

# ISOKINETIC TESTING AND DATA INTERPRETATION

## PRINCIPLES OF ISOKINETIC

The principle behind Isokinetic exercise and testing is that the lever arm moves at a preset fixed speed allowing for accommodating resistance to the effort the subject applies. This means that the resistance encountered by the subject is equal to their effort.

The set lever arm speed allows the dynamometer to measure the torque output by the patient throughout the range of motion (ROM). This is unlike manual muscle testing which is a static test, and Isotonic testing which measures strength at the strongest portion of the ROM and is also affected by speed of movement.

Isokinetic resistance will accommodate to pain, fatigue, changes in length tension curve and biomechanical leverage of the muscle allowing for safe efficient exercise and testing. Because of the accommodating resistance the muscle is loaded throughout the ROM, the patient's resistance is then equal to the effort they apply, regardless of the length tension curve which varies with Isotonic loading or pain. Therefore, making it a safer and more efficient form of exercise than Isotonics, which maximally loads the muscle at its weakest points. Also, when the patient begins to fatigue and they are unable to continue with the exercise they are still loaded maximally with the isotonic resistance, unlike Isokinetic resistance which will accommodate to this variable.

Much like the ROM carry-over effect seen with Isometric exercise, there is a 30° ROM carry over with Isokinetic exercise. The carry over is 15° on each side of the end ROM exercised. This will allow for strengthening of the muscle within the non-exercised ROM. (Davies A.T. Sports Health Care Perspective 1995 Vol 1:4)

There is also a 30°/sec physiological overflow between the speeds. This is important with exercise training, as each speed does not have to be exercised. For example, if you start an exercise at 60°/sec, you do not have to exercise at 90°/sec as the overflow will compensate for this. The variety of speeds and physiologic overflow has a distinct advantage over Isotonics, which are usually performed at 60deg/sec. (Davies as above)

## Speed Factor

	Velocity Spectrum (degrees/second)		
Slow	Medium	Fast	
2-180	180-240	300-500	

The one principle of Isokinetics which is important to remember for clinical applications and testing is that torque production varies with speed. The lower the preset speed the more torque can be produced concentrically, increasing the preset speed concentric torque production will decrease. More motor units can be recruited at lower speeds than at higher speeds allowing more torque production. The converse is true eccentrically, the higher the preset speed the more torque will be produced, this is due to the nature of eccentric muscle physiology.

Compressive and translational forces across a joint will vary with speed also. Faster speeds have less compressive forces than slower speeds. This is important to remember clinically, as it will apply to treating specific pathologies. For example, patellofemoral pathologies should be started out at higher speeds to reduce the compressive forces across the joint which in turn will protect the joint surface and will be more comfortable to the patient. On the other hand, a shoulder with multidirectional instability should be started out with lower speeds to use the compressive forces to stabilize the shoulder in the glenoid fossa.

Translational forces across a joint also vary with speed. The knee joint experiences anterior translation of the tibia with slower speeds. This is due to the force vectors created by the quadriceps, and the biomechanics of the knee joint. Slower speeds should be avoided or used with care when rehabilitating an ACL deficient or post surgical patient. The opposite is true with the shoulder, the faster the speeds the more translational movements. This is also due to the biomechanics of the joint and the force vectors created by the musculature.

The use of speeds are also important with curve analysis, as deficits will be more pronounced at the slower speeds. This is due to the fact that the muscle has enough time to recruit motor units

and generate torque allowing compressive and translational forces which may elicit pain, or in the case of an ACL deficient patient translation of the tibia, which will alter the biomechanics of the joint. This is apparent as a dip in the torque curve.

At higher speeds there will be more artifact spiking. This is due to the lever arm decelerating into the end stop causing a spike in the torque curve at the end ROM. This may appear as a peak torque value, and can be eliminated, as you will see later, by windowing the data.

### **Isokinetic Training Effects**

Since the subject essentially needs to "catch" the machine to develop resistance, isokinetic exercise helps to develop some of the following (further details of these values will be explained later):

- **Time Rate of Tension Development (TRTD):**  
Up slope of a curve. Indicates how quickly torque can be developed during a muscular contraction. An example of this would be torque at .20 seconds.
- **Decreased RIT (Reciprocal Innervation Time):**  
Time interval between the end of the agonist contraction and the beginning of the antagonist contraction. For example, the time between the ends of the quadriceps contraction to the start of the hamstring contraction.
- **Strengthens Musculotendinous Junctions:**  
This occurs with any resistance exercise as the body adapts to the demands imposed on it. SAID Principle.

## **ISOKINETIC TESTING**

According to Kevin Wilk, to determine the best type of test for a situation, avoid thinking of tests as a means of measuring strength. Instead, consider the type of test that will help identify problems of overall muscle performance during the functional activities.

Therefore, isokinetic testing offers significant clinical controls, such as: isolate particular muscle groups, determined contraction types and range of motion, and accommodated resistance.

As mentioned before, the bottom line is a set lever arm speed measuring muscular output by the patient making it an efficient method for the assessment of muscle performance.

Range of motion is another controlled aspect of testing or exercising. By controlling the ROM, tests and exercises can be performed in an area of pain free ROM.

The accommodating resistance offered by isokinetics will address pain issues and variations in the length tension curve. This can be seen in the peaks and valleys of the strength curve. When a patient experiences pain or a "weak" point in the ROM, it will be represented as a dip in the torque curve.

Perhaps the most important reason for isokinetic testing is that it provides an effective way to attain objective measures. These objective measures are valid, reliable, and reproducible. Many studies have been performed to document this validity and reliability.

Isokinetics assess the muscle performance values. A specific muscle group can be assessed for the following values, to name a few:

- **Peak Torque** - an absolute strength value, much the same as a one repetition maximum isotonic strength test
- **Work** - a more functional value of muscle performance, as work is torque sustained over distance in the active case, and torque sustained over time in an Isometric test.
- **Power** - This is how effectively the muscle can perform work over time.

These values and others will be explained in greater detail later on.

Isokinetic testing can be used to provide valid, reliable, objective measure of a muscle's performance time after time. Following the guidelines established by Kevin Wilk can further assist these measures. The goal of these parameters is to improve the reproducibility of the test results.

The parameters are as follows:

- **Patient Education**

As with other modalities in the clinic, a patient will be less apprehensive and respond more favourably to treatment if they understand the procedure. Educate your patient verbally about Isokinetics and allow them a few practice sessions, if possible. This will make them more comfortable, and will produce better results as there is a learning curve associated with new movements. Wilk has shown that a patient educated through practice sessions is 80% more likely to give maximal effort of a test, while a patient who is not comfortable with the activity will only give 60% effort.

- **Test Order**

It is important to remember that a patient likes consistency. To make your results more reproducible between test sessions and patients (intra-test), your patient should perform the tests in the same order every time. The key to a good test session is consistency. By keeping the same order every time, it will reduce the clinicians time in administering the test. This will also make your patient more comfortable with your skills as a tester.

- **Axis Rotation**

This is important to allow for safe movement of the joint, and allows for isolation of muscle groups. Should there be any unnatural movement of the joint it will cause poor biomechanics, which in turn can cause joint surface irritation and substitution of the muscles being tested.

- **Warm-Ups**

Warm ups are broken down into 2 types:

1. General Warm up
2. Pre-Speed Warm Up

A muscle which is properly warmed up will function more safely and efficiently than a muscle which is not.

It is recommended that the patient perform a general cardiovascular warm up for at least 10 minutes, this should be done by concentrating on the body part to be tested. For example, if the shoulders are going to be tested; warm up should be performed on an Upper Body Cycle.

Pre-Speed warm ups should consist of three (3) sub-maximal efforts, and one (1) maximal effort. This will allow the patient to get a feel for the speed of the lever arm and what it will feel like to apply sub-maximal and maximal effort at the various speeds.

- **Stabilization**

Stabilization is important to prevent accessory movements of the segments. Accessory, or compensatory, movements may allow the patient to obtain higher torque values. It is recommended to use the straps provided on the chair to help stabilize the patient.

Make sure that they are snug, but not too tight, as this may cause ischemia or change the length tension relationship of the muscles being tested (much like a chopats strap does for the patellar tendon) and ultimately affect the test results.

- **Position**

George Davies recommends testing in non-biased position so the muscle is then unaffected by active or passive insufficiency. It may be necessary to recline the seat to reduce the pre-stretch effect of tight hamstrings.

Positioning will vary with each body part tested. Remember to be consistent when administering multiple tests to the same patient.

- **Verbal Coaching**

Research has been done in terms of how a patient is affected by verbal coaching. A patient will respond to any verbal encouragement that is given. If the clinician is not consistent or another clinician administers a test without verbal coaching, this may effect the test results.

- **Visual Feedback**

As with verbal encouragement, visual feedback is another variable that could affect the outcome of the test results. Research has also been performed regarding these effects and it has been determined that there are benefits to both.

During a training session, it is helpful to have the biofeedback that may provide motivation for the patient. However, during a test the patient may fatigue sooner if they are using visual feedback, as they may try to improve torque output from the previous repetitions. Patients may also use the visual feedback to try and match the previous repetitions, giving possibly submaximal efforts and therefore alter the results.

- **Angular Velocities**

Choosing angular velocities are important. Traditionally, slow speeds have been considered "strength speeds" (60°/sec to 120°/sec) and fast speeds (180°/sec to 300°/sec) have been considered "endurance speeds." This is a fairly true assumption, however, ADLs are comprised of variable speeds and muscular strength needs to be assessed as such. Peak Torque, work, and power can be assessed at any speed chosen. It is important to remember to be consistent between tests, as this allows for comparison of like values.

- **Planes of Motion**

Tested When isolating a particular joint, it is important to remember the biomechanics patterns and movement specific to that joint. For example, to isolate the quadriceps and hamstrings, flexion and extension occur in a sagittal plane. This ensures a safe movement pattern and isolation of these muscles.

- **G.E.T. Gravity Effect Torque.**

This is essentially the torque produced by of the limb and the attachment. For patterns effected by gravity, it is necessary to measure GET.

This is done by the dynamometer, recorded by the software, and added to movements against gravity, and subtracted to movements assisted by gravity. For example, in the knee the quadriceps work against gravity and the hamstrings are assisted by gravity. Therefore, GET is added to extension and subtracted from flexion to compensate for the effect of gravity. In doing such, an unbiased torque value is given. There may be a difference between uninvolved and involved. This difference may be due to edema or muscular atrophy. GET should be measured in the whole ROM each time.

- **Test Repetitions**

Repetitions should be kept consistent between test sessions. By increasing the number of repetitions, the patient may experience fatigue or discomfort during the test.

At least three (3) repetitions are needed for the Software to calculate correctly the test data, provided the patient meets Isokinetic Speed. Slow speed tests are generally conducted with 5-6 repetitions, and faster speeds are usually performed at 10 to 15 repetitions.

Standard isokinetic knee testing is as follows:

- 60 deg/sec .....5 reps
- 180 deg/sec .....10 reps
- 300 deg/sec .....15 reps

- **Isokinetic System Level**

This last parameter is just as important as the first. If there is excessive movement of the dynamometer, it may be displayed in the test results. This is a variable, which can be controlled. The machine should be placed in a stable area, away from excessive clinical

traffic, as the dynamometer is very sensitive. If the machine needs to be moved or becomes unstable, make sure to find a stable space within the facility.

### **Testing Protocol**

1. • Patient performs general CV warm up
2. • As the patient is warming up, set up the computer information and dynamometer.
3. • Seat and Stabilize patient
4. • Pre-Speed warm up
5. • Run test set
6. • Rest period
7. • Repeat steps 4-6 to complete other test speeds

## **NUMERICAL ANALYSIS**

The software collects and stores real time data. Every time test data is recalled, regardless of the actual test date, it will be exactly as it was collected during the original test. This is beneficial when comparing data points between tests.

The questions you should ask yourself with data interpretation is, "What do I want to do with this data?", and "What am I trying to determine from testing?". Do you want to use the data for patient advancement, patient discharge, baseline information before a rehabilitation/training program, etc. The following section will define the test data, and describe what may affect each variable. This basic knowledge should be helpful to interpreting data.

As mentioned before, you should determine what are you trying to gain from testing. Use Specific Criteria for Interpretation and consider the following:

- What do you want to do with the data: research, patient advancement
- What are you looking for from the data: %deficit, Acceleration/Deceleration time, etc..
- Population Criteria: Age, Sport, Position, Activity specifics
- Pathology: Curve Analysis

Use other clinical tests and correlate these findings to your Isokinetic test results. This is analogous to a Physician using X-rays and MRIs to confirm suspicions of a fracture or a torn ligament. You need to be a detective, and the test results are clues to help you solve the clinical mysteries for a successful rehabilitation.

### **READING TEST RESULTS:**

The first concern of data interpretation is to determine if the test is reliable and valid. This can be done in two ways.

- Coefficient of Variance (CV) This is how much variation occurred during the test between repetitions, or in more technical terms, the standard deviation of the torque data divided by the mean average torque Large CVs can be attributed to underlying factors such as: pain, lack of maximal effort, apprehension due to unfamiliarity of the movements (Wilk), and/or poor instructions given by tester, to name a few.
- Work first 3 and Work last 3 This will determine when the most effort was produced and the amount of effort given during the test. More work should be produced in the first 3 repetitions if the patient is working at maximal effort and less work during the last 3. This is graphically represented as a down slope from left to right.

### **ACCEPTABLE COEFFICIENT OF VARIANCES ARE AS FOLLOWS:**

- Large muscle groups: < 15% Large muscle groups are primarily movements that cover a larger ROM and include: knee, shoulder, back, elbow. It is easier for a patient to produce torque for these joints due to increased time for major recruitment.
- Small muscle groups: < 20% Small muscle groups are joints, which cover a smaller ROM and primarily include ankle and wrist patterns.

After determining the acceptance of the test as valid or invalid analysis of the data is the next step. Data analysis can be made either as Bilateral Comparisons, in which case percent deficit is looked at; or Unilateral Comparisons, in which use of Normative Goals are used, even if the intra-patient and intra-tester reliability of the normative data is not so high.

Unilateral muscle ratios are also important to look at and will also be mentioned later.

### **PERCENT DEFICIT**

Bilateral deficits are gained by comparing the uninvolved to the involved. The software calculates the percent difference. Percent differences between 10-15% are considered acceptable. A negative value implies the involved side is stronger than the uninvolved, provided the uninvolved was tested first. There are limitations to this range. For example, if you are treating a right handed pitcher or tennis player, you will need to rehabilitate the involved right extremity to a percent difference to greater than 10-15%. This is due to the fact the uninvolved side is not as dominant in the activity and therefore should not necessarily be used as a baseline measure. The acceptable range is -15% to +15%, except in special cases where side dominance is important.

***NOTE:** There are limitations to Bilateral Comparisons. Should the uninvolved limb be deconditioned secondary to lack of activity, insufficient rehabilitation, or bilateral injuries, then percent deficits are not helpful in this case. This is where it is helpful to look at other measures; Peak Torque to Body Weight for example.*

### **PEAK TORQUE (PEAK TQ)**

Defined as the highest muscular Peak Torque produced by the muscle. This can be determined within each rep. for the entire set. Peak Torque can also be evaluated specific to time (Torque @ 0.20sec) or to ROM (Torque@ 30°).

Peak Torque indicates the muscle's maximum strength capability. This is also the equivalent to a 1-repetition maximum (RM) isotonic strength test.

Peak Torque is an absolute value. Used alone, Peak Torque is difficult to assess the strength specific to a person. For example, two subjects can produce a Peak Torque of 150 Nm. It would appear they are equally strong. However, if patient #1 weighed 70Kg and patient #2 weighed 100 Kg, it is then more apparent which patient is stronger (Davies).

### **PEAK TORQUE / BODY WEIGHT (PEAK TQ/BW)**

Peak Torque to Body Weight is a ratio displayed as a percentage of the maximum torque produced to the subject's body weight. This value is more relative and pertinent to functional activity. By looking at the previous example, patient #1 is stronger than patient #2, as they both produced the same Peak TQ. In looking at body weight, patient #1 is 30 Kg lighter than patient #2.

The test value should fit into a certain range (machine, speed, joint, sex, age and attitude dependent). Patients that demand high performance should be at the high end of the range or beyond. This is perhaps one of the better indicators of successful rehab, as this is a more relative value to base safe activity on. (Wilk)

### **TIME TO PEAK TORQUE**

A measure of time from the start of a muscular contraction to the point of the highest torque development (Peak TQ). This value is an indicator of the muscles functional ability to produce torque quickly. The value is taken from the Peak Torque repetition.

### **ANGLE OF PEAK TORQUE**

Defined as the point in the ROM where peak torque is produced. It usually occurs at the same range in the ROM for similar movements and speeds. Angle of peak torque typically occurs in the mid range of a motion. This should be at the point in the ROM where the length tension relationship of the muscle is maximal. This value is also taken from the Peak Torque repetition

### **MAX REP TOTAL WORK**

Defined as the maximum work produced in a single repetition. The equation for work is:  $W = F \times D$ . This is a better indicator of the function of a muscle group than Peak Torque, as torque must be

maintain throughout the ROM shows more neuromuscular rehabilitation than Peak Torque values, as the muscle need to keep maintain torque over distance.

The repetition with the most total work is called the Max Rep Work. It should occur within the first few repetitions of a test bout.

The units of measurement are Joules.

**MAX WORK REP #** Previously stated, this is the repetition where the maximum amount of work was accomplished during the test bout. This can be used to determine if most of the work was accomplished at the beginning or end of the test/exercise bout.

The maximum amount of work in one repetition should occur within the first few reps of a test bout.

### **TOTAL WORK**

The sum of work for every repetition performed in the bout. This represents the muscle's capability to maintain torque throughout the test bout.

Total work is most useful to determine rehabilitation of an injury. In order to accomplish ADL's, movements must be maintained over distance. This value may be affected by low peak torque values or variations in the ROM and should be evaluated as such.

If a patient's overall torque production is low, the amount of work capability can be affected. If the ROM is smaller on one side, the total work will be affected even if the peak torque is the same.

### **WORK FIRST 3... WORK LAST 3 (also Endurance Index)**

The ratio between sum of work produced in the last 3 reps and the first 3 of the test bout. With maximal effort from the patient, there should be more work in the First reps and less work during the Last 3 reps.

If the patient does not give a consistent effort, the work completed in the first 3 may be less than the work completed in the last 3. This, along with a poor CV, may be an indicator of poor effort by the subject due to pain, lack of effort, and poor instruction.

This is a useful measure to determine work fatigue. As the patient improves his or her endurance, the work in the last 3 should start to become more and more equal.

### **AVERAGE POWER**

Power = Amount of total work divided by the time to complete that total work.

This value is used to provide a true measure of work rate intensity. This value indicates how quickly a muscle group can perform work over time and averages the power for every repetition. An important value to evaluate as power development is important for injury prevention.

**RANGE OF MOTION** This is the greatest Range of Motion (ROM) the joint achieves during the set. (This may vary from the set ROM as the patient does not reach full ROM.) Allows analysis of the test curve in relation to ROM.

**AGONIST TO ANTAGONIST RATIO** Reciprocal muscle group ratio in percentage. Peak torque HS Peak torque QS.

Imbalance may predispose a joint to injury as opposing muscle groups provide dynamic joint stability. These values specific of each joint and speed, also depends from sex, age and habits of the patient and usually are between 50 and 80% for the knee.

### **GRAVITY EFFECT TORQUE (GET)**

This is the torque effect produced by the weight of the limb and the attachment. Used to eliminate the additional torque applied to the muscle tested and gives a measure of true muscle torque production. The GET is added to torque when limb is working against gravity (in the case of the Quadriceps) and GET is subtracted when working with gravity (in the case of the Hamstrings). This should be taken for each limb, as oedemas and atrophy may cause variations. Allows standardization between tests and subjects.

## CURVE ANALYSIS

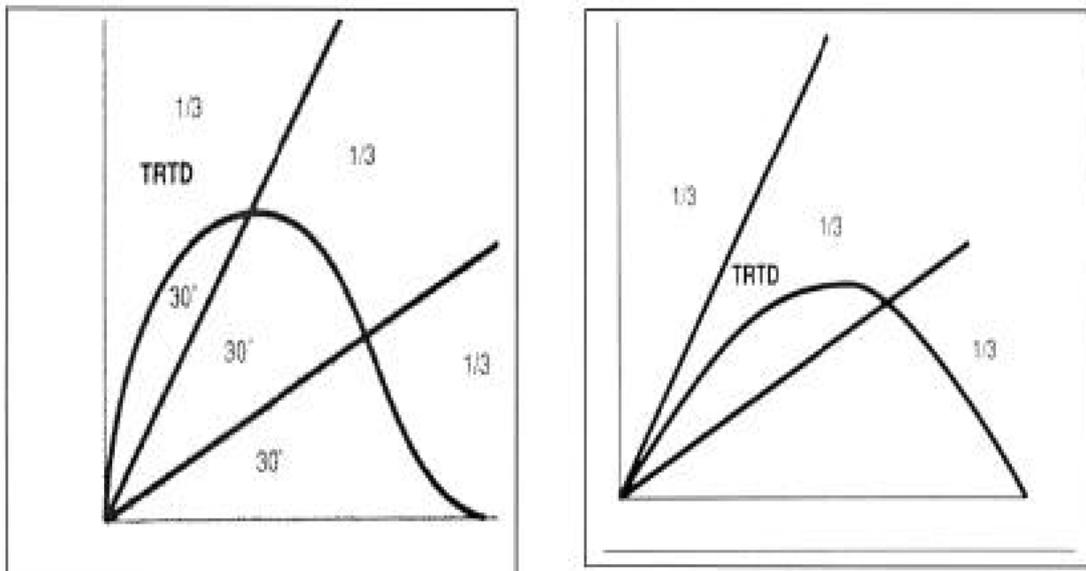
There is correlation between the shape of the torque curve and the patient's symptoms (Davies). However, keep in mind that curves should have a consistent variation to them and pathology should not be based on one curve or curves alone. They should be used in conjunction with other clinical findings. The 4 areas of a curve used in analysis are as follows:

1. Time Rate of Tension Development
2. Torque Obtainment
3. Force Decay Rate
4. Reciprocal Innervation Time

### TIME RATE OF TORQUE DEVELOPMENT (TRTD)

This is also known as Time Rate of Tension Development. It is the upward slope of the torque curve and indicates how quickly torque is developed during a muscle contraction.

If the X and Y-axis are divided into 30° segments, the TRTD portion of the curve should be within the 60°-90° portion. A prolonged TRTD indicates a problem developing force quickly.



#### • TRTD can be examined relative to:

- Peak Torque: Measured from start of muscle contraction to the highest point on the torque curve
- Predetermined Torque Value
- Predetermined Time: Torque at .20 sec., for example
- Specific Point W/I ROM: Torque at 30°, for example.

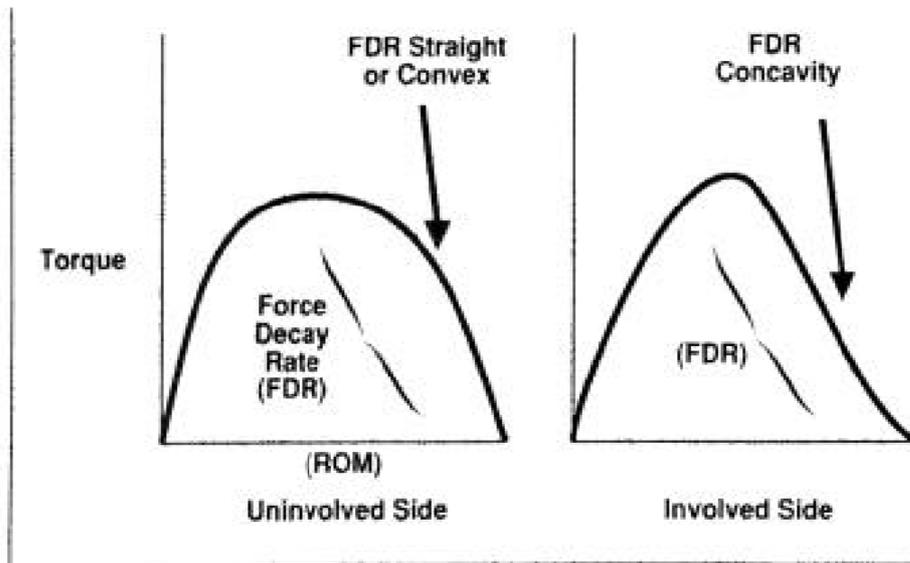
### TORQUE OBTAINMENT

#### • Values include:

1. Peak Torque: Highest point on the curve
  2. Work: Total area under the curve
- Pathologies that are indicative of poor Torque Obtainment exhibit problems maintaining torque, possibly associated with poor neuromuscular control, general weakness, or pain. Examples include, Chondromalasia Patella, and Musculotendinous strains.

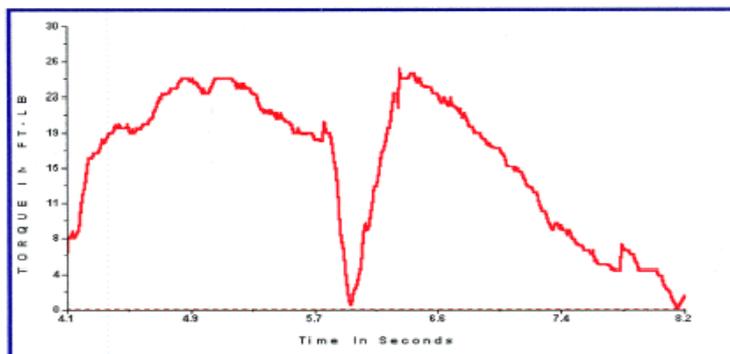
• **Force Decay Rate (FDR) The downward slope of the torque curve.**

This should be straight or convex and may be indicative of difficulty maintaining original “producing and maintaining” force at the end ROM. For example, a clinician sees concavity w/ ACL deficient knees between 20°-30°, commonly seen during a Pivot Shift test.



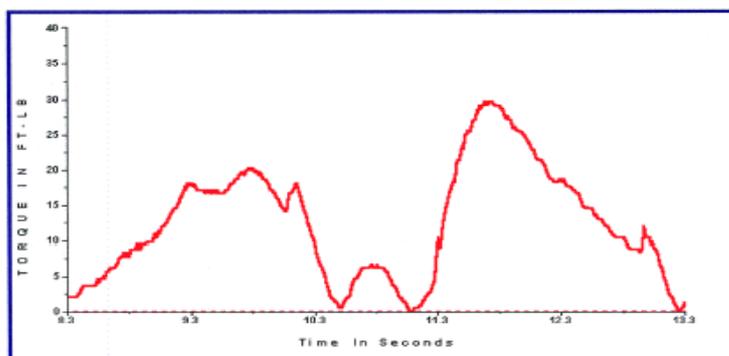
• **Reciprocal Innervation Time (RIT)**

Time interval between the end of the agonist contraction & the beginning antagonist contraction. RIT should have a "V" shaped appearance (Figure 1). A prolonged RIT will appear as a "U." (Figure 2)



**Protocol:** Isokinetic Unilateral      **Description:** manual  
**Joint:** Knee      **Pattern:** Extension/Flexion  
**Set Description:** Speed 60/60      **Side:** RIGHT  
**Comments:**

Figure 1. Normal Reciprocal Innervation Time



**Protocol:** Isokinetic Unilateral      **Description:** manual  
**Joint:** Knee      **Pattern:** Extension/Flexion  
**Set Description:** Speed 60/60      **Side:** RIGHT  
**Comments:**

Figure 2. Poor RIT

Figure 1 shows a "normal" RIT, while Figure 2 shows a delay in RIT. This delay may be due to a decreased time of recruitment for motor units at the neuromuscular level.

By working in smaller ROMs and at higher speeds, this can be rehabilitated provided there are no disruptions at the neuromuscular level.

RIT is important during function, as a poor RIT means that a patient may have difficulty generating power. The ability to generate power is crucial to injury prevention. For example, the hamstrings protect the ACL during movements that require quick change of directions or stop and start movements.

## SAMPLE CURVES

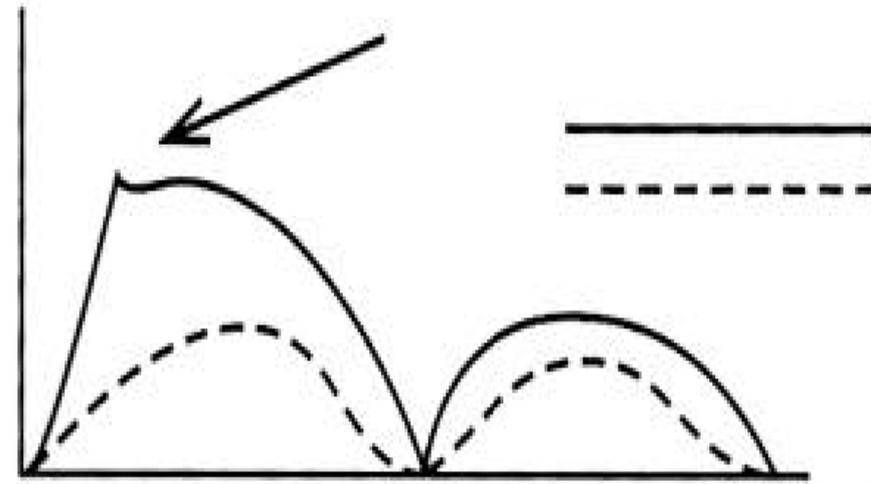


Figure 1. Isokinetic Torque Curves Normal torque curves represented in normal line Atrophic torque curves represented by dashed lines

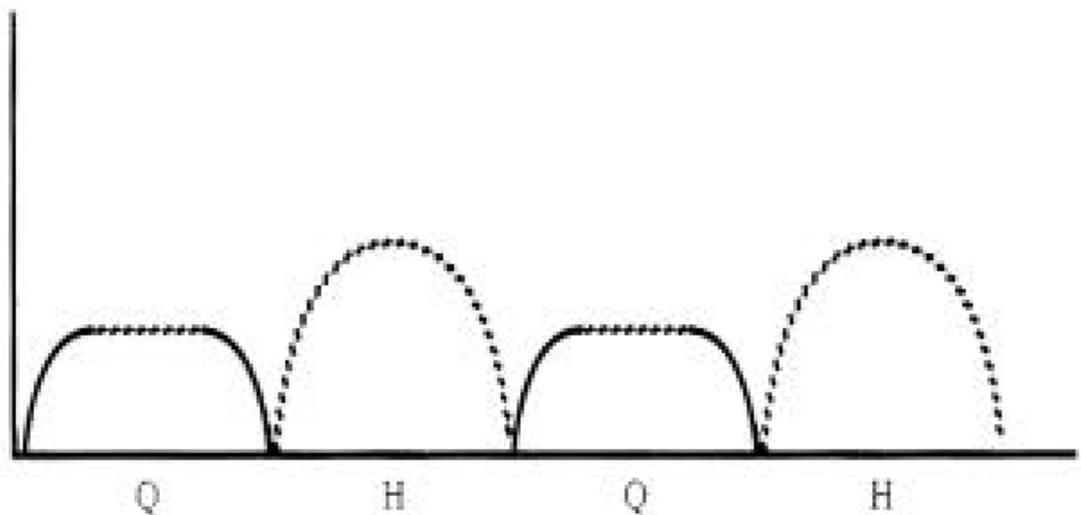


Figure 2. CHONDROMALACIA PATELLA\*

• Characteristics:

1. Decreased torque
  2. Plateau through mid ROM
  3. Irregularity (waviness) in torque curve
- Davies, G, (1992). A compendium of isokinetics in clinical usage and rehabilitation techniques (4th Edition). Onalaska, WI: S&S Publishers pp. 71-81.

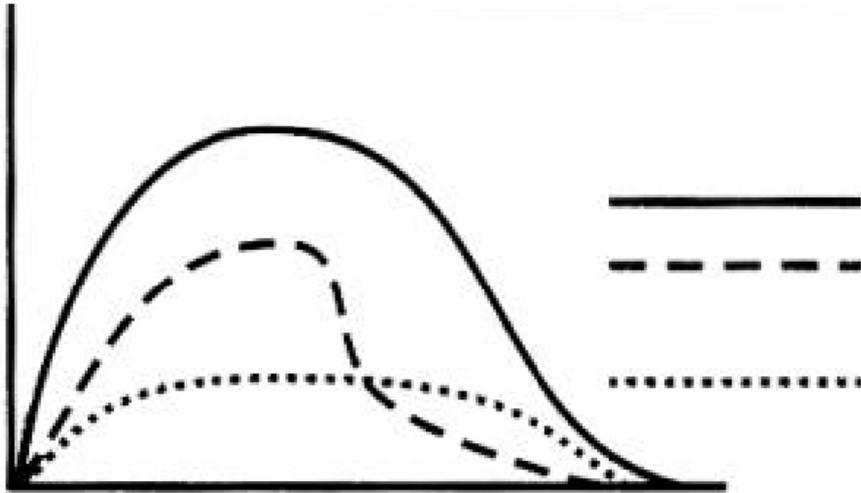


Figure 3. FEMORAL SHAFT FRACTURES

Characteristics:

- Proximal Femoral Shaft Fracture (----- dashes)
  1. Rapid force decay rate (FDR)
- Distal Femoral Shaft Fracture (..... Dots):
  1. Poor torque
  2. Poor Time rate of tension development (TRTD)

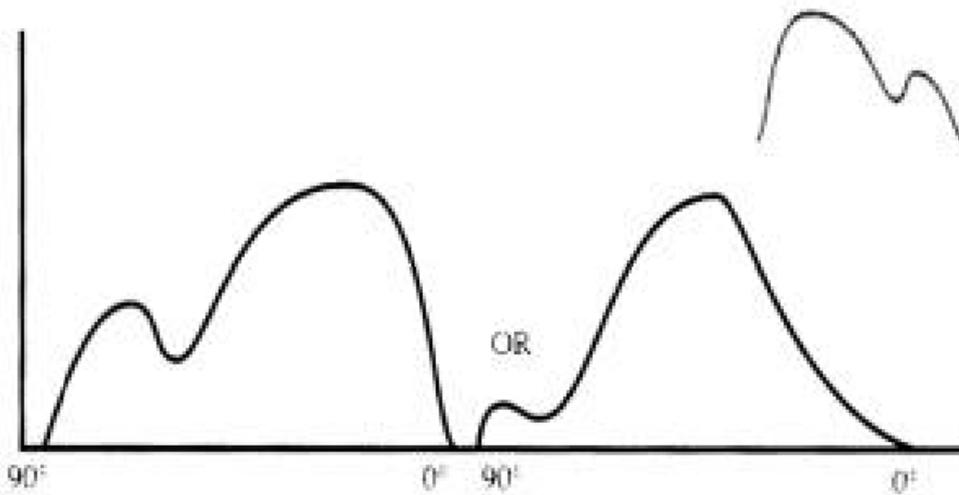


Figure 4. PLICA SYNDROME

• Characteristics:

1. Double-hump curve
2. Second hump is always higher than first
3. Commonly a decrease in the down slope of curve or rapid force decay rate

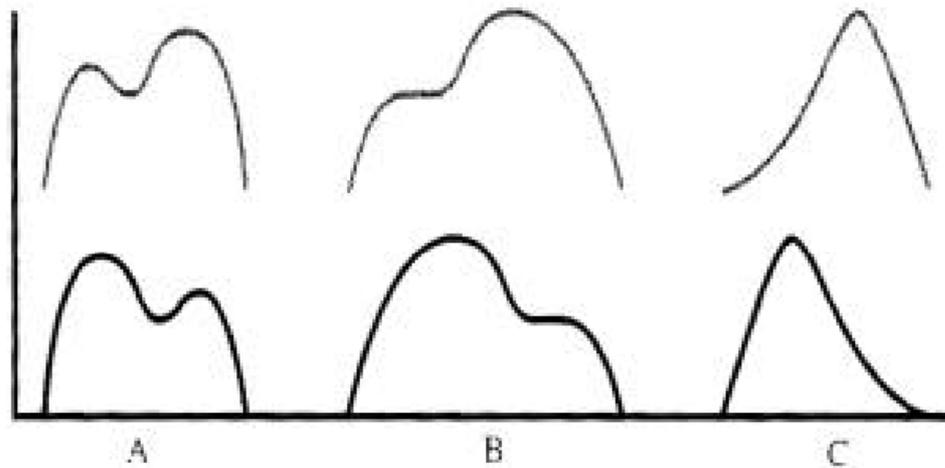


Figure 5. PATELLA SUBLUXATION

- Characteristics:
  1. Double-humped curve
  2. First hump always higher

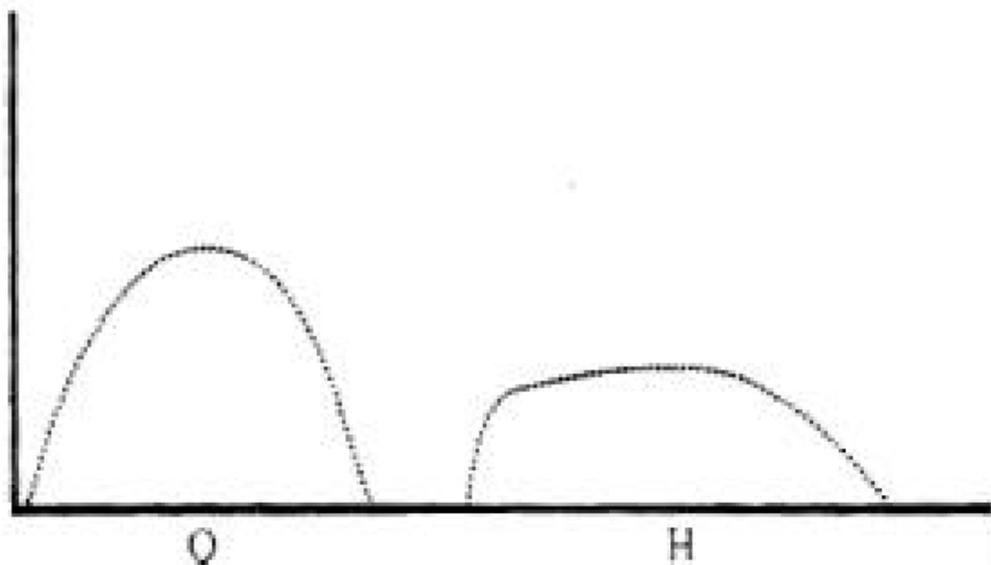


Figure 6. MUSCULO-TENDINOUS STRAINS

- Characteristics:
  1. The torque curve simulates the shape of the normal curve
  2. Irregularity (waviness) in the curve
  3. Decreased torque production

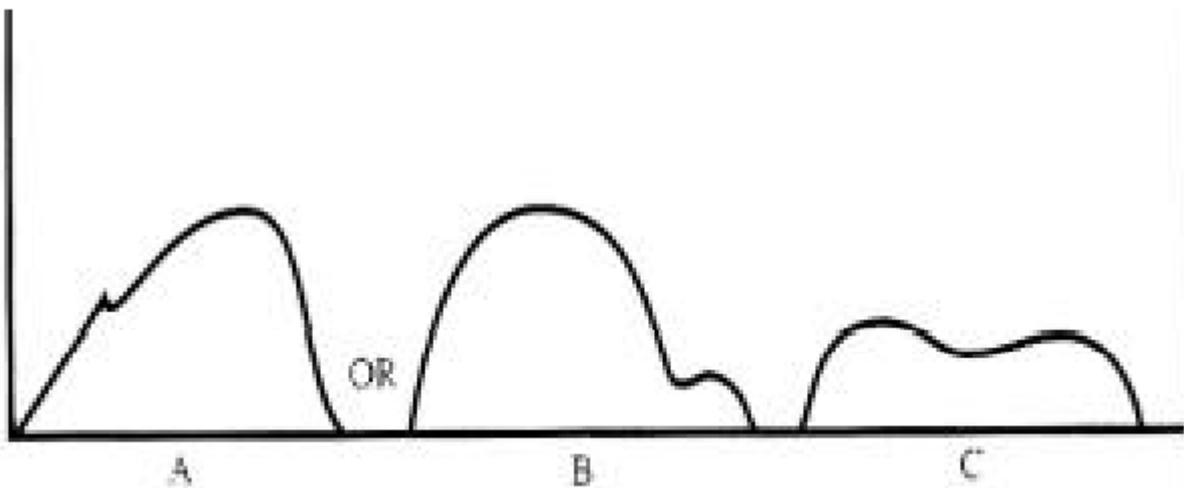


Figure 7. CAPSULAR/LIGAMENOUS INSUFFICIENCIES

• Characteristics:

1. Simulates shape of normal curve
2. Significant anterior instability seen as an irregular dip on the upslope (Curve A)
3. Positive pivot shift will show a dip in the down slope of the curve (Curve B).
4. General ligamentous insufficiency or ACL deficit (Curve C).

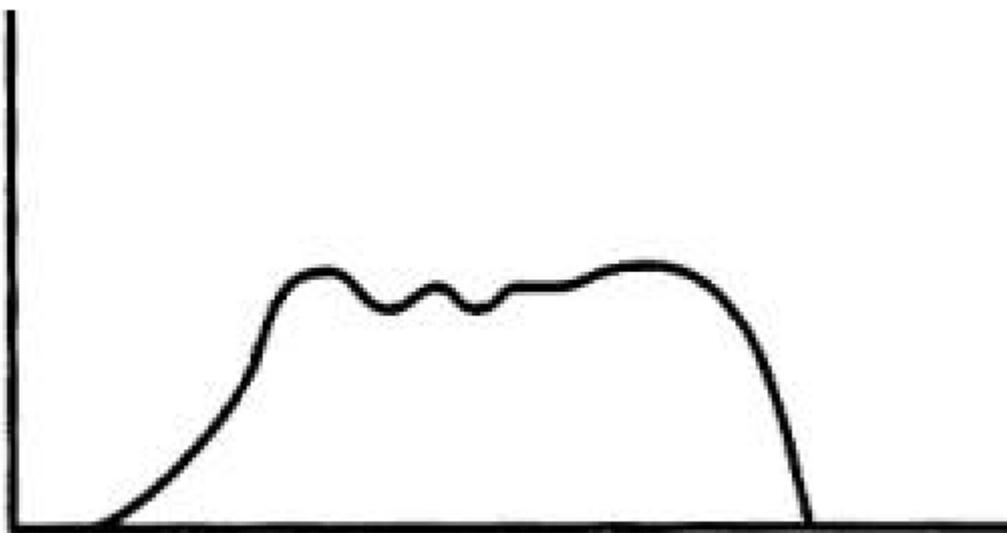


Figure 8. MENISCUS LESIONS