Laxity-Based Return to Play

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16.1 Introduction

Anterior cruciate ligament (ACL) rupture is a troublesome injury for a football player and the long-term consequences, such as early-onset osteoarthritis [1]. Interestingly, a recent study reported an increase in the number of annual ACL injuries recorded in US Major League Soccer (MLS) from 1996 to 2012: there has been at least one ACL tear per year and a greater number of ACL tears of the left versus the right knee. The ACL injury rate is 0.4 per team per season, which means that a club on average will see an ACL injury every second season [2]. In particular, injury is more frequent in female soccer players (they have almost 7 times the odds of sustaining a primary ACL tear compared with their male counterparts) [3], total rupture rate is significantly higher than the partial rupture rate, and the match ACL injury rate is 20 times higher than the training injury rate [4].

A debated risk factor in the literature is fatigue, but many of the ACL injuries actually occur early in the first half or among newly substituted players in the second half [5]. This finding suggests that if fatigue is a risk factor, it is probably more an effect of accumulated fatigue over time, for

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example, owing to a congested match calendar [6, 7], than energy depletion per se in the match where the ACL injury occurs.

16.2 ACL Treatment in Professional Football Players

The general opinion among football medical doctors is that football players with an ACL injury need an ACL reconstruction in order to continue playing. The rationale for surgical intervention after ACL injury is to restore the pre-injury activity level [3].

The caretaking at the elite level represents, in many ways, the optimal situation: players at this level are supported by a highly qualified medical team, the time to diagnosis for this court is as a mean 8 days, and access for a diagnostic MRI is straightforward.

Marcacci et al. compared clinical results of surgical reconstructions within 15 days, and after 3 months from the injury, they obtained better results in terms of return-to-sport and laxity testing in the early reconstruction group [8]. Early surgery can thus be another factor behind the high success rates at elite level, but it is not completely proved [9].

Another important factor is the postoperative rehabilitation. Most certainly, the rehabilitation after ACL surgery has improved markedly during the last 20 years, but the possibility of being helped by a physiotherapist also differs between elite and amateur level. In Scandinavia, for example, an amateur football player is normally helped by a physiotherapist for about 1 h 2–3 times a week following ACL surgery; on the other hand, a player at elite level normally receives help from a team physiotherapist several hours every day [10].

Even if a majority of players can return to football after ACL injury/reconstruction, some sustain further knee problems and need of surgery [11, 12].

Walden et al. [4] have previously reported that many elite football players suffer from synovitis and other overuse injuries shortly after their comeback to football, possibly indicating premature return. At the professional level, economy has to be considered as an additional factor, with monetary implications increasing the desire to return to play. The high numbers of return to play after ACL surgery might reflect a satisfactory outcome, but could also be regarded as knee abuse with a risk of further joint injury and subsequent development of osteoarthritis. Another important finding is the mean absence from full team training between 6 and 7 months after surgery. This means that, even with optimal caretaking and resources, this is the time it takes and shorter rehabilitation could create an additional problem.

Fact Box 1
Generally, all players who underwent ACL reconstruction are able to return to training, but the re-rupture rate is not negligible. Even if 89% of professional athletes play within 12 months, only 65% competes at the highest level 3 years later.

Generally, all players who underwent ACL reconstruction for a total rupture are able to return to training, but the ipsilateral re-rupture rate (4%) and the need for other ipsilateral knee surgery (3%) before return to competitive activity are not negligible. Finally, the return-to-practice (RTP) rate within a year after ACL reconstruction for a total rupture is very high within 10 months (>90%), 89% participates in elite match play within 12 months, but only 65% compete at the highest level 3 years later. ACL re-ruptures are seen especially in younger athletes who return to sports. In particular, according to Wiggins et al. [13], when they are compared to uninjured subjects, they have a 30–40 times greater risk of ACL injury higher than those for uninjured subjects. The risk for ipsilateral graft rupture seems to be greatest in the first 2 years after ACL reconstruction, and a relatively higher proportion of contralateral ACL ruptures are seen with increasing follow-up periods [14].

It is well known that release for RTP after injury/surgery is a complex process, and, trying to understand which factors could influence outcomes, it is possible to determine extrinsic and intrinsic factors.

Between extrinsic factors only the "accelerated rehabilitation" concept by Shelbourne and Gray [15] is considered a vital goal, especially for high-level athletes. Application of this principle allowed professional athletes to return to sport as soon as 6 months after ACL reconstruction. However, caution should be used, as early return to sport has been demonstrated to be related to ACL failure, especially in cases of primary reconstruction with allograft tissue [16]. There are other extrinsic factors on outcome, such as type of graft, surgical technique, or fixation technique.

Intrinsic factors are patient's anatomy, biological response, and type of lesion. Morphological knee parameters such as tibial slope, notch width, and femoral condyle shape have been correlated with increased risk of ACL injury, ACL reconstruction failure, or postoperative laxity [17]. Furthermore, with regard to knee alignment, varus deformity has been demonstrated to increase tension on the ACL [18]. Furthermore, every patient has their own specific genetic makeup and biology, and lack of incorporation of the graft and biological failure are well-recognized causes of poor outcomes after ACL reconstruction [19]. Clinicians must consider the lesion pattern and concomitant injuries: medial meniscus deficiency is responsible for increased stress on the ACL during AP tibial translation [20], while lateral meniscal deficiency is responsible for increased rotational laxity during the pivot-shift maneuver [21]. Grade II medial collateral ligament (MCL) lesions were recently recognized as a risk factor for ACL failure with an odds ratio of 13, and untreated posterolateral corner lesions have been demonstrated to increase the risk of ACL failure and to worsen outcomes [22, 23]. Finally, concomitant lesions (such as cartilage injuries) are a fundamental variable in the final return-to-sport decision, as even isolated cartilage procedures like microfractures usually need a longer recovery time compared with ACL reconstruction, about 8–12 months even in competitive athletes submitted to aggressive rehabilitation [24, 25].

16.3 The Role of Laxity Assessment

The static function of the ACL in the knee stability is to provide constraint when a force is applied (posteriorly) to the tibia, forcing it to translate forward from the femur. From a dynamic point of view, the intact ACL (especially its posterolateral bundle) limits the internal rotation and anterior subluxation of the lateral compartment of the knee, assuring its stability when complex vectors of forces are applied, such as during pivoting sports [26].

The assessment of the knee laxity represents a key factor when approaching the ACL-injured athlete in the presurgical phase, since knee laxity represents an important diagnostic tool and determinates the treatment algorithm. It was demonstrated that a high grade of pre-reconstruction knee laxity significantly increases the odds of graft failure and revision [27].

Also an intraoperative evaluation of the residual laxity might suggest the need for additional surgical procedures. In fact, although the ACL is the main ligament for static and dynamic knee stability, other anatomical structures such as menisci and the anterolateral ligament (ALL) have been demonstrated to play a minor role in knee stability [28, 29].

For this reason the authors recommend always to perform a complete assessment and reconstruction of the damaged structures, to obtain the best results in terms of return to sport.

Finally, it is useful to evaluate the knee laxity throughout the postoperative period, to verify the integration of the graft and to decide the right moment for the athlete to return to professional sport activity [30].

It was demonstrated, with a biomechanical in vivo experiment, that rotational stability of the ACL-reconstructed knees did not show much improvement at the 3-month follow-up after surgery, but at the 12-month control, they showed a rotational stability comparable to the healthy contralateral side. This suggests that the graft undergoes significant remodeling over time detectable by laxity assessment [31].

16.4 Clinical Evaluation of the Knee Laxity

In the clinical setting, the most elementary and rapid tools for the physician to evaluate the ACL function are the anterior drawer test and the Lachman test [32] for the static laxity (Fig. 16.1). The dynamic laxity is evaluated with the pivot-shift test (PS) [33] (Fig. 16.2).

These examinations were described during the 1970s and led to better accuracy in diagnosis of the ACL injuries; in particular the Lachman has been demonstrated to be the most sensitive test, while the PS is the most specific test, especially under anesthesia [34].

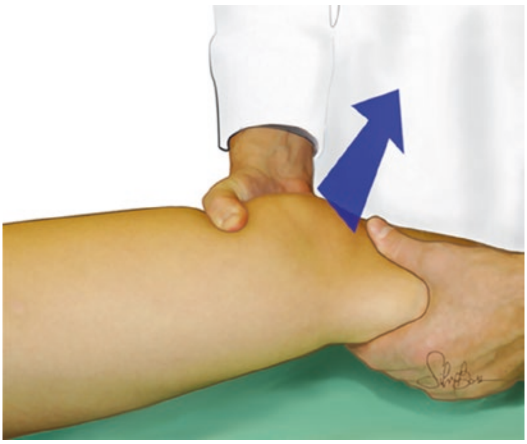

Fig. 16.1 The *arrow* shows the direction of the force applied on the tibia during the Lachman test

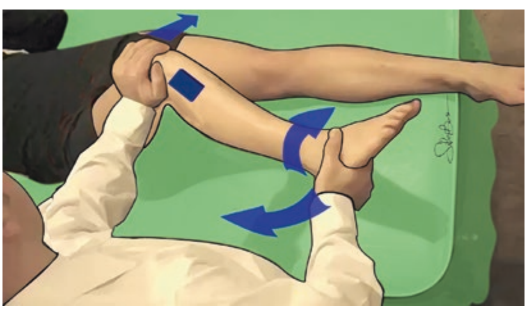

Fig. 16.2 The execution of the pivot-shift test, *arrows* show multiple vectors applied on the limb

The execution and grading of these tests are dependent on the experience of the physician and thus subjective; moreover, they involve great intra- and inter-examiner variability since applied manual loading cannot be standardized [35].

Nevertheless, a wide accepted clinical classification of the International Knee Documentation Committee (IKDC) ranks the knee laxity in four grades (from “A” to “D”) based on the millimeters of anterior tibial translation in Lachman and anterior drawer test and on the subjective feeling of tibial reduction for the PS test. In this classification the contralateral healthy side is taken as reference [36].

16.5 Instrumented Quantification of the Unidirectional Static Laxity

Among the first instruments designed for the evaluation of the ACL injuries, there are KT1000 (MEDmetric Corp, San Diego, CA, USA) and the Rolimeter (Aircast, Europe). These mechanical joint arthrometers are inexpensive and easy to use, allowing their application in an ambulatory setting. The KT1000 resembles the Lachman test in its execution and permits to calculate the force (in Newton) applied on the proximal tibia at 20° of flexion and to quantify its consequent anterior subluxation (in millimeters) [37] (Fig. 16.3).

Nowadays, this device is extensively used in the management of ACL reconstruction [38].

Rolimeter, which is normally used to quantify the anterior drawer test, is a simpler device that measures the anterior translation of the tibial tubercle, at 20° of flexion when a manual load is applied (Fig. 16.4).

Despite its simplicity, Rolimeter have been demonstrated to be as reliable and reproducible as KT1000 in the knee laxity assessment [39, 40]. Anyway, the opinion about the relation between KT1000 and Rolimeter data and clinical outcome is not unanimous, so the utility of these two instruments is not wide yet.

Fig. 16.3 KT1000 measures the anterior tibial translation when a standard force is applied

Fig. 16.4 Rolimeter measures anterior tibial translation during an anterior drawer maneuver

16.6 Assisted Assessment of the Multidirectional Dynamic Laxity with the Pivot-Shift Test

The pivot shift is a phenomenon occurring in the ACL-deficient knee when, in extension, the lateral tibial plateau is anteriorly subluxated: at a certain degree of flexion, the increased tension elicited by the iliotibial band causes a sudden reduction upon the condyles. The combined movement of the tibia during this maneuver can be divided in external rotation and posterior translation [41].

Given the complex kinematics of the PST, a number of parameters have been described in the literature for quantification. These parameter can be classified in four groups (translations, rotations, acceleration/velocity, and others), thus pointing out the lack of consensus and of standardized methodology among physicians [42].

During recent years several devices have been developed for the assessment of the knee dynamic laxity, the most promising being surgical navigation, electromagnetic sensors system, inertial sensors, and image analysis system [43].

16.6.1 Computer-Assisted Surgical Navigation

First developed during the 1990s, computer-aided surgery (CAS) has been used during ACL reconstruction to implement the tunnel drilling and the isometry of the graft and later to evaluate the knee kinematics [44].

Determination of the patient anatomy is needed for CAS, and this can be achieved with a preoperative computer tomography, intraoperatively with fluoroscopic X-rays, or more commonly with an image-free digitalization of certain anatomical structures using navigated pointers. In order to evaluate knee kinematics, either electromagnetic or optoelectronic technology is utilized to evaluate joint positions and movement. Trackers and receivers are fixed invasively to the bones under anesthesia; thus, no skin-related artifacts are present with this technology [45]. Using a navigation system (BLU-IGS, Orthokey, Lewes, Delaware, DE, USA), static and dynamic laxity measurements demonstrated that compared to single-bundle ACL-R, the double-bundle technique provides better laxity control during the PST [46].

16.6.2 Electromagnetic Sensor System

In vivo first evaluation of the knee movement during PST in 6 degree of motion (DOF) was performed by Bull et al. [41] using the electromagnetic system; they used sensors which were fixed into the femur and tibia with pins. Their measurements were accurate but the technique was invasive.

Noninvasive electromagnetic tracking devices (FASTRAK or LIBERTY, Polhemus, Colchester, VT, USA) have a sampling rate of 60 Hz and 249 Hz, respectively, and a root square accuracy of 0.03 mm and 0.15° of rotation [47].

The system is composed of three electromagnetic receivers and transmitters that produce an electromagnetic field. The first and the second receivers are fixed on the thigh and below the tibial tubercle with braces; the third is utilized to record and reconstruct the three-dimensional anatomy of the limb through seven bony landmarks. The respective movements of the tibia and femur are then visualized and analyzed on a laptop as a virtual limb [48].

Electromagnetic devices have been used for over a decade and are precise, reliable, and noninvasive. Nevertheless, metallic objects can produce signal disturbances, and wireless systems are yet to be developed to facilitate examinations.

16.6.3 Inertial Sensors

These devices have received growing attention during the last years; they exploit the fact that the lateral aspect of the tibia undergoes a sudden acceleration during reduction in the pivot-shift maneuver. This value can be calculated (in m/s^2) and visualized on a graph (Fig. 16.5).

16.6.3.1 Triaxial Accelerometer

KiRA (Orthokey, LLC, Lewes, DE, USA) is attached with a strap between the tibial tuberosity

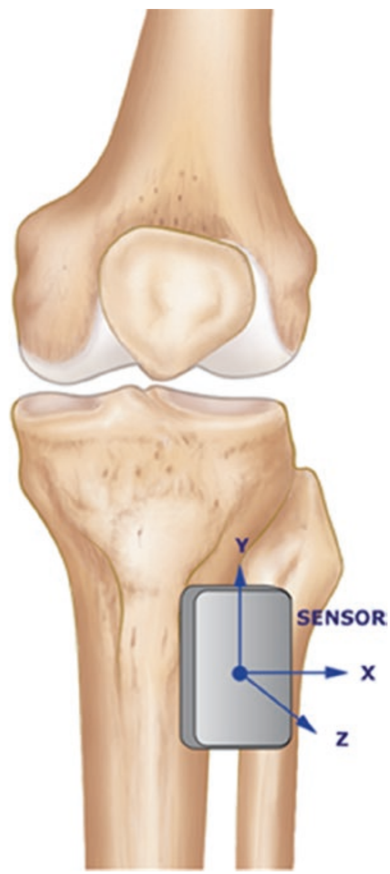

Fig. 16.5 Triaxial accelerometers are able to measure the accelerations in the three-dimensional space

and Gerdy tubercle and connected wireless with a tablet. The PST examinations can be performed before surgery and under anesthesia and is able to show statistically significant differences in acceleration between ACL injured and intact knees [49, 50].

At the 6-month follow-up, the values of acceleration normalized. However, it was shown that the specificity of the device varies from 50% to 90% depending on the experience of the tester [51].

KiRA was validated for clinical practice in the treatment of the ACL injury [52].

16.6.4 Optical Motion Capture Technique

Image analysis measures posterior translation of the tibia during pivot shift correlating with clinical grading of the PST [53, 54].

Using an iPad technology (PIVOT, Impellia Inc., USA), the recorded translation of the lateral compartment was related the IKDC clinical classification. Significant differences were found between the ACL-injured and contralateral side of the included patients; moreover, there was a significant difference in mean translation between knees graded as 1 when compared to knees graded as 2 [55]. It has been demonstrated that both inertial sensors and image analysis devices are able to differentiate between high-grade and low-grade PTS results according to the IKDC classification, making them optimal tools for diagnosis and follow-up [56].

Fact Box 2
Inertial sensors exploit the fact that the lateral aspect of the tibia undergoes a sudden acceleration during the pivot-shift maneuver: this acceleration can be on a graph. Moreover, the KiRA device has been validated for the evaluation of the anteroposterior laxity.

16.7 The Neuromuscular Factor After ACLR

There is a significant difference between PST in awake and anesthetized patients; in particular, they obtained lower values of tibial acceleration and lateral compartment translation in the awake group. This suggests that the neuromuscular component might play an important role in determining the grade of dynamic knee laxity [57]. It was also demonstrated that the local neuromuscular condition varies during the first postoperative year, influencing the stability of the knee joint as well [58].

According to the author's clinical experience and studies, KiRA device permits the evaluation when the neuromuscular response of the operated limb reaches the same level of the uninjured knee, during the rehabilitation of the athlete [59]. This can be a useful aid in the return-to-sport decision process (Fig. 16.6).

Take Home Points

- Most physicians prefer manual testing of the Lachman and PST to assess the athlete readiness to return to play [60]; in particular the PST correlates to clinical outcomes and the development of osteoarthritis [61, 62].

Fig. 16.6 The accelerations occurring during the pivot-shift test are measured with KiRA and visualized on a tablet

- Anterior laxity measured with KT1000 cannot predict return to football [63–65].
- Dynamic laxity 5 years postoperatively was greater in ACL-reconstructed knees than in uninjured knees, suggesting that this may affect the return to sport and risk of osteoarthritis [66].
- Currently, the timing of when an athlete returns to sport varies with rehabilitation programs, but no consensus rehabilitation program exists for athletes recovering from ACL reconstruction [67, 68].
- Actually, the return-to-sport decision is mostly based on subjective non-specific criteria [69]; on the other hand, objective criteria (like muscle strength, ROM, effusion) are used less [70].
- The vast majority of surgeons consider 6–8 months as a cut-off value for allowing sport resumption [71].
- The authors' preferred approach is using a sport-specific program to obtain more effective rehabilitation programs for athletes after surgery that allowed 95% and 62% of professional male soccer players to return to the same professional sport activity 1 and 4 years after surgery [72].
- Anyway, using a restricted test battery, the majority of patients who are 6 months after ACLR require additional rehabilitation to pass RTS criteria [73].
- It is important to create a new RTS battery with objective and restricted criteria in order to optimize the decision-making regarding RTS after ACLR with the aim to reduce incidence of second ACL injuries.

Fact Box 3
The sport resumption decision is now based on subjective non-specific criteria. Gokeler et al. demonstrated that using a more restricted test battery, the majority of patients who are 6 months after ACLR require additional rehabilitation.

Take Home Message
Despite the large number of clinical tests and accelerated rehabilitation, the improvement of diagnostic tools, and surgical technique, long-term results in professional football players are not excellent. A better pre- and postsurgical evaluation of knee laxity with new objective and restricted criteria, associated with the use in clinical practice of new devices for laxity assessment, have the potential to improve patient evaluation and to provide athletes with a safer instruction to return to sport.

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