Exercise & Sports Biomechanics
Dr. Rahul Tiwari
High performance Analyst – Biomechanics, SAI
Netaji Subhas National Institute of Sports, Patiala (PB)
Week 11
Lecture 52
Biomechanical parameters in Isokinetic testing

[Let us discuss the biomechanical consideration of isokinetic dynamometer].

Isokinetic Dynamometer:

An isokinetic dynamometer is a device used within sports and exercise science as well as clinical testing environment that is used to evaluate joint torque. Isokinetic dynamometers are able to test the strength and power of different muscle groups. In sports biomechanics, an isokinetic dynamometer is a device used to assess muscle strength and power by measuring joint torque at a constant velocity during movements, providing valuable data for training, rehabilitation and injury prevention. Most commonly, isokinetic dynamometers are used to assess limb strength after injury or surgery and to compare the affected to unaffected limbs. The percentage of unaffected limb strength can be used to determine when the athlete can return to sports.

In short, isokinetic dynamometer tests your muscles. It gives you the total torque production capacity of a muscle. It tests the asymmetry and symmetry level between right and left side and it gives you the ratio of agonist as well as the antagonist muscle growth.

An isokinetic dynamometer is a sophisticated biomechanical device used to measure muscle strength, power and endurance by controlling the speed of muscle contraction. The term isokinetic that originated from Greek word called iso which means same and kinetic which means the movement referring to a situation where the muscle contraction at a constant speed regardless of force exerted by the muscles.

Why it is important in biomechanics over the other different tests?

You know traditionally the muscle strength test like one rep max test, we call it one RM test or the manual muscle test. It provide limited insights because they do not isolate the muscles performance under consistent speed over the resistance, On the other hand, the isokinetic provides the platform where you can test the muscle at the constant speed throughout the range of motion. The other importance include; they allow precise measurement of muscle strength, fatigue, and power without the influence of momentum or gravitational resistance.

They also provide the objective quantifiable data that essential for diagnosing the muscle imbalance, designing targeted rehabilitation programs, assessing athlete performance, and obviously monitoring the injury progress. For example, if a soccer player you know he had an ACL injury and he underwent an ACL reconstruction so obviously after that that he may reduce the quadriceps strength so an isokinetic dynamometer can measures the exact torque output of the quadriceps during knee extension at different velocities, helping the trainers design their specific strength building exercises in the program. Similar way, the isokinetic dynamometer also helps a physiotherapist in order to identify the exact status of the muscle so that he can design the specific rehab program for that particular athlete.

The principles of isokinetic testing:

An isokinetic contraction occurs when a muscle contracts at a constant speed despite varying level of the force. The isokinetic dynamometer ensures that the speed remains unchanged by adjusting the resistance automatically.

How isokinetic dynamometer works?

If the muscle generate more force the dynamometer increases the resistance to maintain the constant speed and that is how it basically maintains the constant speed throughout the range of motion despite changing the resistance at the different degrees of the motion. It is differ from the other type of muscle contraction like the isometric contraction or the isotonic contraction. So you know the isometric contraction we all know that it is the contraction where there is no change in the length of the muscle. Iso is same and the metric is measurement. For example, holding a particular position like holding a plank.

Although it is a very simple, that is the advantage of this, but there is no range of motion which is involved. And in case of the isotonic contraction, iso is same and tonic is the tone or the constant load the muscle is having. So the muscle contracts while changing length with the constant load. That is called isotonic contraction. So in this exercise the length changes and the load remains the constant and the speed also changes because the speed depends on the load and all. So the examples are, doing normal exercises like biceps curl using a dumbbell, it is a functional that is a good advantage of this but the momentum and the gravity affects output, so that we cannot use it wisely for the exact testing of the muscle under the constant speed. And the isokinetic we all know that this is the muscle contracts at a constant velocity regardless of the force, so the speed throughout the range of motion remains constant. It is controlled and accurate muscle strength measurement can be done using the isokinetic dynamometers. You can have a look at this particular pictures in order to have this three kind of muscle contraction I am talking about.

Talking about the component of the isokinetic dynamometer:

The device content or has a motorized resistance unit. which is also called the dynamometer in the device and it provides the variable resistance to maintain the constant velocity and it also plays an important role while placing the particular athlete or the subject for the testing because there is an axis of rotation for this particular dynamometer you can see that axis of rotation here in the picture as well see yeah this one this part This is the axis of rotation. So whatever joint we are testing, we just need to align that particular joint axis of rotation with the axis of rotation of a dynamometer. It is as simple as that.

Then we are having different lever arms or I can say it is the extensions which are available for the different joint testing. So for example, in this particular picture the extension or the lever arm which is used it is for the shoulder joint. Similar way we are having different extensions or the lever arm for the different joints like knee, hip, ankle, elbow, wrist and it connects the tested limb to the machine. We do have an adjustable chair or the platform with the isokinetic dynamometer. So this is like there is a chair which can rotate in all the directions like the 360 degree it can rotate.

It can go into the flat position or into the upright position. It can shift forward or backward. It can shift as a whole, so that we can align the joint with the dynamometer and position the subject for the right and left side testing very easily. We do have a range of motion limiter in the dynamometer. So, it is there to restrict the movement to a safe, controlled range.

The one you are seeing in the picture is the mechanical lock. However, we can also have an automatic sensor-based lock. This will be discussed when we talk about the testing and demonstration of the device. The device has a computer and a software interface. These collect and analyze the data.

The data collected include torque, power, velocity, and range of motion. The device can measure different types of muscle actions, such as concentric, eccentric, or even isokinetic. This particular device can measure two muscle groups simultaneously. These two muscle groups are the agonist and antagonist muscle groups, the opposite muscle groups.

Let us take an example of this. So this is a biceps, let us say, and there is another muscle here, which is the triceps. So if we are testing these two muscle groups, we are testing the elbow flexion and extension. So in this case, I can test both muscles or measure the muscle action as concentric and eccentric muscle action, or I can measure both as eccentric and concentric muscle action. I can have one as concentric and one as eccentric, or this as eccentric and this as concentric. So any permutation or combination I can use to measure the muscle action for a particular joint action. So this is an example of a concentric one.

Similarly, there is an example for eccentric. In the same way, we can definitely go for isometric contraction as well. The simplest way to do this is to fix the dynamometer at a particular position and ask the subject to apply force against the fixed position of the dynamometer so that at that particular position only, that amount of time the athlete is applying the force or the torque production is being recorded by the device. This device is called an isokinetic device. This is made by the company called HUMAC NORM. Earlier, this used to be CYBEX. In our old school books, we all have studied the isokinetic device as the CYBEX.But now they have a new name called HUMAC NORM. So that does not cover any of this.

[We are moving towards the property of the device]

The property of the device:

As already discussed in the slides that isokinetic move of contractions are basically the type of contractions in which the speed throughout the range of motion limits constant. This device basically helps us to achieve that. And these are the parts of the device. This is the chair, the chair can be rotated in any direction like all physical motions we can do to the chair. So that we can easily accompany the right and left side desk tool and all.

Apart from that chair can move like the forward and the backward like this. The chair can move into the flat position, into the normal position like this. And the chair can move as a whole in backward and the forward direction. So that we can adjust the athlete in such a way that the athlete will be in perfect position for the particular joint testing. And this is called the dynamometer.

You can see that dynamometer is basically having one arm here and this particular part is called the axis of the dynamometer. So while adjusting the athlete for the testing and all, the only setting that we need to do is we need to realign or we need to align the joint axis of rotation with this axis of rotation. If they too are come in the proper alignment so that the person or the subject will achieve the good range of motion or the maximum possible range of motion while doing the movement. So there are two end you can see.

This is the shorter end of the head, and this is the taller end. As per the requirement of the testing and all, this needs to be shifted. You can see there are some alphabets written in two directions. So one is in the teal color and one is in the white color. So this is for the left and right end. These are the mechanical stops. of the range of motion for the safety purpose and the dynamometer also can move in any direction like from this direction to this direction for the left and right it can go down it can go come up so that we can align this extra protection with the joint extra protection apart from that the dynamometer can tilt so you can see this so it can tilt also like as per the join orientation and the last part of the device is the software, software I am just discussing here, you can have a look at the video screen, so the software is basically converting all the data and analyze the thing so that you can get the digital form of the data as well as you can get some graphs.

In the software you can see, the interface still call it as the patient because earlier the device is used only for the clinical settings, used only in the clinical settings but now they changed the device in such a way that they can produce much more torque so that we can use it in the sports setting as well. The device can be used for testing, training, rehab, anything. Let us move to the profile and all.

Here we can create the profile, and by providing the demographic data, we can create the profile here. And apart from that, I will go to some already created profile. These are the number of tests that we can do here. You can see that we can start from all the time.

We can test the ankle, knee, hip, shoulder, elbow, wrist and all the possible movement can be done very easily using this particular dynamometer. The only thing is that these are all the extensions for the joint testing. So, for example, this particular thing, it is required for the knee and the hip testing so this adapter that need to be attached here with this end of the dynamometer as per the requirement of the testing and as per the position of the joint so that we can definitely we can use it to achieve the range of motion and all similarly we are having different attachments so that all the attachments can be applied here for the particular joint of testing. So all the biomechanical parameters, we can divide them into the three categories.

These are called the torque parameters, the position parameter, and the time parameter. So, in the torque parameter, the device is measuring the peak torque, the work per repetition, and the average power per repetition. In the position parameters, the device measures the joint angle at the peak torque, the range of motion, and in the time parameter, it measures the time to peak torque, time peak torque held, force decay, reciprocal delay, and the delay time. We will discuss all the parameters in detail in the upcoming slides. So, this is roughly how the report looks.

You can see the graph here. This graph is basically the torque versus position curve. This is the joint angle on the x-axis, sorry, and on the y-axis, we have the torque. So, these are some muscle groups which are called extensors, and these are called the flexors. So, this is basically the report of the knee extension and flexion.

This is of the quadriceps, and this is of the hamstring. You can see the graph is in two colors: the red and blue color. So, the blue color is the right side, and the left side is the red color. And the report itself indicates that this is an isokinetic test for concentric and concentric motion. You can see concentric and concentric, and the speed was 60 and 60 for both quadriceps and the hamstring. For the extension and the flexion both 60 degree per second. And we did for the 5 repetitions. So whatever we are getting, this is the part of the extensors and this is a part of the flexors the whole value right, we are getting the value, we are getting the coefficient of variant, and we are getting the percentage of body weight here and on the other hand we are getting the ratio as well.

[So, let us discuss everything in detail now].

This is the kind of typical graph that we are getting so if you look at the graph. Again, this is the torque I am talking about and this is the position of the joint angle we are talking about, right? And this is the left side and this is the right side for the quadriceps. And for the hamstring again, this is the left side and this is the right side. So by looking at the graph itself, I can say that my quadriceps is much stronger than that of the hamstring.

The graph is much lower than that. And that is the natural case, but how much? That is the question. How to interpret the value?

[I will tell you in the next slide and all. Okay,] but here for me the problem is not that—the problem is basically this portion, which is nothing but the gap between the right and left side. So I can say that there is an asymmetry between the right and left side, where the left is much stronger than the right. How much that is, we will also get in the detailed report. Apart from that, I can see that this portion is where I am getting the peak torque value for the quadriceps, and this is where I am getting the peak torque value for the hamstring.

I can correlate with the graph here—I am getting the peak torque somewhere around 30 to 45 degrees for the quadriceps and around 20 to 30 degrees for the hamstring. So roughly, I can say that my joint is somewhat stronger from 20 to 45 degrees because both muscle groups reach their peak torque within this range. Let us discuss —all the parameters as such. So the first parameter we are getting is the peak torque and The peak torque is basically the maximum rotational force exerted during movement, and it is a key indicator of muscle strength.

You can see here—this is the peak torque. Torque is force multiplied by perpendicular distance. We have already discussed that. That is why the unit of torque is Newton-meter—force and distance, Newton-meter—and whatever we are getting here is the average value of all repetitions. So we have done 5 repetitions.

The value we are getting is the average of 5 repetitions. So that is why it is important while doing the testing. To ask the athlete or the subjects to go for maximal effort in all the repetitions so that we can get a good average value and there are no outliers that can occur. This is important, the command is very, very important. Right? So, what we are getting is the right value. For the left, you can see that for the right, it is around 212 newton meters, and for the left, it is around 239 newton meters. Similarly, for the hamstring, we are getting 160 and 167 for the right and left, respectively. These are the direct values we are getting.

Apart from that, there are certain more values, such as the coefficient of variation, percentage of body weight, and the ratio. So I will discuss everything. The second parameter we are getting is called work per repetition, and this is again the average value we are obtaining. So we are getting the separate value for the right here and the separate value for the left here. For the hamstring, the same applies: the separate value for the right and the separate value for the left. The work per repetition is basically the total energy output per repetition, and it represents endurance and the ability to sustain effort.

Talking about the next parameter, that is the **average power per repetition**.

We talked about the torque here, we talked about the work here, and now we are talking about the power per repetition here. So this is again the average value for the right and left, both separately. And this is nothing but the rate of performing the work that is torque multiplied by the angular velocity. So torque we know that it is tau and that is multiplied by angular velocity that is omega. And it measures the muscle explosiveness. So we can get the value for right and left separately for quadriceps and the hamstring here. So in all this torque parameter, so we are getting the values here. Okay, the values are the direct values. Apart from that, we are getting the deficit value here. So deficit is nothing but the percentage difference between the right and the left. Between the right and the left, the percentage difference will be nothing but the deficit.

From here we can easily interpret the symmetrical index, the symmetry index, whether there is a symmetry in the right or left or whether there is an asymmetry in right or left. So similar way you can get, see, so this is the separation of the two things. This is for the extension here and this is for the flexion here. So you can see here also we are getting the deficit percentage. So you can see the values - see, this is 212 here and 239 here. So there is a difference of 11%. And here, the difference is less. You can see 60 and 67. 160 and 167. So the difference is only 4%. And we are getting the coefficient of variation. This cof var is nothing but the coefficient of variation. So this is a statistical parameter. It basically indicates the variation between the repetitions.

All five repetitions that we asked the athlete to do. So what is the variation between all these repetitions? That is nothing but the coefficient of variation. The lower the value, the more perfect the conducted test is. Then we will get the percentage body weight.

While we are registering the patient into the interface, we will be having the demographic data of the athlete and with his body weight, how much amount, what is the percentage of body weight of the force or the torque that he has applied here that is being indicated here. So I can say that for the quadriceps on the right side he has applied around 271% of the body weight or roughly I can say it is 2.71 times body weight. For the left it was 3.07 times body weight. I can say the left is much stronger than the right.

The red one is upper side. You can see here as well. For the hamstring it is again roughly around 2 times body weight for the right side and 2.15 times body weight for the left side. So these are the values that we are getting apart from that one more important thing which are getting that is nothing but a ratio. So this ratio is the ratio of flexor is to extensor, or I can say this is HQ ratio. The H is to Q ratio, right? So this is for the right side and this is for the left side here. So the for the right side, the ratio is 76. And for the left side, the ratio is 70, or I can say, compared to the quadriceps, my hamstring is 76% strong on the right and 70% strong on the left. So this is how we can basically look at the values. And the same thing we are getting for the work parameter and for the power parameter. Moving ahead to the other parameters, which is called the Position parameter.

The position parameter, the first one we are talking about is the joint angle at the peak torque. So here we are getting the joint angle for the right side and the left side for quadriceps and hamstrings separately. So you can see that for the right side, the quadriceps peak torque is achieved at 44 degrees, and the hamstring is achieved at 21 degrees, and for the left side, it is achieved at a somewhat different degree. We can also see the differences, like you can see the left is somewhat having different values compared to the right. So, this is the angle at which the peak torque is generated, and it helps in evaluating the biomechanical efficiency of the particular joint.

However, we can utilize this particular value in the practical aspect, like for example, in this particular case, I can say my joint is much stronger between 20 to 50 degrees, let us say, for example. So I can use that joint angle, the knee flexion angle, as a position for my starting block so that I can have a strong start. I can have that particular position as a position for my starting paddle for the cyclist so that I can have a strong start, I can train my wrestler to be in that particular position when they are crouching down so that they will be stronger in the beginning and all. So these are the different ways we can interpret all these values.

The other parameter which we are getting is the range of motion, and this is the total angular movement of the joint, and it measures the flexibility and the mobility. So again, we are getting the range of motion for the right and left. So you can see the range basically went from 0 to 90 degrees for the right side and 0 to 92 degrees for the left side.

You can see from here also 0 to 90 or the 92 kind of thing. It is coming here as well. So it measures the flexibility and the mobility. Another, so moving to the other parameters, that is the time parameters. So we have already discussed the torque parameter and the positional parameter.

Now we are discussing the **time parameter**, and it measures the speed and the endurance. So the first parameter which we are discussing here is time to peak torque, and that is in seconds. So the time is the time taken to reach the peak torque, and the shorter time indicates better explosive strength. You can see the time here. So this is the time for the right quadriceps to reach the peak torque, and this is the time for the left quadriceps.

Again, you can see the left quadriceps time is a bit less. So I can see the left quadriceps is much more explosive compared to the right side. The same thing is happening somewhere here as well, more or less the same, 30 and 37, right? So it basically indicates explosiveness, and from here only we can identify the torque-velocity relationship as well. And it reflects the muscle fiber type and the functional performance of the particular muscle group at the particular joint.

This muscle fiber type is an indirect parameter to identify whether we have a fast-twitch muscle fiber or a slow-twitch muscle fiber. You know, muscle groups that take less time here generally have more fast-twitch muscle fibers compared to those that take more time to reach peak torque. So that is the indirect one. Directly, we all know it is nothing but the muscle biopsy.

Another parameter we are discussing here is the **time peak torque**:

This is the duration for which the athlete maintains peak torque, and it assists in endurance and stability. So you can see here the time peak torque is held. This particular athlete held peak torque for 0.08 seconds on the right and 0.06 seconds on the left, and the same applies to the hamstring here. Another parameter we are discussing here is the force decay time, which is, the time taken for the torque to reduce after the peak. It helps evaluate the fatigue index. Once the athlete reaches peak torque, the time taken to decline is called the force decay time. You can see the values here again for the right and left separately.

The best way to utilize these values is to establish a baseline for all athletes and compare them with future test results. I believe this is the best way to use testing parameters in sports conditions, as research values or normative data are often based on specific athlete populations. Geographical factors also matter; for example, European data may not fit Indian conditions. Therefore, it is better to establish a baseline first and compare results with it. Another parameter we are discussing is reciprocal delay, which is the transition time between extension and flexion movements. Since we are testing both flexion and extension, the transition time is called reciprocal delay. That is nothing but reciprocal delay.

And it is important for rapid movement sports. So you can see that values are here. We can get the value for right and left separately this way, right? So these are the parameters which we get from the testing. So broadly categorized into the torque parameter, time parameter, and the position parameters.

The last one is **delay time**:

Delay time is basically the time taken to reach to the peak torque. Sorry, it is the time lag. So last one is the delay time. So delay time is the time lag between the muscle activation and the force production.

And it basically indicates the reaction ability of an athlete. So there are several biomechanical factors which need to be considered while testing like the joint and the muscle alignment. So the proper alignment ensure that the torque produce reflect the muscle strength rather than the joint stability. That is why the alignment of the joint axis of rotation with the dynamometer axis of rotation is much, much more important. And that is why the dynamometer is flexible enough to move in any direction.

The misalignment can cause the inconsistent torque measurement. It causes the stress on the joint and there may be the risk of damage to the ligament and the cartilages. For example, during the knee extension testing, the axis of the dynamometer lever arm should align with the knee joint axis, and this mass alignment may lead to and you know artificially low peak torque and increase the ligament stress. Another consideration which i am discussing here is the gravity compensation, so the gravity influences the muscle loading, right. So, especially in the limb-based testing. And the modern dynamometer measures the gravitational effect and compensate for it to provide accurate torque ratings. And this compensation provides reliability in non-horizontal tests, like the knee extension and the shoulder abduction, which goes against the gravity.

For example, if the tested limb weighs 5 kg, the dynamometer will account for this weight to avoid the false torque reading. So we have the facilities in the software and the dynamometer that we can nullify the effect of gravity. We can measure that as well. Another consideration which I am discussing here is the range of motion. So the setting proper range of motion is critical for accurate measurement of muscle strength across the functional range for preventing the hyperextension or the impingement.

And it is important in order to reduce the range of motion, you know, sorry, it is important if the range of motion is reduced, it can lead to underestimate the strength and there is increased risk of joint stability. One more consideration which is discussing here is the speed and the velocity. So the isokinetic testing occurs at the different angular velocity. So the speed of the isokinetic device ranges from 0 to 500 degree. So considering the slow speed, it is basically considered to be 30 to 60 degrees per second. It measures the strength and the peak torque of an athlete. So mostly for events where strength is an important parameter. The moderate speed is considered to be like 90 to 180 degrees. And it measures the functional power and endurance.

The high speed is basically obviously more than 240 degrees per second. It goes up to 500 degrees per second. And it assesses rapid muscle contraction and reactive strength. So for example, a sprinter's knee extension strength at 240 degrees per second is more relevant for performance than at 60 degrees per second. Because in real life, he undergoes rapid movement and rapid muscle contraction. Talking about one more consideration, that is nothing but the torque-velocity relationship, and it is like, you know, the muscle force decreases as velocity increases due to the force-velocity relationship.

The speed and the resistance are inversely proportional to each other. The slow-twitch muscle fibers are better suited for low-velocity contraction, while the fast-twitch muscle fibers perform better at high velocity. So for example, again, at 30 degrees per second, the peak torque may be 300 Newton-meters, but at 240 degrees per second, it may drop to, let us say, 150 Newton-meters only. The fatigue resistance and endurance are another parameter of consideration. So it is like the endurance can be measured by the decline in peak torque.

Over repeated contractions, we need to keep an eye on that as well. If the drop is more, there is a higher fatigue level, obviously. For example, again, a soccer player's quadriceps torque dropping by 30 percent over 20 repetitions reflects poor endurance. Because they want strength and endurance both.

The advantages of isokinetic devices include eliminating momentum and gravitational effects. It provides consistent resistance and speed. The isokinetic dynamometer enables bilateral and unilateral comparison. And it is suitable for objective and reproducible data. It is safe for post-injury rehabilitation as well. There are some challenges and limitations, like it is costly equipment, and non-functional movement patterns are something which is difficult to measure. However, some of the devices are considering that as well. And it requires training and familiarization—obviously, an expert is needed for that. There is also a high-speed limitation. As far as I consider the device, I have only seen up to 500 degrees per second as the maximum speed, not more than that. So that may be one of the limitations and challenges.

It can be used at various levels in sports and rehabilitation, like measuring performance by assessing explosive strength in sprinters or evaluating muscle imbalance in athletes. So we can use it as an injury prevention device for the mechanism as well. So by identifying the weak muscle group and designing the targeted strength program and all. So if you are looking at this particular graph here, you can see the curve—it is a very scattered curve.

The scattered curve indicates that there is very instability in the muscles. So we can plan our program, the strength program or the rehab program, by looking at the values in the graph. Rather, you know, we can use it for rehabilitation purposes by tracking the recovery properly and by giving a specific program like the one which produces a specific amount of torque and which at a particular speed, so this can be used for various purposes as well.

[Thank you, and see you in the next video].