the power time curve begins to plateau as we have already seen. It is critically, critical power is significantly correlated with performance in endurance events lasting 3 to 100 minutes. It is a useful laboratory predictor of success in endurance sports.

There are several tests to determine something called exercise economy. Economy of movement has a major influence on the energy cost of the sport and in determining endurance performance. A runner who is uneconomical will expend a greater amount of energy to run at a given speed than will an economical runner. The measurement of exercise economy is useful when performing laboratory tests to evaluate an athlete's performance potential.

Exercise economy is assessed by graphing energy expenditure during a particular activity at several speeds. The energy costs of running, cycling or swimming can also be determined using similar methods. The economy of running is quantified by measuring the steady state oxygen cost of running on a horizontal treadmill at several speeds.

The oxygen requirement of running is then graphed as a function of running speed. At any given speed, we can see in the graph, runner B requires less oxygen and therefore expends less energy than runner A. That means runner B is more economical than runner A. A marked difference in running economy between athletes can have an important impact on performance.

We can also use these performance predictors to do race predictions. The prediction of potential performance in any endurance sport involves the use of VO2 max, economy of movement, lactate threshold, etc. However, there are a number of outside factors such as motivation, race tactics and environmental conditions that can influence racing performance.

What is the take home message from this lecture? There are several common laboratory tests to measure endurance performance including measurement of the lactate threshold, measurement of critical power and measurement of peak running velocity. These measurements have proved useful in prediction of performance in endurance events. The lactate threshold represents an exercise intensity at which blood lactate levels begin to systematically increase.

Basically, what happens is, blood lactate is a direct mirror of muscle performance. If more muscle fibers are being recruited, more blood lactate is being produced. It reaches a level generally when blood lactate is being produced, there are mechanisms in the body which remove the blood lactate from the body. However, if the rate of production of blood lactate exceeds the rate of removal of blood lactate, then the blood lactate level begins to rise and that is called as lactate threshold. We know that lactate threshold can be determined directly and indirectly.

Success in distance running performance can be estimated by using both the lactate threshold and other measurements of running economy. We cannot predict performance by only using one method. We use different methods or a combination of two or three methods to give a subjective and an objective opinion regarding the distance running performance. Success in an endurance event can be predicted by a laboratory assessment of the athlete's movement economy and lactate threshold. These parameters can be used for determining the maximum race pace that an athlete can maintain for a given racing distance.

These are the references, ladies and gentlemen. I strongly urge you to go through the references and in the interest of better understanding and more deeper learning of this topic.

I seem to have finished, ladies and gentlemen. Thank you for your patience and your time. Do let us know your questions and comments in the email flashing on the screen and thank you very much, ladies and gentlemen, thank you and Jai Hind.