The fibular (lateral) collateral ligament (FCL) is the primary varus stabiliser of the knee. FCL injuries are most commonly associated with damage to other structures contributing to the postero-lateral corner. Isolated FCL injuries are rare and there is a paucity of evidence documenting prognosis, rehabilitation and outcome.

According to the UEFA Champions League Injury Audit 2014 to 2015, isolated FCL injuries accounted for 0.01% of injuries at a rate of 0.05 injuries per 1000 hours. To put this into context, the mean injury rate in training and match play respectively was 3.1 and 23.3 injuries for every 1000 match hours.

During the 2014 to 2015 season Liverpool Football Club sustained two high-grade FCL injuries. The protocol recommended by orthopaedic knee specialists comprised a 6-week bracing period and 10 to 12-week return-to-play (RTP) prognosis. In one instance surgery was implicated as a distinct possibility should conservative management be sub-optimal. Following discussion, the specialists agreed to an accelerated criteria-based rehabilitation underpinned by sound clinical reasoning. Both players returned to first team English Premier League football in 5 to 6 weeks with no functional detriment, residual laxity or re-injury.

The aim of this review is to justify the accelerated rehabilitation programme relative to initial prognoses, in order to help guide future practices in professional football. Particular attention will be focused on how implementation of applied anatomy and biomechanics informs rehabilitation.
FUNCTIONAL ANATOMY

Knowledge of the normal anatomy of the FCL and its relationship to the other static stabilisers of the postero-lateral corner is essential to understanding the clinical, imaging and biomechanical features of FCL injury. The postero-lateral aspect of the knee, often termed the arcuate complex, comprises the FCL, biceps femoris tendon, popliteus muscle and tendon, oblique popliteal ligament, arcuate ligament, fabellofibular ligament (if fabella present) and the lateral gastrocnemius head. The interlaced framework of these stabilisers illustrates, in part, why isolated structural injury is uncommon.

The FCL is extra-capsular and defined as ‘pencil-like’. Typically, the FCL origin arises immediately posterior and proximal to the lateral epicondyle of the femur (Figure 1a, b and c). The ligament descends posteriorly and inferiorly, before inserting on the lateral aspect of the fibular head. The antero-lateral ligament, also referred to as the anterior oblique band, takes its origin just anterior to the FCL and projects antero-inferiorly, inserting onto the lateral tibial cortex and more controversially, the lateral meniscal body (Figure 1a). The distal 10 to 12 mm of the FCL courses between the medial and lateral slips of the distal biceps femoris tendon, each of which possess anterior and posterior arms (Figure 1d and e). The anterior arm of the medial slip most commonly inserts onto the lateral tibia, inferior to the insertion of the antero-lateral ligament. The anterior arm of the lateral slip covers the lateral surface of the FCL insertion and blends with lateral crural fascia. The FCL...
is relatively avascular in comparison to its medial counterpart, the medial collateral ligament. The limited blood supply should be taken into consideration with respect to the ligament’s healing capacity immediately following injury.

APPLIED BIOMECHANICS

The FCL is the primary restraint to varus forces at the knee. Isolated sectioning of the FCL has shown increasing varus rotation at all angles of flexion, however it is greatest at 30° knee flexion. Varus rotation at progressively deeper angles of knee flexion decreases. During running, the knee flexes to approximately 30 to 45° during absorption phase and extends to approximately 25° in propulsion phase. Thus, the FCL is susceptible to injury if the knee is subject to significant extrinsic varus force during running.

A secondary role of the FCL is to resist external tibial rotation to varying degrees dependent on knee flexion angle. Surgita and Amis reported that the orientation of the FCL is such that it is a weak restraint to external rotation at 90° knee flexion. LaPrade et al. expanded on this finding demonstrating that the mean external rotation load for the FCL was greatest at 30° knee flexion, which decreased with increasing knee flexion. The implication is that the FCL resists external tibial rotation at angles close to 30°.

MECHANISM OF INJURY

Considering the aforementioned biomechanics, it follows that a varus force with external tibial rotation and the foot planted is the primary mechanism of injury for the FCL. Specifically, extrinsic varus and external tibial rotation loads applied during absorption/propulsion phases of the running cycle or football-specific movements which incorporate approximately 30° of knee flexion will increase the potential for isolated FCL injury.

INJURY CLASSIFICATION

The clinical grading system we used was based on the LaPrade Classification (Table 1). The grading is a postero-lateral corner classification, whereby both injuries were grade 2. Both players attempted to continue either training or playing, however were unable to. Upon initial clinical examination FCL injury was suspected in both cases. In view of the complex anatomy and functional implications of tissue damage in this region, magnetic resonance imaging (MRI) was employed to help differentiate between injured structures. Table 2 details injury mechanism, clinical assessment and MRI findings.

CLINICAL ASSESSMENT

As with any injury, examination of this region should follow a routine systematic approach. Knee swelling and effusion were noted. A small joint effusion may occur following FCL injury; however a large effusion is suggestive of intra-articular damage – the FCL (as already mentioned) is extra-capsular. Palpation, range of motion (ROM), strength and function were subsequently assessed. Due to the high frequency of concomitant injury in this region, assessment included the antero-lateral and postero-lateral drawer tests, reverse pivot-shift test, dial test and intra-articular joint testing. The following two specific FCL tests were performed:

**Prone varus stress test**

The prone varus stress test is derived from the traditional supine varus stress test (Figure 2). The FCL is assessed in full extension and 30° of flexion. The prone position maintains the femur in contact with the examination table, thus fixing one end of the limb. We believe this is more in-keeping with the mechanics of the injury, whereby the limb is fixed– albeit by planting the foot. The distal femur is stabilised with one hand, while the other hand is used to apply varus force at the lower leg. At 30° the test is more specific for FCL injury. The degree of lateral joint line opening can be graded when compared with the contra-lateral limb (Table 1). A grade 3 injury at 0° would indicate FCL and cruciate ligament damage.

**Figure 4 palpation**

The knee is placed in a flexed (‘figure 4’ position) cross-ussed position (Figure 3). The ligament is palpated for continuity and tension along its entire length. Pain over the fibular styloid may indicate fracture, termed the ‘arcuate sign’ due to the attachment site of the arcuate complex.

IMAGING EVALUATION

Radiographs are not routinely performed for a suspected FCL injury. However, postero-lateral corner injuries may occasionally exhibit bony abnormalities.

---

**Table 1**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Sprain type</th>
<th>Clinical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor</td>
<td>Minimal increase in varus translation, external rotation at 30° and 90° and postrolateral drawer at 90°.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>An increase in varus opening less than 1cm (compared with the contralateral side) with a palpable end point; an increase of external rotation at 30° less than 10°; an increase in postrolateral drawer no more than one grade compared with the contralateral side.</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Greater than 1cm of varus opening at 30°; a 10° increase of external rotation at 30° compared with the contralateral side; a one to two grade increase in the postrolateral drawer test at 90° compared with the contralateral side.</td>
</tr>
</tbody>
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Table 1: Clinical classification scale.
Table 2: Mechanism and assessment.

<table>
<thead>
<tr>
<th>Player</th>
<th>Mechanism</th>
<th>Clinical assessment</th>
<th>Clinical classification</th>
<th>MRI evaluation</th>
</tr>
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</table>
| 1      | Tackled in training while foot planted. Varus force. Able to continue but ceased training early when aggravated by side-foot pass. | * Pain on palpation of FCL fibular attachment.  
* Increase of varus <1cm compared with contralateral side on prone stress test.  
* Slight increase (<10°) in external tibial rotation at 30°.  
* Resisted hamstring testing reproduced pain.  
* FCL palpably less taut than contralateral side in 'figure 4' position. | Grade 2 | High grade 2 (80%) partial tearing of the fibula-insertion of the FCL visible on axial images and retraction of the torn fibres on sagittal and coronal images. The anatomical relationship between the FCL and the tendon insertion of biceps femoris is demonstrated. Acute haemorrhage is present between the torn remaining distal FCL fibres and the lateral slip of the biceps femoris tendon insertion (See Figure 4a, b and c). |
| 2      | Tackled during match while running with the ball. Foot was planted and forced into external rotation. Able to continue for approximately 60 minutes but removed from field of play due to lateral knee pain. Linear or off-line running and passing all reproduced lateral knee pain. | * Pain on palpation along length of FCL.  
* Increase of varus 1cm compared with contralateral side on prone stress test.  
* Slight increase (<10°) in external tibial rotation at 30°.  
* FCL continuity on palpation in 'figure 4' position. | Grade 2 | This case had two regions of injury in the FCL. Axial imaging showed a segment of diffuse oedema in the distal FCL arising 8mm proximal to the fibular insertion with mild attenuation (20%) reflecting a low-grade partial tear appreciated on coronal images. There is no fibre retraction in this case and the distal FCL is intact throughout its course between the insertional slips of the biceps femoris tendon. There is a second region of injury located more proximally in the FCL, which showed thickening and oedema. No transverse partial tearing was present in this region consistent with a grade 1 sprain. This combination of two sequential injuries of the FCL was associated with grade 2 laxity on clinical examination (See Figure 4d, e and f). The second series of images performed 10 weeks later, showed resolution of FCL oedema and diffuse low-signal thickening of the region of previously noted attenuation and resolution of oedema more proximally reflecting a radiologically good healing response (See Figure 4g and h). |
such as avulsion fractures on the lateral tibial cortex (Segond fracture) or fractures of the styloid process of the fibular head (arcuate sign). MRI is the primary imaging modality for assessing the extent of FCL injury. The normal FCL appears as a taut black structure on all conventional (T1, T2, proton density) MRI sequences. The degree of oedema, fibre continuity and laxity can be interpreted to define the integrity of the injured ligament. Grade 1 injuries demonstrate superficial oedema but the ligament remains intact. Grade 2 injuries exhibit oedema through the ligament, with partial fibre disruption and possible laxity. Grade 3 injuries reveal extensive oedema, complete fibre disruption, with retraction and laxity usually present. If required, dedicated coronal-oblique sequences can provide more intricate detail of the FCL.

Ultrasound is a useful modality in imaging the FCL as it provides excellent resolution and allows dynamic assessment. By imaging the injured FCL during controlled varus stress, rotation and flexion of the knee, the integrity of high-grade partial tears may be more accurately assessed than on static MRI images. Ultrasound also facilitates image-guided injection procedures such as platelet-rich plasma injection or prolotherapy.

REHABILITATION

Both players underwent a period of bracing. A recent survey has shown no consensus regarding bracing protocol for isolated FCL injury. The limited blood supply to the area and ligamentous laxity on clinical testing were our justification for this intervention. Player 2 had a longer period of bracing enforced due to greater laxity on the prone varus stress test manoeuvre. The rehabilitation outlined in Table 3 illustrates the timescale in which progressions were first implemented, rather than the continuing daily workload. Progressive isokinetic dynamometry, closed kinetic chain external rotation, kicking and on-field work processes were fundamental to the rehabilitation process and are discussed in greater detail below.

IKD PROGRESSIONS

As previously discussed, FCL biomechanics dictate that the ligament is an external tibial rotation restraint at angles closer to extension. Subsequently, an isokinetic dynamometer was used as a passive external rotation rehabilitation tool. The device enables the therapist to reliably reproduce joint-specific ROM angles. The mobilisations commenced at 90 degrees knee flexion and were progressed towards 30 degrees, enabling a specific soft tissue mobilisation (Figure 7). There is unequivocal evidence citing the importance of loading injured ligamentous tissue in

Knowledge of the normal anatomy of the lateral ligament and its relationship to the other static stabilisers of the posterolateral corner is essential to understanding the clinical, imaging and biomechanical features of the injury.
the proliferative phase in order to optimise collagen alignment and ultimately restore biomechanics\textsuperscript{10}. Eccentric strengthening of tibial joint internal rotators was also performed in the same manner, progressing from deeper angles of knee flexion to extension, in order to maximise dynamic control of external rotation.

CLOSED KINETIC CHAIN EXTERNAL ROTATION

The star excursion balance test instrument (Figure 8) was used as a rehabilitation tool for gradually progressing the angle of external tibial rotation with the foot planted in a static position. The same procedure was formally performed later as a component of the RTP criteria (Figure 10). The test is a valid predictor of lower extremity injury risk with excellent intra-rater reliability\textsuperscript{11,12}.

KICKING PROGRESSION

Upon completion of the isokinetic dynamometry and closed kinetic chain external rotation progressions, players embarked on kicking progressions. A velocity-based algorithm was incorporated, whereby players were instructed to reproduce specific modes of kicking at low, moderate or high intensities (Figure 9). Initially, resisted kicking was completed using a pulley-based Keiser system. Equivalent or greater power outputs than the contralateral limb were required in order to progress resistance. Once it was determined that the knee was coping with resisted kicking, ball progressions were included alongside pitch-based rehabilitation using

<table>
<thead>
<tr>
<th>Day</th>
<th>Player 1</th>
<th>Player 2</th>
</tr>
</thead>
</table>
| 1   | *Braced 30 to 70° NWB (FWB supervised in gym)  
*Compex high-intensity muscle stimulation  
*Core strength variations  
*Ultrasound |           |
| 2   | *Quadriiceps strengthening: split-squat/leg press/leg extension (superimposed with Compex)  
*Hamstring strengthening: KDLs/good morning  
*Calf strengthening: seated calf raises  
*Glut strengthening: manual abduction variation/hip extension cables  
*Bed-based neuromuscular control and proprioceptive exercise | *Braced 30 to 70° NWB  
*SLR variations (superimposed with Compex high intensity muscle stimulation)  
*Core strength variations  
*PSWD  
*Ultrasound |
| 3   | *Braced 30 to 90° NWB (FWB supervised in gym)  
*Due to increased knee ROM now able to include shoulder elevated hip lift and bridging exercises for gluteal strength |           |
| 4   | *Braced 20 to 90° FWB  
*FWB neuromuscular control and proprioception progressions (See Figures 5 and 6) |           |
| 5   | *Braced 30 to 80° NWB (FWB supervised in gym)  
*Pre-activation work focusing on deceleration control  
*Alter-g running progressions 12 to 16km/h 60 to 90% bodyweight |           |
| 6   | *Braced 20 to 90° FWB  
*FWB neuromuscular control and proprioception progressions (See Figures 5 and 6) |           |
| 7   | *Braced 30 to 70° NWB (FWB supervised in gym)  
*Quadriiceps strengthening: split-squat/leg press/leg extension (superimposed with Compex)  
*Hamstring strengthening: KDLs/good morning  
*Calf strengthening: seated calf raises  
*Glut strengthening: manual abduction variation/hip extension cables  
*Bed-based neuromuscular control and proprioceptive exercise |           |
| 8   | *Braced 30 to 80° NWB (FWB supervised in gym)  
*Due to increased knee ROM now able to include shoulder elevated hip lift and bridging exercises for gluteal strength |           |
| 9   | *Braced free FWB |           |
| 10  | *Braced free FWB |           |
| 11  | *Braced free FWB |           |
| 12  | *Braced free FWB |           |
| 13  | *Pre-activation work focusing on deceleration control  
*Alter-g running progressions 12 to 16km/h 60 to 90% bodyweight |           |
| 14  | *Braced 20 to 90° NYB (FWB supervised in gym)  
*Alter-g walking progressions 6km/h 60 to 70%  
*FWB neuromuscular control and proprioception progressions (See Figures 5 and 6) |           |
| 15  | *Braced 20 to 90° NYB (FWB supervised in gym)  
*Alter-g walking progressions 6km/h 60 to 70%  
*FWB neuromuscular control and proprioception progressions (See Figures 5 and 6) |           |

Continued on next page...
Table 3 continued:

| 16 | *Straight-line pitch  
| 17 | *IKD knee mobilisation and strengthening  
| 18 | *CKC tibio-femoral external rotation progressions  
| 19 | *Pool off-line exercise (commenced day 18)  
| 20 | *Keiser kicking progressions (commenced day 24)  
| 21 | *Ball kicking progressions (commenced day 25)  
| 22 |  
| 23 |  
| 24 | *Off-line pitch  
| 25 |  
| 26 |  
| 27 |  
| 28 |  
| 29 |  
| 30 |  
| 31 |  
| 32 |  
| 33 |  
| 34 |  
| 35 |  
| 36 |  
| 37 | Substitute appearance in English Premier League match  
| 38 |  
| 39 |  
| 40 |  
| 41 |  
| 42 |  

Table 3: Rehabilitation guide. NWB=non-weight-bearing, FWB=full weight-bearing, RDL=Romanian deadlift, SLR=straight leg raise, PSWD=pulsed shortwave diathermy, ROM=range of motion, IKD=isokinetic dynamometry, CKC=closed kinetic chain.

Coding:

- Acute bracing management
- Base strength
- Neuromuscular control
- Alter-g running
- Straight-line pitch
- Off-line pitch
- Training
- Game

*Braced 20°-free  
*Alter-g walking progressions 6km/h 80 to 90%

*Braced 10°-free  
*Alter-g running progressions 12 to 16km/h 60 to 70%

*Braced 10-free  
*Alter-g running progressions 12 to 16km/h 70 to 80%

*Braced free FWB  
*Alter-g running progressions 12 to 16km/h 80 to 90%

*Off-line pitch  
*IKD knee mobilisation and strengthening  
*CKC tibio-femoral external rotation progressions  
*Pool off-line exercise (commenced day 24)  
*Keiser kicking progressions (commenced day 28)  
*Ball kicking progressions (commenced day 29)

Team training

Substitute appearance in English Premier League match

Played 58 minutes of English Premier League match
the same kicking paradigm. Any specific kicking techniques individualised to the players’ requirements were included after completion of the set model.

ON-FIELD WORK PROCESSES

Players’ physical performance in games changes throughout the season and is related to training status\(^6\). This factor along with individual match profiles were the primary reason for specific changes in the training load processes delivered between these two players. Player 1’s injury coincided with return for pre-season and reduced training loads from the off-season. Therefore, based on specific testing and the known reduction in physical capacity following the off-season\(^4\) the need to improve aerobic capacity, strength and power were necessary and this resulted in almost a two-fold increase in the frequency of training sessions delivered. Player 2 incurred his injury during the late season. Consequently, the relative physical loading prescribed was inferior from an average and total perspective, as in-season fitness profiles are known to be greater than pre-season\(^3\).

During the on-field rehabilitation period a 3-day cycle was implemented for both players. The first 7 to 8 days involved straight-line work (Table 3). These 3 day cycles incorporated a combination of:

- high-intensity aerobic training (>85% maximum heart rate) for day 1,
- high-intensity repeated sprint training with a large emphasis on high-speed-running for day 2 and
- an unloading recovery session for day 3.

The volume (total distance and high-speed-running) and intensity (metres per minute and high-speed-running) was increased over the course of the sessions. The effectiveness of high-intensity aerobic training and high-intensity repeated sprint training has been previously documented\(^15,16\). The period of off-field training also lasted 7 to 8 days (Table 3). This training commenced with the integration of low-intensity change of direction football and position-specific tasks with a gradual session on session increase in change of direction/movement intensity. The straight-line and high-intensity component of training still remained high throughout this period. Additionally, the volume (total distance and high-speed-running) and intensity (metres per minute and high-speed-running) of sessions also increased session by session. Within this training schedule the training emphasis also followed a 3-day training cycle:

- day 1 placing emphasis on short spaces and preferentially loading the quadriceps/gluteals,
- day 2 focusing on high-speed-running

and subsequently hamstrings workload and
- day 3 comprising an unloading recovery session.

All data for sessions was tracked using global positioning systems (Viper pod 2, STATSports – Belfast, UK), which provided data on total distance, metres per minute, high-speed running, peak speeds and player load\(^7\). Supporting this information were match analyses, tracked using ProZone which also provides summaries of speed metrics such as total distance, metres per minute, high-speed running and peak speed\(^8\). This collective information allows for training and game speed metrics to be combined, enabling specific sessions and accumulative loading to be prescribed, thus helping to prepare players for their specific physical demands. Additionally, beat by beat heart rate analysis during sessions and heart rate variability was also used to determine adaptation to the training stimulus throughout the period of rehabilitation. Table 4 demonstrates the total and average load prescribed to both players throughout the duration of the rehabilitation.

DISCUSSION

High-grade isolated FCL injuries are rare and typically conservatively managed over a 2 to 3 month period in professional football.

<table>
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<tr>
<th>Table 4</th>
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</thead>
<tbody>
<tr>
<td><strong>Player</strong></td>
</tr>
<tr>
<td>P1 Total</td>
</tr>
<tr>
<td>P1 Average</td>
</tr>
<tr>
<td>P2 Total</td>
</tr>
<tr>
<td>P2 Average</td>
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</table>

*Maximum reached during rehabilitation

Table 4: Total and average training load for both players during the on-field phase of rehabilitation. HSR=high-speed runs, TD=total distance, HR=heart rate.
Despite limitations with inferences, based on two injury cases, we believe that a criteria-based accelerated rehabilitation programme following high-grade FCL injury allows successful RTP for professional football players (Figure 10). Player 1 was practically a complete rupture on imaging and returned to training in 4.5 weeks. Not only were the players rehabilitated in terms of the specific injury, but they were also physically fit from a central perspective enabling a rapid RTP once back training.

There is no published data on FCL rehabilitation in professional football. Sikka et al. produced a retrospective study reporting on isolated FCL injury and RTP timescales in American Football, using the National Football League Injury Surveillance System between 2004 and 2009. Eight players with high-grade (grade 2/3) injuries were hinge-braced for an average of 4 weeks. Return-to-training ranged from 3 to 12 weeks. Players were permitted to RTP wearing a brace, which is prohibited in the English Premier League. There was no detail provided in terms of the components of rehabilitation.

We believe that this review is the first in press to document the specifics of an accelerated rehabilitation programme following FCL injury in professional football players. Particular focus was placed on restoring the biomechanical function of the FCL by progressively loading external tibial rotation through knee flexion-extension. This non-operative injury management has resulted in excellent short- to long-term results with no associated joint laxity or injury risk.

Figure 4: (a) Sagittal image showing acute injury of the distal FCL with high-grade partial tearing and tear margin retraction. (b) Coronal image showing acute injury of the distal FCL with high-grade partial tearing and retraction of the torn fibres. (c) Acute injury of the distal FCL showing high-grade partial tearing and surrounding haemorrhage deep to the lateral slip of the distal biceps femoris tendon (thin arrow). (d) Sagittal image showing acute grade 2 injury of the distal FCL showing partial fibre disruption and surrounding haemorrhage. (e) Coronal image showing grade 2 injury of the distal FCL centred proximal to its course between the slips of the biceps femoris tendon insertion. (f) Axial image showing acute partial tearing (grade 2 injury) and surrounding haemorrhage of the FCL (block arrows) located anterior to distal biceps femoris tendon (thin arrow). (g) image showing low-signal thickening and scarring of the distal FCL following PRP injection. (h) Low-signal thickening and scarring of the distal FCL following PRP injection. (i) Axial image showing resolution of haemorrhage and low-signal scarring of the distal FCL post-PRP injection. PRP=platelet-rich plasma.
Figure 5: The neuromuscular control paradigm.

Figure 6: The proprioception paradigm.

Figure 7: Isokinetic dynamometry external tibial rotation.

Figure 8: Closed kinetic chain external tibial rotation.
Figure 9: The kicking progressions paradigm.

References


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<td>Pain Nil</td>
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<td>Concentric quads peak torque</td>
<td>60°/s 90°/s</td>
</tr>
<tr>
<td>Left</td>
<td>Right</td>
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**Figure 10:** Fibular collateral ligament injury return to play criteria. ROM=range of motion, L=left, R=right, IKD=isokinetic dynamometry, GPS=global positioning system, RTP=return to play.