Disorders of the inert structures: ligamentous instability

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Ligamentous instability

If the knee becomes unstable after a ligamentous injury, permanent problems may result, especially if the patient is an athlete with high functional demand.

If the history indicates that there is possibly instability, an examination to detect the exact location and degree of this is performed. It is important to make this supplementary examination only when symptoms and signs found in the routine clinical assessment indicate ligamentous instability to be the cause of disability. Indeed, it is important to realize that not every lengthened ligament leads to problems. If the athlete’s muscles are strong enough to provide dynamic stability, a slightly unstable knee will not cause trouble. Conversely, it is quite possible that an athlete with slight laxity of one or more ligaments has a chronic painful lesion as well. If the diagnosis of the latter is missed because the routine functional examination is not performed, it may well be that the patient is sent for surgery, which will solve the slight instability but does not cure the main problem.

Types of instability

Knee instability is the result of loss of static and dynamic function. Stability depends on the tautness of the ligaments, congruency of joint surfaces, effectiveness of the menisci and the well-balanced action of all musculotendinous units acting across the knee joint. Of these structures, muscles and tendons play a central role in joint stabilization. They are said to be the ‘first defenders’ in distortion and loading situations.

Degree of instability

The degree of instability is demonstrated during stress tests and can be graded on the following scale (Fig. 1):

- **mild/1+** = 5 mm or less separation of joint surfaces
- **moderate/2+** = between 5 and 10 mm separation
- **severe/3+** = greater than 10 mm separation.

This scale is not very precise but is effective for clinical and therapeutic purposes. It should be remembered, however, that under anaesthesia the results of the stress tests are often exaggerated so that patients with 2+ instability often show 3+ instability in the test.

Classification of instability

Instability may be classified as straight or rotatory.

**Straight instability**

This is defined as an increased range of angular movement in the frontal plane, i.e. valgus/abduction or varus/adduction movement (Fig. 2), or an increased range of gliding movement in the sagittal plane, i.e. the simultaneous forward or backward gliding movement of the tibial condyles in relation to the femoral condyles (Fig. 3).

**Rotatory instability**

This implies increased rotation movement of the tibia on the femur. The posterior cruciate ligament, located in the centre of the joint, is the fundamental stabilizer and is the axis of the joint, both in flexion–extension and in rotation. Consequently, this ligament is always intact in rotatory instabilities; from the moment the ligament is completely torn, there is no longer a centre of rotation and any kind of straight instability can result.

There are three types of rotatory instability:

- **Anteromedial rotatory instability:** there is an abnormal forward gliding movement of the medial tibial plateau
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• Anterolateral rotatory instability: there is an abnormal forward gliding movement of the lateral tibial plateau with respect to the lateral femoral condyle, while the medial tibial plateau retains a relatively normal relationship with the medial femoral condyle (Fig. 4b).

• Posterolateral rotatory instability: there is an abnormal backward gliding movement of the lateral tibial plateau with respect to the lateral femoral condyle. Again, as in anterolateral rotatory instability, the medial tibial plateau remains in normal contact with the corresponding femoral condyle (Fig. 4d).

Various combinations of these rotatory instabilities can occur. The most commonly encountered are combined anterolateral and anteromedial, and combined anterolateral and posterolateral.

Posteromedial rotatory instability does not exist because an intact posterior cruciate ligament prevents any backward gliding movement of the medial tibial condyle in relation to the medial femoral condyle.

Functional examination

If the history or routine clinical examination indicates the possibility of instability, a supplementary examination is performed to detect the exact localization and degree of ligamentous insufficiency.

Acute stage

In the acute stage, only the first few hours after the accident are suitable for clinical detection of ligamentous laxity. After this, effusion and muscle spasm resulting from the capsulitis will prevent a detailed examination. This is particularly the case in lesions of the medial collateral ligament because of its close relationship with the capsule. So assessment should be made as soon as possible, preferably at the scene of the accident.
Passive adduction or varus stress test in 30° of flexion

This test is performed in the same position as the previous one, but the hands are changed; so one hand is placed about the medial aspect of the knee while the other grasps the lower leg at the outer side of the ankle (Fig. 6). The degree of movement and end-feel are estimated.

Adduction stress is applied to test the stability of the lateral compartment ligaments: the lateral collateral ligament, meniscotibial or meniscofemoral capsular ligaments and the arcuate ligament.

Instability of the lateral compartment is less common but causes significantly more disability than a comparable amount of instability medially.

Lateral instability cannot be detected when the test is performed with the knee in full extension because the intact tight posterior cruciate ligament precludes any movement in this accident. If intra-articular bleeding is present, which especially accompanies tears of the anterior and posterior cruciate ligaments as well as of the medial collateral ligament, the first few minutes are often the only time available to make a proper clinical assessment of ligamentous laxity. When time has elapsed, examination under general anaesthesia, eventually followed by arthroscopy, is the only course of action. However, if the lesion seems to be less serious, supplementary examination can wait until a proper clinical evaluation can be made.

Chronic stage

In the chronic stage thorough clinical examination suffices to estimate, in almost all instances, the degree of functional instability and to determine the type of treatment required.

Tests

Passive abduction or valgus stress test in 30° of flexion

The patient is placed supine on the couch, the head resting on a pillow to enable observation of the examiner without active raising of the head (which often causes tightening of the hamstrings). The thigh rests on the couch and the lower leg hangs over the side, with the knee in 30° of flexion. One hand is placed about the lateral aspect of the knee, the other grasps the lower leg at the ankle (Fig. 5). Then abduction stress is applied gently and repeatedly, gradually increasing up to the point of pain. The degree of movement and the end-feel are estimated.

The normal limb is assessed first, especially in acutely injured patients, because this shows the patient that the examination will not be rough and is unlikely to be painful. The examiner also gets a measure of the stability of the unaffected knee.

Instability indicates a tear limited to one or more of the medial compartment ligaments, i.e. the medial collateral ligament, meniscotibial or meniscofemoral capsular ligaments and the posterior oblique ligament.

If the abduction stress test in full extension also shows instability, the posterior cruciate ligament is probably also ruptured. It should be borne in mind that, in the fully extended position, an intact posterior cruciate ligament still holds the joint surfaces in firm apposition, even in complete tears of the medial compartment ligaments.

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Anterior drawer test in external and internal rotation

The patient is positioned as for the abduction–adduction stress tests. The hip is flexed to 45°, the knee to 80–90°. The foot is placed on the couch, well fixed by a portion of the examiner’s buttock resting on the dorsum of the forefoot.

The examiner places both hands around the upper part of the tibia with the index fingers palpating the hamstring tendons to make sure they are relaxed. Both thumbs are placed at the anterior border of the joint so that they can estimate the range of movement. Then the proximal part of the lower leg is pulled forward repeatedly, first gently then with a somewhat stronger pull.

The test is first performed with the lower leg and foot externally rotated beyond the neutral position and as far as is comfortably possible, then internally rotated (Fig. 8).

The findings are compared with those of the basic examination, for example in 0° rotation, as well as with the other knee.

With the tibia in external rotation

Anteromedial rotatory instability is indicative of a tear of one or more of the medial compartment ligaments: the medial collateral ligament, meniscotibial or meniscofemoral capsular ligaments and the posterior oblique ligament. An associated anterior cruciate ligament tear increases the amount of subluxation of the medial tibial condyle. This ligament is the second line of defence; in an acute isolated tear of the anterior cruciate the anterior drawer test will be negative.

With the tibia internally rotated

In patients with a medial compartment laxity, the test becomes negative because of the increased tension of the posterior cruciate ligament. Simultaneous forward subluxation of the tibial condyles indicates that the posterior cruciate ligament is torn. In this case, the rotational element is eliminated and straightforward instability exists.

Isolated forward subluxation of the lateral tibial plateau, for example anterolateral rotatory instability, can only be demonstrated if the knee is held in the neutral position, because internal rotation of the tibia will tighten an intact posterior cruciate ligament and prevent any subluxation. This type of instability is indicative of a tear of the middle third of the lateral capsular ligaments.

Prone rotation test

Sometimes doubt remains as to whether the range of rotation has been increased. A decisive assessment can be made with the patient prone and the knees flexed to a right angle (Fig. 9). The movement of external or internal rotation is performed bilaterally and the range of movement is assessed by the twisted position of the feet.

An increased range of lateral rotation results from a lack of stability of inert structures at the medial compartment (medial collateral ligament, meniscotibial and meniscofemoral capsular ligaments and the posterior oblique ligament) and/or the arcuate complex (arcuate ligament, lateral collateral ligament). An associated tear of the anterior cruciate ligament still increases the amount of rotation.

An increased range of medial rotation is indicative of laxity of the middle third of the lateral capsular ligaments, the anterior and the posterior cruciate ligaments.
A positive result is indicated if, on attaining about 30° of flexion, relocation occurs with a sudden movement, which is called a ‘jerk’. The forwards shift can be seen and felt by the examiner. At the same moment, the patient will recognize the feeling of instability.

The test demonstrates an anterolateral rotatory instability because of a tear in the middle third of the lateral capsular ligaments. Frequently, the anterior cruciate ligament and/or menisci are also ruptured and increase the instability.9

Anterolateral instability can also be demonstrated by carrying out the manoeuvre in the reverse direction, starting from a position of a few degrees of flexion: the pivot-shift test.

Bach et al10 found that the degree of pivot shift, probably because of the role of the iliotibial band, strongly correlates with the position of the hip and knee joint. They advised 30° of hip abduction and 20° of tibial external rotation as the position in which instability is most clearly demonstrated.

The examiner stands at the foot of the couch in order to monitor hip position carefully. The ipsilateral hand cradles and holds the foot in external rotation. The other hand, slightly supinated, holds the proximal and lateral leg. An axial load and valgus movement are applied simultaneously as the knee is slowly flexed passively from the extended position.

**Posterior drawer test**

The patient is in supine position with the hip flexed to 45° and the knee to 90°. The foot is flat on the couch, in neutral position. The heels of both hands are placed anteriorly against the proximal part of the tibia (Fig. 10). Both thumbs at the anterior border of the joint can estimate the range of movement. The proximal part of the tibia is then pushed backwards repeatedly, first gently then with a strong jerk.

The posterior drawer test, which includes palpation of the tibia–femur step-off, was recently demonstrated to be the most sensitive and specific clinical test for posterior cruciate ligament deficiency (accuracy 96% with a 90% sensitivity and a 99% specificity).8

**‘Jerk’ test and pivot-shift test**

The patient lies supine, the hip flexed to about 45°, the knee to 90°. The examiner supports the patient’s leg, with one hand at the foot, the other at the proximal end of tibia and fibula. The hand at the foot rotates the tibia slightly internally while the other hand exerts a mild valgus stress at the knee (Fig. 11). Extreme internal rotation may dampen a shift significantly. Maintaining slight internal rotation and mild valgus stress, the examiner gradually extends the knee. A positive result is indicated if, on attaining about 30° of flexion, relocation occurs with a sudden movement, which is called a ‘jerk’. The forwards shift can be seen and felt by the examiner. At the same moment, the patient will recognize the feeling of instability.

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Practitioner’s checklist

- An associated acute partial tear of the medial compartment ligamentous structures makes the test too painful to undertake
- A false-positive test may occur in the presence of a torn meniscus
- In children, and in patients who have mild to moderate congenital genu recurvatum without symptoms, it is normal to find the ‘jerk’ and pivot-shift tests, and the anterior drawer test with the tibia in 0° rotation to be mildly positive on both sides

External rotation–recurvatum test

The patient lies supine on the couch. Both legs are lifted simultaneously by grasping the big toes (Fig. 12). The amount of external rotation of the proximal end of the tibia and the degree of recurvatum are observed. In a positive test, unilateral excess of external rotation and recurvatum is obvious, which is seen as increased tibia vara.

The test demonstrates posterolateral rotatory instability, which is located in the structures of the arcuate complex: the arcuate ligament, lateral collateral ligament and possibly the popliteus tendon. It is also advisable to observe the patient standing and actively extending the knees maximally or to observe a barefoot walk.

Sometimes external rotation–hyperextension is absent, while these patients often walk with a slightly bent knee to avoid terminal extension.

Clinical tests for knee instability are summarized in Table 1.
## Table 1 Summary of clinical tests for instability

<table>
<thead>
<tr>
<th>Type of instability</th>
<th>Structures probably ruptured</th>
<th>Diagnostic test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight valgus</td>
<td>Capsuloligamentous structures of medial and posteromedial compartment, and posterior cruciate ligament</td>
<td>Abduction stress test in full extension</td>
</tr>
<tr>
<td>Straight varus</td>
<td>Lateral compartment ligaments and posterior cruciate ligament</td>
<td>Adduction stress test in full extension</td>
</tr>
<tr>
<td>Straight anterior</td>
<td>Middle third of medial and lateral compartment ligaments, and anterior cruciate ligament</td>
<td>Anterior drawer test, Lachman test</td>
</tr>
<tr>
<td>Straight posterior</td>
<td>Posterior cruciate ligament and arcuate complex</td>
<td>Posterior drawer test</td>
</tr>
<tr>
<td>Rotatory anteromedial</td>
<td>Medial and posteromedial compartment ligaments, and anterior cruciate ligament</td>
<td>Anterior drawer test from mid-position and in internal rotation, Abduction in 30° flexion, Lachman test</td>
</tr>
<tr>
<td>Rotatory anterolateral</td>
<td>Middle third of lateral compartment ligaments, and anterior cruciate ligament</td>
<td>Anterior drawer test from mid-position, Adduction in 30° flexion, ’Jerk’ test, Pivot-shift test</td>
</tr>
<tr>
<td>Rotatory posterolateral</td>
<td>Arcuate complex</td>
<td>External rotation–recurvatum test, Posterior drawer test from mid-position and in external rotation, Adduction in 30° flexion</td>
</tr>
</tbody>
</table>

### Treatment

**The best chance of success in treating a knee affected by ligamentous instability is within days of the original injury.** Management can be non-surgical or by surgical repair. Which is chosen depends on the structure(s) at fault, the degree of rupture and the extent of the lesion.

### Conservative treatment

In general, conservative treatment is indicated in all grade I and II sprains and in isolated grade III sprains of the medial collateral ligament. Acute complete tears of the anterior cruciate ligament, with an absent (0) or mild graded (1+) pivot-shift test, show excellent or good results in half of the cases.

The results of conservative treatment of isolated grade III sprains of the lateral ligament compartment are generally poor and not acceptable.

### Surgery

Surgical treatment of knee ligament injuries, particularly of the anterior cruciate ligament, is still controversial because the complex functional role of these ligaments makes them difficult to reconstruct effectively. Given that reconstruction is performed using high-strength bone–ligament–bone autogenous graft, placed isometrically and securely fixed internally, failure rates after 2 years’ follow-up have decreased to about 30%.

### Conservative treatment in acute instability

**Medial collateral ligament**

Isolated acute grade III lesions of the medial collateral ligament seldom result in lasting instability. Successful conservative treatment of these lesions has been reported, with only a very small number of patients requiring subsequent reconstruction. However, this applies only to isolated injuries in which, for example, valgus stability in full extension is normal. The key to success in non-surgical management of complete tears of the medial collateral ligament is to exclude those with concurrent damage to the anterior cruciate ligament or menisci.

Therapy must also include a structural rehabilitation programme with early protected motion, followed by progressive strengthening. A small residual amount of medial laxity does not appear to have any influence on the ability to return to competitive athletics.

When surgical and non-surgical treatment is compared in isolated acute grade III lesions of the medial collateral
ligament, similar results are obtained. However, non-surgically treated patients are rehabilitated in significantly less time. In combined injuries, it has been shown that the non-surgical management is successful only in 15%.

**Rehabilitation in non-operated, acute complete tears**

In the first 2 weeks the knee is partially immobilized in a rehabilitative brace that prevents the joint from moving beyond the painful range and protects against hyperextension, excessive lateral rotation and valgus strain. In order to maintain mobility while healing, Cyriax advocates moving the ligament by deep transverse friction to and fro over the adjacent bone in imitation of its normal behaviour. The first day, 1 minute’s friction thus suffices, in that no unwanted adhesions have yet formed. Friction is followed by passive flexion and extension movements, within the limits of pain. This treatment is repeated daily. Within a week, tenderness is declining and friction is performed for an increasing time, for up to 15 minutes, on alternate days during the second week (see p. 701).

From the moment the patient can undertake straight leg raising, weight bearing with crutches is started, provided the patient can tolerate it. At this time, isometric exercises are commenced (three times daily, 15 contractions) in order to avoid muscle wasting.

This period is followed by 4 weeks of controlled mobilization in a rehabilitative knee brace that allows a range of motion to be set within the limits of pain; hyperextension should still be prevented. This provides the opportunity to perform stationary biking and to start isotonic exercises for the quadriceps and hamstrings muscles. Thereafter, isokinetic exercises are added.

After 6 weeks the orthosis is replaced by a functional knee brace. Isotonic and isokinetic muscle training are continued. Running exercises can be started from the moment the quadriceps has reached at least 60% of the strength of the unaffected muscle. At this stage, hamstrings strength is equal to that of the opposite leg.

If quadriceps strength has returned to 80% of normal, agility drills can be undertaken. At this stage training is, if necessary, intensified to reach the level required for competitive sports. Strength, power and endurance should be compared with the unaffected leg. Contact drills are allowed, although still with a functional brace on the knee to protect it as much as possible against valgus stress.

The average time from injury to return to full activity and competitive sports is about 9 weeks.

**Anterior cruciate ligament**

**In acute complete rupture** of the anterior cruciate ligament, surgical repair is the treatment of choice, although secondary repair operations can still be undertaken.

Non-surgically treated complete ruptures of the anterior cruciate ligament commonly lead to recurring effusion into the joint after slight trauma and, because of the integrated nature of the whole stabilizing complex, intact restraining structures may gradually be stretched as well so that a number of structures are eventually involved and chronic instability results. After some years an advanced arthrosis is often the rule.

Buckley et al., in their study of conservatively treated partial anterior cruciate ligament tears, found that most patients developed a symptomatic knee but the majority did not have a sufficiently significant functional disability to warrant reconstructive surgery. Furthermore, they found that knee function following a partial tear did not appear to deteriorate with time (49 months after injury).

**Rehabilitation programme in conservatively treated grade II ruptures**

In the first 2 weeks the knee is immobilized in 30° of flexion. Isometric hamstrings and quadriceps exercises are instituted within the first 3 days. Hamstring muscle function is essential, because the hamstrings act as dynamic agonists to the anterior cruciate ligament in preventing forward gliding of the tibial plateau during walking, running and twisting.

After 2 weeks, limited motion in flexion between 30° and 60° degrees is allowed and can be increased to 30–70° after 4 weeks. Flexing the hip should be avoided until week 3 or 4, because quadriceps activity during this movement may stretch the injured ligament.

Partial weight bearing, using crutches, is permitted approximately 2–4 weeks after the injury. Full weight bearing is allowed after 4–6 weeks.

Approximately 6–10 weeks after the injury the patient may start resisted exercises, such as swimming and stationary bicycling, while wearing a functional brace. Terminal extensions and bodyweight load should still be avoided.

Jogging is allowed about 3–6 months after the injury.

Muscle exercises must be continued until there are no differences between the legs in hamstring and quadriceps strength. Athletes are not allowed to return to competitive sports earlier than 6–12 months after the injury.

Any swelling during the entire course of rehabilitation indicates that some overload has taken place and the programme should be modified accordingly.

**Posterior cruciate ligament**

Recent studies have shown that conservative management is also acceptable in isolated complete ruptures of the posterior cruciate ligament. Good results are obtainable even in athletes who wish to return to competitive sport.

In contrast, as found by Fowler and Messieh, surgical techniques of posterior cruciate ligament repair and reconstructions are generally difficult and the long-term results are unpredictable.

**Rehabilitation programme**

This resembles the programme for the anterior cruciate ligament. However, in posterior cruciate ligament instability, it seems to be essential that quadriceps atrophy is avoided.

**Lateral ligament compartment**

The long-term results of non-surgically treated grade II sprains of the lateral ligament compartment of the knee are reported as good and acceptable; however, in grade III sprains the results are mostly poor and unacceptable, resulting in an unstable knee with severe symptoms and post-traumatic osteoarthritis. On examination in 30° of flexion, these grade III sprains showed a severe (3+) adduction instability. In full extension there is still some adduction instability, graded as mild (1+) or moderate (2+). Kannus emphasizes that in grade III sprains the anterior cruciate ligament is often injured as well, and the
Conservative treatment in chronic instability

In chronic instability the action of the mechanical receptors in the lengthened ligaments is normally decreased. This loss of reflex activity influences the ‘protective reflex arc’ formed by the ligaments and their companion muscles and leads to lack of active stability.

In chronic grade III instability it is impossible to improve upon the loss of proprioception within the joint without surgical repair. Such repair is thereby limited to young and well-motivated patients with no radiological evidence of degenerative disease.33

Late examples of posterior cruciate and isolated lateral ligament instability cannot be repaired with confidence.11 Thus early detection and repair are most important.

In all cases of chronic instability the patient should still be encouraged to undertake an intensive programme of muscular training to improve the strength and endurance of all related muscles – knee flexors, extensors, internal and external rotators. Meanwhile the surgeon and therapist are able to judge the patient’s motivation and to select patients appropriate for surgical treatment. Exercises include isometric, isotonic and isokinetic contractions performed daily. Care should be taken again not to overload the joint, because this can lead to capsulitis, patellofemoral pain or increasing crepitus. Such symptoms should be seen as a sign that progress with exercises has been too quick. During more functional actions, such as jogging on even or uneven ground, running in figures of eight and jumping, it is advisable that the patient initially wears a knee brace to control the instability. Which appliance is appropriate is determined by the type of instability that is to be controlled. The level of muscular condition determines the grade of sport activity and the types of sport that are appropriate for each individual.

Rehabilitation management after surgical repair

Rehabilitation takes at least 6 months. It should be instituted carefully, because revascularization and structural conversion of any transplanted tissue is a very slow process. The final result is obtained about 1 year after the operation.34–36

The rehabilitation programme can be divided into four phases.37

- Assisted ambulatory phase
- Early strength training phase
- Intensive strength training phase
- Return to sports.

Assisted ambulatory phase

During the last decade a trend has developed to replace the period of immobilization after surgical repair by early mobilization in order to decrease the risk of contracture building up and to prevent detrimental effects on cartilage. For example, after complete rupture of the anterior cruciate ligament, the use of a high-strength bone–ligament–bone autogenous graft, placed isometrically and securely internally fixed, made it possible to commence joint motion, muscle re-education and, with the protection of a knee orthosis, even weight bearing up to 50% from the first week.38–42

A study of the results of accelerated programmes of rehabilitation after anterior cruciate ligament reconstruction indicated not only the need for individualized, evaluation-based rehabilitation, but also that caution should be used when introducing high loads or repetitive exercises within the first few months after surgery.43

For this reason postoperative clinical evaluation of graft failure, excessive pain and effusion must be strictly and regularly performed until termination of the rehabilitation. This includes joint arthrometer tests and stress diagnosis after the first week of rehabilitation and at every second week during the first 6 weeks, so as to have an accurate and objective evaluation of anterior displacement before progression to a more strenuous phase of rehabilitation.37

Any increase in joint displacement of 2 mm or more than the last result is an indication for adjustment of the rehabilitation programme. Weight bearing must be delayed, joint motion must be limited to between 20 and 90°, and resisted exercises for hamstrings and quadriceps must be limited at an angle of 70°. These measures decrease the tension on the graft. After 1 week the arthrometer test is repeated.

Excessive synovial fluid may be another sign that therapy has been too aggressive. It inhibits not only quadriceps contraction44–46 but also may degrade cartilage matrix.47

Pain must also be controlled to block harmful effects on circulation and muscular action. This can be achieved by medication and physical agents such as cool packs (10°C) and transcutaneous electrical nerve stimulation (TENS). Signs of sympathetic reflex dystrophy contraindicate the use of low temperature methods.

Programmes that are performed too aggressively, with running and agility drills 5 to 6 weeks after surgery and return to full activity and competition 16 weeks’ postoperatively, show 11–52% abnormal displacements at follow-up.48–50 In a less aggressive rehabilitation programme, with delay of high loads and strenuous activities for at least 4 months after surgery, abnormal displacements decreased to 15%, from which only 5% showed failure (6 mm or more of increase).43

Early strength training phase

On the second day after surgery active assisted exercises are started. This prevents formation of adhesions which usually occurs within 2 weeks of immobilization. Excessive scar production is estimated in 10–20% of cases. Because structures of the supra- and infrapatellar region and the posterior joint capsule are particularly prone to the development of contractions, motion exercises must include passive mobilizations of the patella in all directions.

Several studies recommend continuous passive motion via an externally applied force, especially if postoperative joint motion causes difficulties.39,51,52 It has been shown not to increase effusion or haemarthrosis.42 However, if pain and
The protective action of the hamstrings on the graft. These so-called close-kinetic exercises (standing with continued ground reaction force) also seem to reduce forces on the patellofemoral joint.

From the moment the patient has achieved full weight bearing, which is normally 6 weeks after surgery, it is advisable to start progressive muscle training with an overload at each exercise but only on condition that there is no pain, effusion or difference of tibial anterior translation between the involved and uninvolved limb and there is a full and painless range of motion. Patients with palpable patellofemoral crepitus are at risk of deterioration and are better to avoid strong resisted exercises.

The improvement of quadriceps and hamstrings must be evaluated weekly by isometric manual tests on strength and by the measurement of thigh circumference.

Proprioceptive neuromuscular facilitation (PNF) training is another recommended exercise to increase motor activity. It improves strength and endurance of the whole limb, from proximal to distal. With allowance for pain and weakness, resistance can be performed in an isometric or a concentric manner (either eccentric or isotonic).

After 2 months, training is broadened with more functional elements such as walking, pool walking and stepping. The use of a knee orthosis to control rotatory movements and the flexion–extension range within 60° and 20°, respectively, must be continued.

Isokinetic contractions have their own value. Because muscular defects have been shown to be more likely diagnosed at special velocities, it is of great advantage to investigate that aspect of muscular deficiency. With the use of a device, resistance can be adjusted accurately at the indicated velocity.

It is advisable to perform three sets of 10 repetitions twice a day on every other day and the load should not exceed 70% of maximum effort. However, because of the process of incorporation of the graft, it seems better not to start such exercises before the sixth postoperative week and also in the absence of pain and swelling. The effect of isokinetic exercises on force and endurance has been shown to be greater than that of isotonic exercises. The high loading contraindicates these exercises when there is patellofemoral crepitus, unless this is limited to the range of motion outside the crepitus.

Return to sports

After 3 months, bicycling can be started, which is stimulating for the quadriceps and hamstrings with little effect on the graft. At the beginning duration is 15–20 minutes. At that time resisted exercises are still increased, although muscular effort must not exceed 75% of maximum.

Running is allowed from the sixth postoperative month and, according to the patient’s goals, turning, twisting, cutting and jumping may gradually be added.

The use of a knee orthosis is still continued, especially in new training situations that impose high loads on the graft. ‘Joint reactions’, such as recurrence of pain and effusion, patellofemoral crepitus and any increase in anterior translation of the tibia, should always modify the programme.
To be successful in rehabilitation, exercises must also be similar to the specific demands of the individual sport or activity. Strenuous and difficult aspects are trained in isolation until proficiency has again been obtained. From that moment, and on condition that pain, effusion and patellofemoral crepitus are absent and forward translation of the tibia stays normal, training in the group can restart.

Return to competition is thereafter a matter of time and methodical building of strength. The level required for competitive sport can be judged from the following schedule: six 60 metre runs at full speed with 30 seconds' rest after each run; six 60 metre runs with small side jumps; 100 metre running with 10 left and right turns without losing speed. The whole question of successful rehabilitation is primarily one of motivation. Older and athletically inactive patients tend to do less well.

Table 2 and 3 give a survey of the whole rehabilitation programme after anterior cruciate ligament (ACL) reconstruction.

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Table 2: Evaluation-based rehabilitation advanced weight bearing and minimal protection programme: range of motion after ACL reconstruction. Weeks 1–5

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Weeks 2–3</th>
<th>Weeks 4–5</th>
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<tr>
<td>When</td>
<td>Weight bearing with two crutches when:</td>
<td>Weight bearing with one crutch when:</td>
</tr>
<tr>
<td></td>
<td>— postoperative pain is controlled</td>
<td>— pain is controlled without narcotics</td>
</tr>
<tr>
<td></td>
<td>— haemarthrosis is controlled</td>
<td>— effusion is controlled</td>
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<tr>
<td></td>
<td>— patellar mobility is normal</td>
<td>— ROM 10–100°</td>
</tr>
<tr>
<td></td>
<td>— voluntary quadriceps contraction</td>
<td>— muscle control throughout ROM</td>
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<tr>
<td>Evaluation</td>
<td>Pain</td>
<td>Pain</td>
</tr>
<tr>
<td></td>
<td>Haemarthrosis</td>
<td>Effusion</td>
</tr>
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<td>Patellar mobility</td>
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<td>Joint arthrometer</td>
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<td></td>
<td>ROM</td>
<td>ROM</td>
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<tr>
<td></td>
<td>Quadriceps contraction and muscle spasm</td>
<td>Muscle control</td>
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<td></td>
<td>Soft tissue contracture</td>
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<tr>
<td>Treatment</td>
<td>Pain management</td>
<td>Pain management</td>
</tr>
<tr>
<td></td>
<td>Control haemarthrosis</td>
<td>Control effusion</td>
</tr>
<tr>
<td></td>
<td>Mobilize patella</td>
<td>Mobilize patella</td>
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<tr>
<td></td>
<td>Motion exercises</td>
<td>Motion exercise 0–125°</td>
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<td>Flexibility programme</td>
<td>Flexibility</td>
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<tr>
<td></td>
<td>Muscle re-education</td>
<td>Increase quadriceps exercises and add mini-squats</td>
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<td></td>
<td>Knee orthosis</td>
<td>Muscle re-education</td>
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<tr>
<td></td>
<td>CPM</td>
<td>Knee orthosis</td>
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<tr>
<td>Goals</td>
<td>ROM 20–70°</td>
<td>ROM 0–125°</td>
</tr>
<tr>
<td></td>
<td>Adequate quadriceps contraction control, inflammation and effusion</td>
<td>Muscle control</td>
</tr>
<tr>
<td></td>
<td>25–50% full weight bearing</td>
<td>Control inflammation and effusion to prevent scarring</td>
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<tr>
<td></td>
<td></td>
<td>Joint arthrometer remains within 2 mm of last test</td>
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<tr>
<td></td>
<td></td>
<td>50–75% full weight bearing</td>
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</tbody>
</table>

*Rationale: Achieve full weight bearing and full range of motion without compromising graft fixation or graft maturation.

CPM, continuous passive motion; ROM, range of motion; RSD, reflex sympathetic dystrophy.

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### Table 3 Evaluation-based rehabilitation advanced muscle training after ACL reconstruction. Weeks 6–52

<table>
<thead>
<tr>
<th>Weeks 6–12</th>
<th>Weeks 13–24</th>
<th>Weeks 25–52</th>
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</thead>
<tbody>
<tr>
<td><strong>Evaluation</strong></td>
<td>Hamstrings and quadriceps strength testing</td>
<td>Hamstrings and quadriceps strength testing</td>
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<td>Swelling</td>
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<td>Joint arthrometer</td>
<td>Joint arthrometer</td>
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<tr>
<td></td>
<td>Patellar mobility and crepitus</td>
<td>Patellar mobility and crepitus</td>
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<tr>
<td><strong>Treatment</strong></td>
<td>Discontinue EMS</td>
<td>Increase speed and resistance for isotonic and closed chain kinetic exercises</td>
</tr>
<tr>
<td></td>
<td>Increase isotonic exercise</td>
<td>Advance isokinetic exercises</td>
</tr>
<tr>
<td></td>
<td>Start isokinetic exercises</td>
<td>Advance isokinetic exercises</td>
</tr>
<tr>
<td></td>
<td>Start proprioceptive neuromuscular facilitation</td>
<td>Continue isokinetic exercises</td>
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<tr>
<td></td>
<td>Start aerobic conditioning</td>
<td>Start plyometrics</td>
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<td></td>
<td>Proprioceptive training</td>
<td>Knee orthosis</td>
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<td></td>
<td>Therapeutic modalities</td>
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</tbody>
</table>

**Goals**

- Increase strength endurance so there is no fatigue with ADL
- Increase strength & endurance of lower extremity for limited activity
- Increase function
- Maintain strength & endurance
- Return to previous activity level

*General criteria: No effusion, painless range of motion, joint stability; performs activities of daily living without pain; range of knee motion 0–125°; full weight bearing. ADL, activities of daily living; EMS, electrical muscle stimulation.*

### References

27. Buckley SL, Barrack RL, Alexander AH. The natural history of conservatively


