

#### **4.1 Fixating the lower leg:**

The fixation of the lower leg is adjusted to directly above the medial malleolus. For patients with injuries of the cruciate ligaments the fixation must be adjusted as proximal as possible on the lower leg in order to reduce the stress on the cruciate ligaments.

#### **4.2 Fixating the upper leg and trunk:**

There are two fixation belts belonging to the EN-Knee, designed to tight the patient to the chair. One of them is made for the upper legs. This femoral belt should run just proximally to the knee joints.

The other belt is made for the trunk and pelvis. This belt should run over the pelvis and lower abdomen.

Make sure that the patient remains properly fixed, but not inconveniently tight. The motion must be executed unrestrained.

Research has shown that adding thoracic strapping improved quadriceps strength significantly. Using an extra belt could be a solution if there are difficulties fixating the patient (2).

#### **4.6 Use of handgrips:**

In addition to the fixation belts, the patient should grab the two grips at the sides of the chair, in order to achieve maximal fixation.

Gripping the chair is an important stabilising factor. Its effect is mainly explained by the counter-force that the handles exert against the forearm. Ultimately, this force works to stabilise the thorax. However, since all subjects cannot grip with the same efficiency one must have this factor in mind when analysing and comparing results (2).

#### **4.7 Attention with ACL injuries:**

In case of ACL injuries, the Anterior Drawer Prevention (ADP) must always be used. It is crucial that the ADP is positioned at the distal edge of the tibial tuberosity. In most cases, this spot will be found approximately 10 centimetres below the imaginary knee axis.

Avoid the last 30 degrees of extension, since tension on the ACL is very high in that range.

Make use of high testing/training velocities. Velocities of 120° per second or more are appropriate, since the quadriceps develops less power with such velocities. This means less tension on the ACL.

Make sure that the lever arm axis corresponds as much as possible with the knee axis. If they do not correspond, the ADP can become the turning point for the lower leg and will cause more damage than good.

Position the fixation for the lower leg directly beneath the ADP. In this way the lever arm of the lower leg becomes shorter, hence decreasing the resistance. In case of a weak ACL there is a need to reduce the anterior (translocating) force of the rotary component of the quadriceps. The quadriceps will develop less torque when moving a "shorter" lever arm. This again leads to less stress on the ACL.

## 5. Isokinetic Testing

Time on video: 15 min. 12 sec.

### 5.1 Filling in personal data

Click "demographic data". Fill in data and click "OK". It is important to fill in information about weight, height and which leg is injured.

This information is relevant when you analyse the results from a test. This is because you can expect more power from a heavy person than a light person because the legs of a heavy person in general gets more load than the legs of a light person. You can expect more power from a person with long legs than from a person with short legs because a long-legged person has a longer lever arm and can therefore produce a higher peak torque with the same amount of force as the short-legged person. It is also of course, important to know which is the injured leg. All this information must be taken into account to be able to make a thorough analysis.

The screenshot shows the 'Enraf-Nonius - [EN-Knee]' software interface. The 'Demographic data' window is open, displaying the following fields and options:

- Demographic data** (Title bar)
- Demographic data** (Tab)
- Last name** (Text field)
- First name** (Text field)
- Address** (Text field)
- Place** (Text field)
- ID** (Text field)
- Date of birth** (Text field)
- Phone (private)** (Text field)
- Phone (business)** (Text field)
- Insurance company** (Text field)
- Insurance no.** (Text field)
- Doctor** (Text field)
- Weight [kg]** (Text field)
- Length [cm]** (Text field)
- Dominant side Left** (Radio button)
- Dominant side Right** (Radio button, selected)
- Female** (Radio button)
- Male** (Radio button, selected)
- Injured side** (Text field)
- Right** (Text field)
- Left** (Text field)
- OK** (Button)
- Cancel** (Button)
- Comments** (Button)
- Number of sets** (Text field)

Click "comments" if you want to write in additional information about the testing/training. It can be useful to write down some extra information about the patient's condition if extra precautions have to be made.

Click "movement" and choose for hip or knee, right or left. Often the right and the left leg are tested after each other for comparison purposes. Another possibility is to test the same leg twice in order to check the consistence in various sets and repetitions.

The screenshot shows the 'Enraf-Nonius - [EN-Knee]' software window. The 'Movement' menu is open, showing options: 'Left leg', 'Right leg', 'Left hip', and 'Right hip'. The 'Demographic data' section contains 'Last name : Voldseth', 'First name : Torgeir', and 'ID : 001'. The 'Movement' section has a label 'Movement :'. The 'Protocol data' section has labels 'Protocol name :' and 'Number of sets :'. The ENRAF-NONIUS logo is in the top right corner.

## 5.2 Reading chair height, position of back-support and fixation arm

Read chair height, position of back-support and fixation arm.  
Important! These three positional settings influence the measurements done by the EN-Knee.  
To make a reliable test these settings must always stay the same for every session with the same patient.

## 5.3 Filling in mechanical data

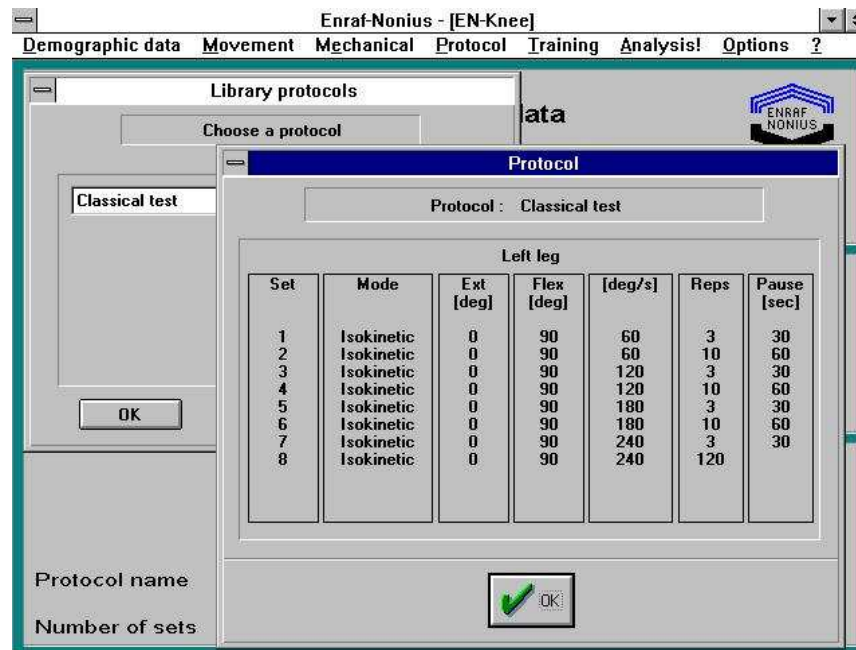
Click "mechanical" and write in the readings that you just checked.

The screenshot shows the 'Enraf-Nonius - [EN-Knee]' software window with the 'Mechanical' menu selected. A 'Mechanical data' dialog box is open, containing three input fields: 'Chair height' with the value '12', 'Fixationarm pos. [cm]' with the value '13.5', and 'Chair Back pos. [cm]' with the value '8'. The dialog box has 'OK' and 'Cancel' buttons. The background software window shows the same demographic and protocol data as the previous screenshot.

## 5.4 Classical isokinetic test-protocol

The classical test protocol is a protocol already set up for you by the manufacturer of the EN-Knee Enraf Nonius. Proceed as follows:

Click "protocol" and choose classical testing.



Set number 1, 3, 5 and 7 consist all of three repetitions at sub-maximal effort. They are implemented to help the patient familiarise with the testing velocity. Only the results of set number 2, 4, 6 and 8 are of any value when it comes to analysis.

Click "training". Click "OK» and decide whether you want to store data from the test. Click "OK" again to confirm training set up.

You are now in the test mode.

### 5.4.1 Warm-up and instructions to the patient.

Before patient starts testing or training it is important to perform a light warm-up (see preparations). Some instructions about the training should also be given by the physiotherapist.

Patient must not move the leg fixated to the lever arm of the EN-Knee before the message "don't move" has changed to "treatment running". It's important that the patient tries to move the leg as fast as possible through the whole range of motion. The speed of the movement will always stay the same, but by trying to move as fast as possible, more resistance is generated.

End of treatment. Click "OK".

#### **5.4.2 New session for the other leg.**

If you want to change leg, Click "Movement" and change settings.

The readings under "Mechanical" always stay the same for the same person.

Click "Protocol" and go to library and find back "Classical test". Click "OK".

Click "Training" and confirm settings.

You are in the test-mode.

Click "Stop" when test is finished.

### **5.5 Special considerations:**

#### **5.5.1 Verbal encouragement**

Verbal encouragement has been shown to affect test results, and thus must be standardised both in research and in test-re-test situations, if at all used. Some literature refers to research that have used verbal encouragement throughout the test, while others instruct the patient to produce maximum effort before each set of test repetition (2).

#### **5.5.2 Visual feedback**

When the patient is training it can be an extra motivational factor to see the graphs moving on the computer-screen. Explain to the patient what you see. Go to chapter about analysis, to get a good interpretation about the graphs.

Note: visual feedback influences test results, increasing the torque output. Any visual feedback should be standardised (2).

#### **5.5.3 Time of day**

The time of testing should be kept within 30 minutes of the same time of the day to ensure that results are comparable. For maximal leg strength values, the measurement should be made close to 18.00 to 19.30 hours as this appears to be the optimal time for producing maximal force (2).

#### **5.5.4 Testing frequency**

Frequency of testing depends on the muscle group being trained. In rehabilitation, once per month is sufficient, whereas athletic monitoring may be less frequent (2).

## **5.6 Standard Dutch test-protocol**

The Dutch association for isokinetics, V.I.N (Verenigin Isokinetica Nederland), being part of the European Isokinetic Association has developed a standard test protocol for knee patients. Based on research literature and experience, the members of the V.I.N have together set up a standard protocol that they use:

5 repetitions x 60 degrees/sec.  
5 repetitions x 180 degrees/sec.  
20 repetitions x 300 degrees/sec.

The pause between each set is 90 sec.

The patients are also given the possibility to rehearse a couple of times on each velocity to get familiar to the equipment.

Both at the Catharina Ziekenhuis in Eindhoven and at the physiotherapy clinic Verzijden in Boxtel, they have made some adjustments. At the Catharina Ziekenhuis they use a testing velocity of 270°/sec. in the last set instead of 300°/sec. This is due to their data bank with results, which also have been taken at this speed. In Boxtel, they have adjusted the second set to be 10 repetitions at the velocity of 180°/sec instead of 5 to get a better view of the endurance capacity of the patients.

In some cases, when it is very difficult to provoke the patient's problems, it is possible to include a set at the speed of 30°/sec. This is however, very demanding and provoking for the patient and should be used with caution (11, 12).

## **5.7 Individual test-protocol**

Click "Protocol" and choose "Individual".

You are now in the window 'Protocol settings' and you must decide number of sets, and whether you want to have the length of your sets determined by number of repetitions or a time limit. When data is filled in, click "OK".

### **5.7.1 Protocol**

In the window 'protocol' you can set all the parameters and make your individual test-protocol. Remember that if you have more than one set, you need to set the parameters for each set separately. You can not set parameters for all sets at the same time. .

### **5.7.2 Mode**

The mode indicates whether an isokinetic or isometric training programme is being used. The isometric programme offers data about one specific angle. The isokinetic programme produces data about one defined range of motion.

### 5.7.3 Velocity

The velocity Can be adjusted between 30° and 240° in steps of 5°. Low velocities are often used to stimulate strength increase, while higher velocities are often used to train endurance.

### 5.7.4 ROM

The range of motion (ROM) is the excursion, which you would like your patient to perform. It can be adjusted in degrees between 0° and 90°.

It is preferred to make the ROM as large as possible since the actine-myosin coupling in the sarcomeres is optimal, which has a positive effect of the power development (4).

Attention: Literature shows that the extension motion of the knee causes a ventral directed anterior draw (sheer force) on the tibia, which causes stress on the anterior cruciate ligament.

The sheer forces appear to be greatest in the last 30° of extension. It is therefore advised to avoid these last 30° of extension when recovering from injuries of the anterior cruciate ligament. For further protection of the anterior cruciate ligament the anterior drawer prevention can be applied. For further explanation of the application of this accessory to the EN-Knee, go to the section about anterior cruciate ligament injuries.

Also be aware of the fact that motion between 0° and 30° can cause patello-femoral pains, because the patello-femoral joint then make to many stereotyped movements under high pressure (4).

### 5.7.5 Repetitions

A repetition consists of one extension and flexion motion. The number of repetitions per set for strength testing purposes must be at least six, as research shows that the peak torque is measured in the first two to six repetitions (4).

When the parameters are set:

Click "Training" and "OK". Decide whether you want to store the data from the test (The software makes it possible to put together patient specific testing and training which can be stored in a library to be used more than once) and click "OK" to confirm your protocols.

You are now in the testing mode.

## **6. Isometric Testing**

Time on video: 22 min. 18 sec.

### **6.1 Individual test-protocol**

To do an isometric test you need to make an individual test-protocol again. To set the test-position you can adjust it directly in the computer-program or you can use the Auto-ROM function.

### **6.2 Auto-ROM function**

The 'Auto-ROM function is an option which can be used to measure the range of motion and to set the position where you want to do the isometric test.

Click "auto-ROM" and let the patient move his leg to the desired position. Then click "OK".

This feature is especially useful if you want to train in the end of the patient's range. Then the patient can choose a pain free position near his current end position.

Remember to set the parameters for each set separately.

When all the parameters are set, go to training, click "OK" and decide whether you want to store the data from the test. Click "OK" to confirm your protocol.

You are now in the testing mode. The EN-Knee now adjusts the lever arm to the chosen position. The patient must not resist this motion. When the 'don't move' sign is switched off, the patient can begin moving and the test can start.

### **6.3 Classical isometric test-protocol**

#### **6.3.1 Determination of the angular intervals:**

The angular intervals, at which data will be obtained, can maximally be 1°. However, intervals of 10° are recommended. At intervals of 10° the information density will be sufficient not to overlook any abnormalities. If at a certain angle irregularities in the building up of the force or in a certain motion parameters are noticed, it is advised to investigate this area again at smaller intervals (4).

#### **6.3.2 Contraction duration, number of repetitions and rest:**

Optimal information about the building up of the force during the isometric contraction is obtained when a contraction is maintained for at least 6 sec. The peak torque is usually measured after approximately 2 sec., after which time the maximum is reached. This maximum will then be maintained for 2 to 3 sec., after which time the power is decreasing again. See the Caldwell Regimen graphics (fig. 2).



## Caldwell Regimen

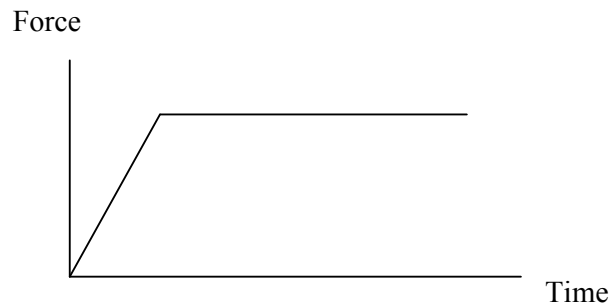


Figure 2.

It is sufficient to make 2 to 3 contractions per angle. Always observe a 1minute rest between the angles (4).

### 6.3.3 Start test

- First test the non-injured or dominant (if no injury) side.
- At one angle, make 3 maximal contractions.
- Have 1minute rest.
- Proceed with next angle.
- After the last contraction on the non-injured or dominant side, 5 minutes rest.
- Repeat test for injured or not-dominant side.

Make sure the patient has an active cooling down period. Approximately 5 minutes bike riding on a stationary bike on low resistance could help preventing delayed onset of muscle soreness.

## **7. Analysis of the measurements**

Time on video: 24 min. 24 sec.

### **7.1 Evaluating findings**

The interpretation of isokinetic findings have been discussed in a large number of studies and some principles was outlined in a paper by Sapega (1990), and are as follows:

- In case of unilateral involvement, the contra-lateral, sound side constitutes the basis for comparison. This assumption is reasonable for symmetrical use of the body segments. In athletes who use their extremities in a non-symmetrical manner this assumption may not be valid.

Thus referring to normal individuals:

- a) imbalance of strength of up to 10% can be considered normal
  - b) imbalance of between 10% and 20% is possibly abnormal
  - c) imbalance greater than 20% is probably abnormal
- 
- If one extremity is expected to be weaker due to a previous injury or disuse:
    - a) imbalance of between 10% and 20% is probably abnormal
    - b) imbalance greater than 20% is almost certainly abnormal
- 
- As a criterion for resumption of sports activity or strenuous physical exertion, a maximum deficit of the involved extremity is 20% for individual muscle groups and 10% for total limb strength. No corresponding figures were suggested for resumption of light activities but 30% for individual muscle groups and 20% for total limb strength seems reasonable.
- 
- In case of bilateral involvement norms should be used. The norms must be gender-, age- and activity level-specific (3).

It is advisable to use imbalance of muscle performance ratios in a physiologically meaningful way, namely the concentric performance of the agonist relative to the eccentric performance of the antagonist. For the EN-KNEE, this will not be an option since it is not possible to use the machine eccentric.

### **7.2 Relations between test results:**

Relations between isokinetic or isometric testresults can be (4):

#### **7.2.1 The left-right difference**

The left-right difference often referred to as the quadriceps/quadriceps ratio (QQR) can give information about the seriousness of the injury of the injured leg. However, you need to realise that there is a natural difference in the capacity of force supply between the dominant and non-dominant leg. The left-right difference can be made visible by testing the left leg after the right leg. The software program of the EN-Knee will then calculate the differences

between the legs in %. Research shows that the difference in peak torque normally is no more than 5-10 % (see section above).

### **7.2.2 The difference to previously measured values (progression)**

For the evaluation of the difference between two measurements it is important that the data can be compared (see chapter about reliability). When different test sessions of the injured leg are compared to each other, it is possible to determine the progression of the rehabilitation. This progression will appear from an increase of the peak torque, the work supplied and the power.

### **7.2.3 The quadriceps hamstrings ratio**

The quadriceps hamstrings ratio reflects the muscle equilibrium around the knee, often referred to as the agonist/antagonist ratio. A difference in this muscle equilibrium can be the result of a relative hypertrophy of one of both muscle groups by e.g. a compensatory position the patient must take as a result of a pathology and/or pain elsewhere. The normal quadriceps hamstrings ratio is around 0,6 (Perrin, 1993). A significant difference of this normal value indicates a difference of the normal equilibrium of the knee, which could cause accelerated pathology.

### **7.2.4 The peak torque compared with other persons**

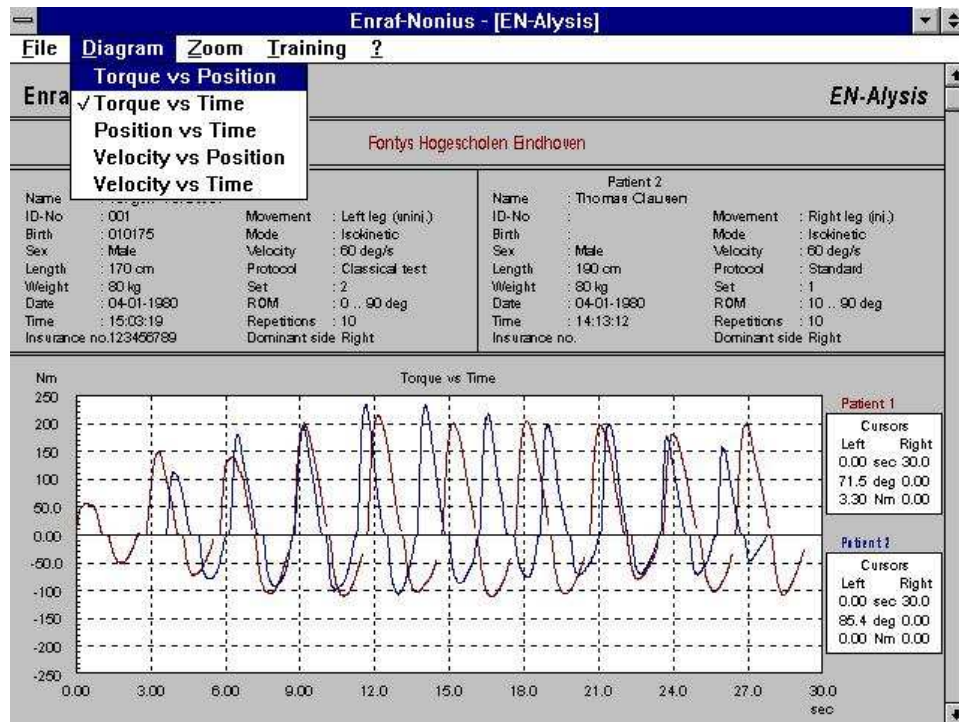
In literature we can find a number of populations of test values for peak torque. One can generate norm data by standardising measurements (division according to sex, age, body weight mode (active athlete or person without much exercise) etc. An advantage of using your own database is that you know the norm population and that the test conditions are uniform.

## **7.3 Interpretation of Graphics:**

It is possible to visualise by means of a diagram some five different graphics. Which variables are shown in the graphics can be seen in the left upper corner and the right lower corner of the graphics block. See appendix B.

Click “Analysis” and choose session and set. Click “ OK”.

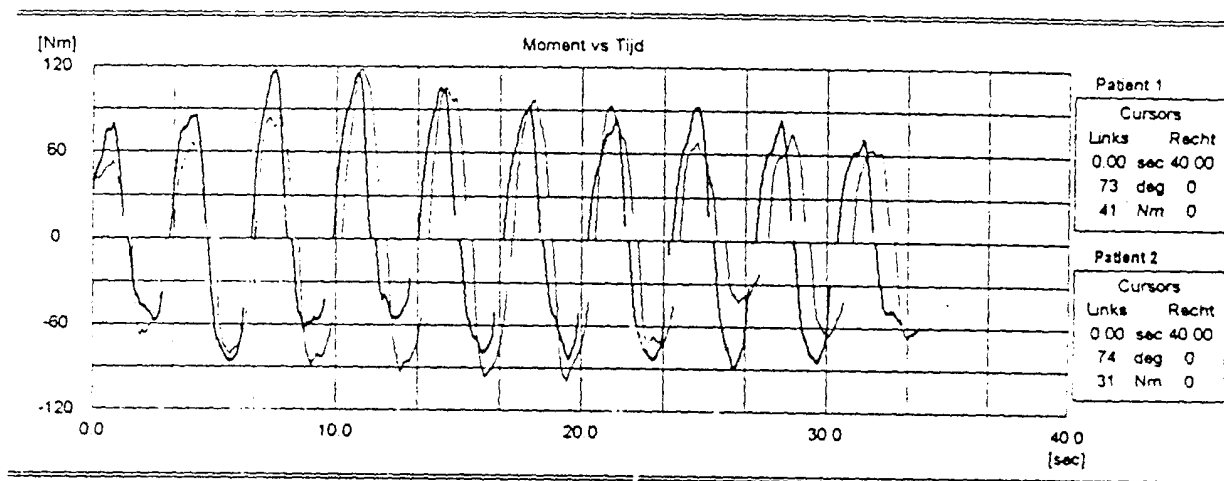
The graph ‘Torque vs. Time’ appears. To view a graph with other parameters click "Diagram". You then get the choice of the following 5 graphs seen on the figure on next page:



See appendix B for examples of the graphics after a classical test protocol.

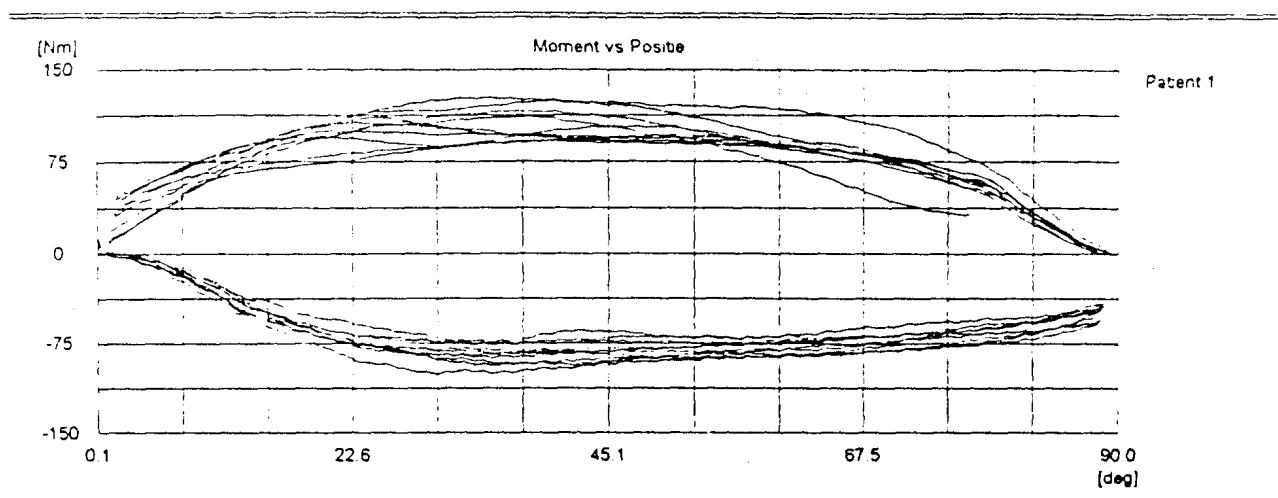
The EN-Knee is able to present the different motion parameters in 5 graphic representations. On top of the graphics the variables of the graphics are mentioned. The positive moment values are caused by the extensors, the negative torque values by the flexors. The graphics reveal most information by zooming in into one or two repetitions. With help of the cursors you can then read the time, angle and torque on the position of the cursor and examine the size of an abnormality in the course of the curve.

### 7.3.1 Torque vs. time



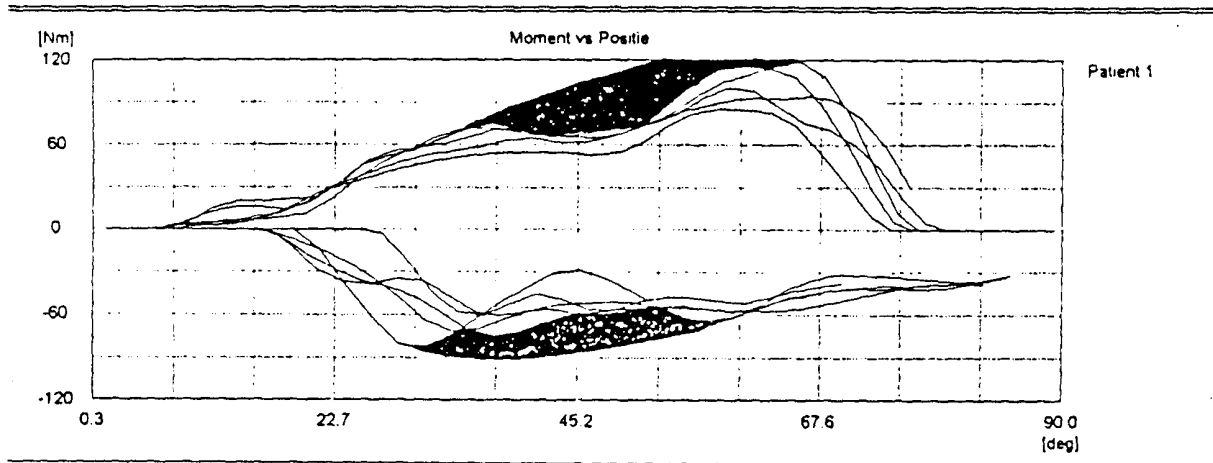
This graphics shows how the generated torque develops in time. As the motion is isokinetic, time increases proportionally with the position. The characteristic forms of these curves will therefore be indicated in the Torque vs. position graphics. The advantage of the Torque vs. time graphics is that all repetitions are written one behind the other, so that the influence of fatigue can be seen from the form of the curve. When a choice is made for the isometric form, the Torque vs. position graphics does not give information because no motion takes place and therefore the Torque vs. time graphics will supply the most important information about build up of the force and the endurance (4).

### 7.3.2 Torque vs. position



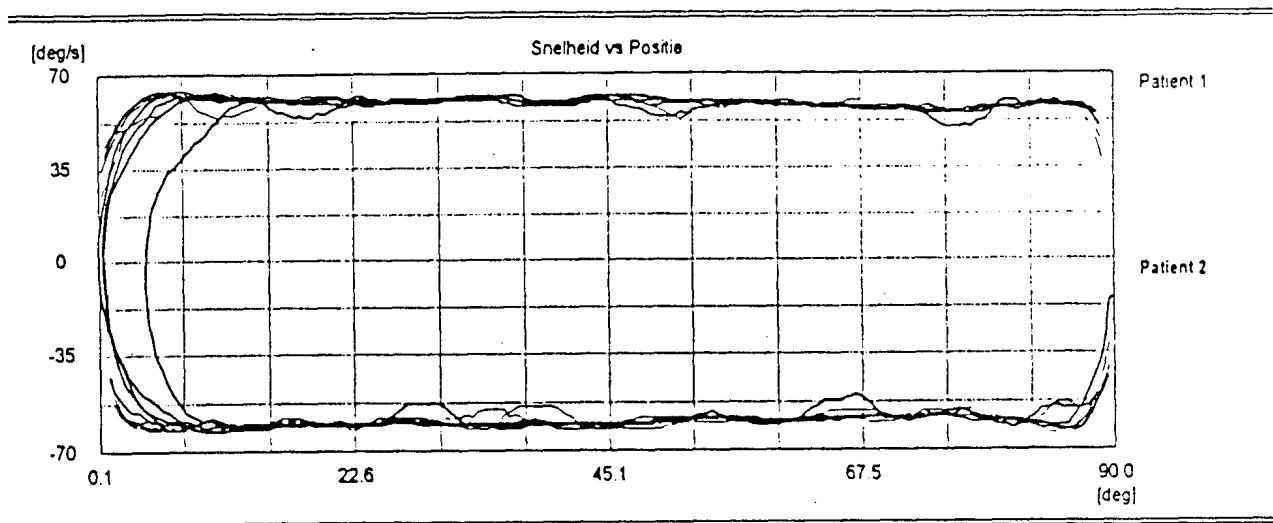
From this graphics we can read how the torque develops itself in relation to the angular displacement and the amount of work supplied: The surface under the torque vs. position

graphics. An undisturbed curve shows a flowing course. In case the course is not flowing, usually there is a disturbance in the musculo-skeletal system. Disturbances in the flowing course of the curve can vary from fine or gross disturbances to regular dips in the curve. See e.g. figure below (4).



In this figure it is clear to see that this person is not able to produce a torque of normal size between 30° and 55°. The dark coloured area on the graph shows the amount of work that normally should have been done between 30° and 55° (4).

### 7.3.3 Velocity vs. position



The velocity vs. position graphics is interesting because with this graphics you can check whether the previously set up velocity was really reached. When the set up velocity is reached, the graphics shows a horizontal line. At the beginning and the end of the range of motion the velocity decreases rapidly towards zero and then the direction of speed turns around (4).

#### **7.4 Measurements results:**

Click on the graph you want to view. Under every graph (scroll down) important data from the test is listed. This simplifies the analysis because the computer has already listed the most important data for you.

##### **7.4.1 Peak torque**

The peak torque is the highest measured torque in a series of repetitions. This is the point in the ROM in one of the repetitions where the force exerted upon the lever arm is greatest. Torque is measured in the unity: Nm.

##### **7.4.2 Average peak torque**

The average peak torque is the average of all peak torques from every repetition of a certain set. Unity: Nm

##### **7.4.3 Peak torque / kg body weight**

This parameter is the absolute highest measured torque divided by the number of kilos body weight of the patient. Unity: Nm/kg.

##### **7.4.4 Average position at peak torque**

The EN-Knee registers with every repetition where the peak torque is registered. At the end of the set the EN-Knee calculates the average position of the time when peak torque was reached.

##### **7.4.5 Average power**

The average power is the average amount of work performed per second, calculated over a certain series of repetitions.

##### **7.4.6 Total work**

The total work is the total amount of energy exerted by the patient during a certain number of repetitions.

##### **7.4.7 Difference patient 1 and 2, left/right, session 1 and 2**

When you wish to compare two sets (of different patients, different legs or different sets of the same leg), the test results will be shown in 2 columns. The differences between the two sets will be presented in percentages in the third column to the right. As these differences accompanied with a plus or a minus mark, you can at a glance see which set scored the best.

##### **7.4.8 Ratios flexion / extension:**

The ratios mentioned hereunder are the relations of flexion and extension parameters:

##### **7.4.8.1 Average peak torque flexion / extension**

This parameter indicates the relation of the average peak torque values of flexion and extension motion; the hamstring-quadriceps ration. Agonists, antagonists and synergists are together responsible for a good static and dynamic balance around a joint. A hypertrophy of one of these muscle groups will disturb the natural balance and can cause accelerated pathology.

#### 7.4.8.2 Average power flexion / extension

This ratio indicates the relation of the average powers supplied.

#### 7.4.8.3 Work flexion / extension

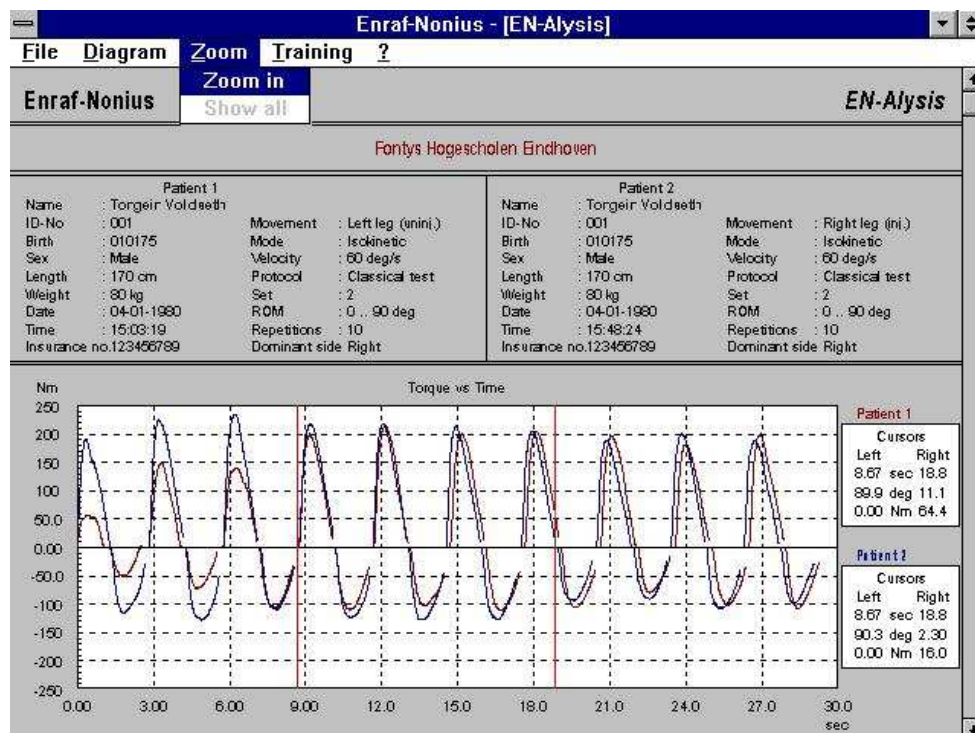
This ratio indicates the relation of the total work performed of the flexors and the extensors.

#### 7.4.9 Standard deviation

An important measurement is the 'standard deviation'. This is a calculation of the difference of performance between sets of same duration and speed. This gives you an indication of the reliability of the test. The standard deviation should be lower than 10 to be considered reliable (11).

### 7.5 Cursor positions

Two cursors are positioned one at each side of the graph window. Click on one of these cursors and move them by moving the mouse while holding the left mouse button pressed down. You get the exact readings in the two cursor boxes on the right side of the screen. With these cursors you can scan the graphics accurately. In this way it is possible to determine at any position in the graphics the following variables:



Sec: Here the cursor reads the exact position in time. Time is being measured from the beginning of the first repetition.

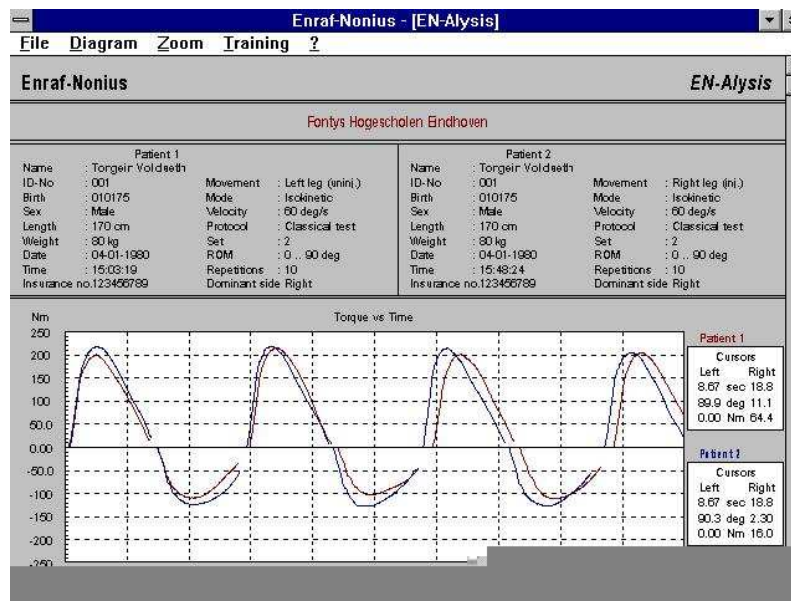
Deg: Here the cursor reads the angle position of the load arm of the EN-Knee.

Nm: At this position the cursor reads the size of the generated torque.



Due to pathology of muscles or joints, abnormalities of the flowing patterns on the graphics can be seen. It is possible to determine the size of the above mentioned variables on the position of the abnormalities by using of the cursor. In this way the seriousness of the abnormality can be measured and the progression of the recovery can be quantified (4, 12).

To zoom in on an area in the graph, mark the area you want a closer look on with the two cursors, click "zoom", and "zoom in". To go back to original size, click "zoom" and "show all".

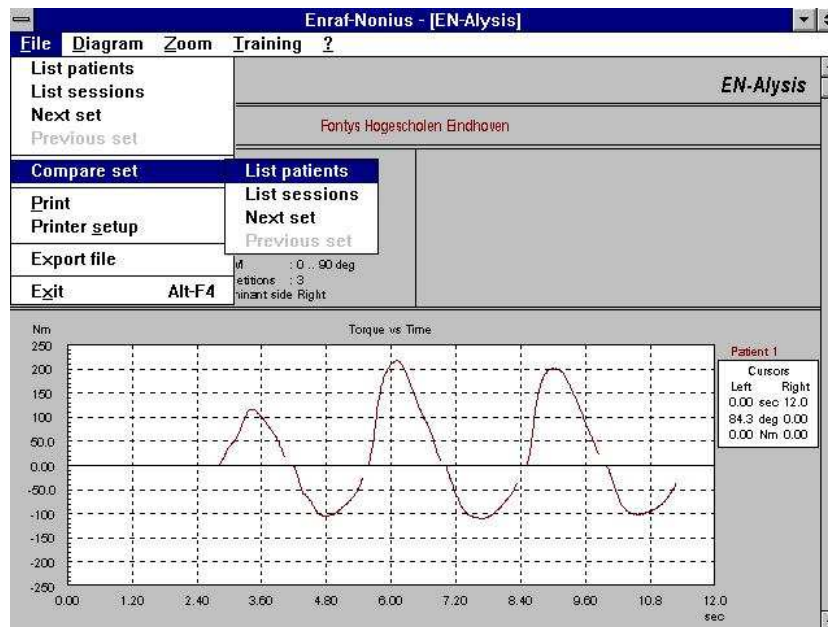


## 7.6 Comparisons

### 7.6.1 Comparisons of sessions.

To compare two sets: Click “Analysis» and decide which set from which session you want to open first.

Click “file” and then "compare set". The set that is open will now be compared to the set chosen from the other session.



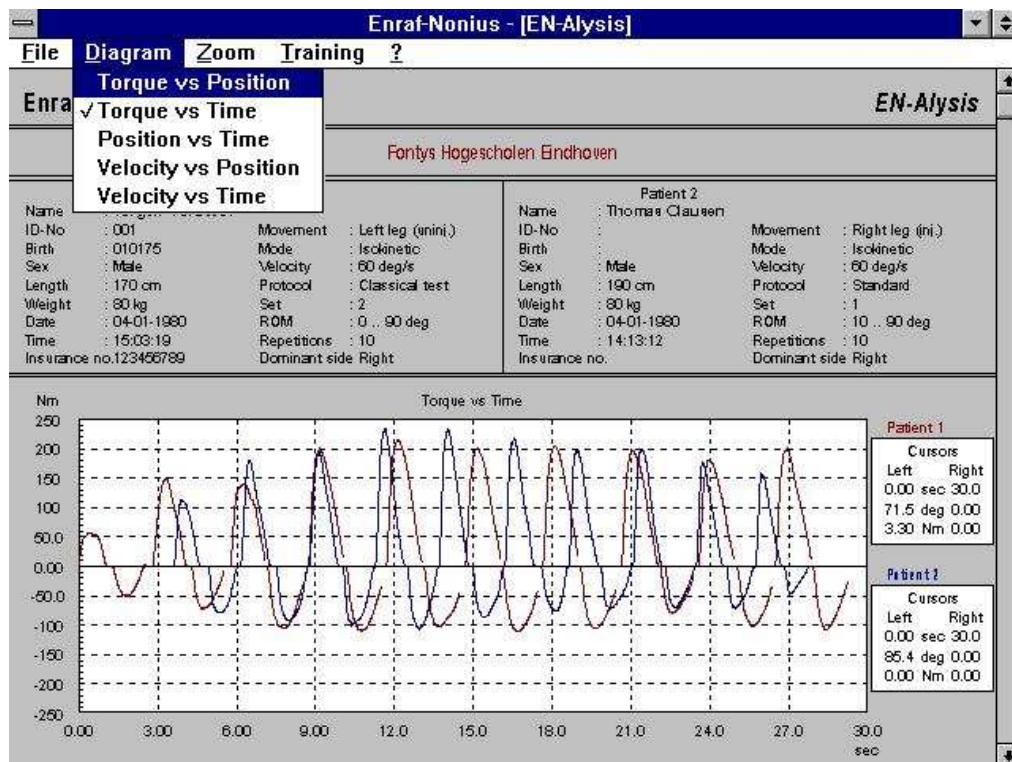
For example: To compare the two next sets, click “file” and then “next set”.  
Now you compare set two from the first session with set one from the second session.  
Go to “file” again; click “compare set” and then “next”. You now compare set two from the first session with set two from the second session.

Go to “diagram” to view different graphics of the same comparison.

## 7.6.2 Comparisons of patients.

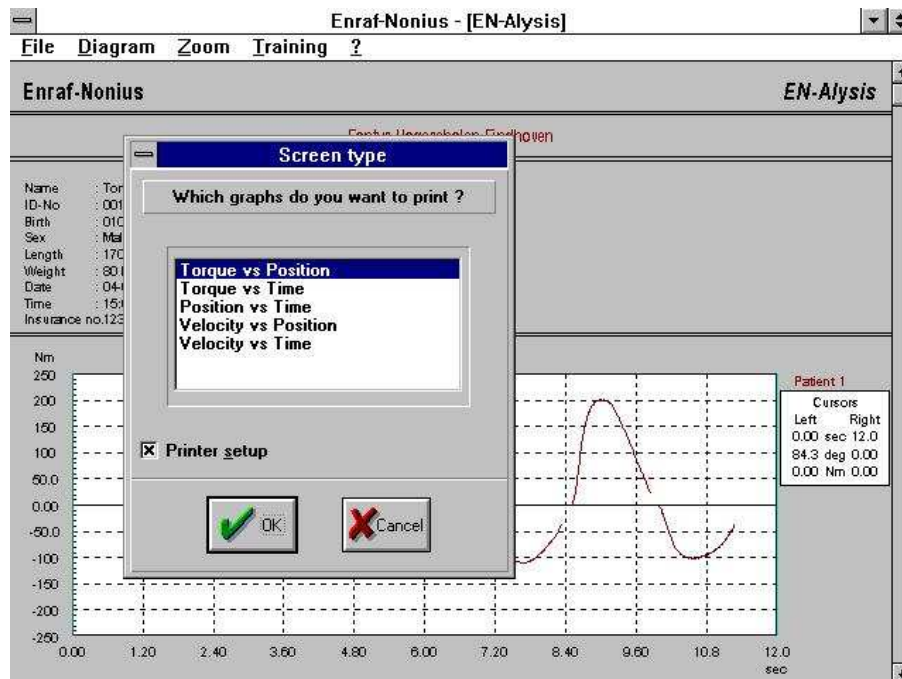
To compare sets from different patients go to “list patients”. Choose patient. Again choose which set from which session you want to compare with the set that is already open.

Make sure that the sets correspond in number of repetitions and velocity to get a relevant comparison.



## 7.7 Printing

1. Click "file" and then "print".
2. Now choose which set you want to print. You can print more than one graph at the same time.



3. Click "OK".

