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The role of the iliotibial band during the pivot shift test

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Abstract

Purpose Several studies have suggested that the iliotibial (IT) band plays a role in knee laxity and that it may affect the magnitude of the pivot shift observed. However, the extent of the role played by the IT band, as well as its mechanism of action, is not currently known. This cadaveric study aimed to quantify the effect of the IT band and the hip abduction angle on the magnitude of anterior tibial translation (ATT) during the pivot shift.

Methods Six fresh-frozen hip-to-toes specimens were used. Serial sectioning of the anterior cruciate ligament (ACL) and the IT band was performed. Lachman and mechanized pivot shift manoeuvres were employed at each stage, and ATT of the lateral and medial compartments was measured using navigation. Three hip abduction angles were tested for each condition: 0°, 15° and 30°.

Results Sequential sectioning of the ACL and the IT band resulted in a significant increase in ATT in both the lateral (Intact = 0 ± 0.5 mm; ACL deficient = 8.1 ± 0.2 mm; ACL + IT deficient = 10.8 ± 0.3 mm) and medial (Intact = 6.7 ± 0.4 mm; ACL deficient = 8.4 ± 0.3 mm; ACL + IT deficient = 9.9 ± 0.3 mm) compartments. No significant increase in ATT was observed after changing the hip abduction angle at each stage.

Conclusions An increase in the magnitude of the pivot shift and the Lachman was observed as the constraint of the IT band was removed. Additionally, it was shown that the hip abduction angle at which the pivot shift test was performed did not significantly affect the magnitude of ATT in this cadaveric model.

Keywords IT band · Pivot shift · ACL injury · Hip abduction angle

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Introduction

Although the symptoms of the pivot shift phenomenon had been observed and reported for the greater part of this century, the term pivot shift was first coined by Galway et al. in [14]. The pivot shift is a complex, mulitplanar manoeuvre that incorporates two main components: translation (the anterior subluxation of the lateral tibial plateau followed by its reduction) and rotation (the rotation of the tibia relative to the femur) [7, 8]. The test is used to detect rotatory instability of the knee. Because of its high specificity [5, 17], the pivot shift is used in addition to the Lachman test to detect anterior cruciate ligament (ACL) deficiency in the knee [5, 18].

The contributions of the soft tissues surrounding the knee to the biomechanics of the pivot shift phenomenon are yet to be fully understood. Several studies have examined the role that the iliotibial (IT) band plays on the pivot shift [3, 31, 32]. It is known that the IT band serves as a lateral restraint through its bony attachment sites, which include anchoring to the iliac crest and to Gerdy's tubercle on the tibia [23]. It has been suggested that these attachment sites provide the IT band with the ability to support the knee and prevent subluxation and/or dislocation. It has been implied that, without the IT band, the pivot shift phenomenon may not be observed in an ACL-deficient knee, because the lateral tibial plateau would remain anteriorly subluxed [22, 32]. These studies suggest that the IT band plays a role in knee laxity and the degree of the pivot shift observed. However, the extent of the role played by the IT band, as well as its mechanism of action, is not currently known.

In addition to the importance of the IT band, the effect of hip position on the pivot shift has also been studied. The IT band relaxes when the hip is abducted, whereas it tightens when adducted. Bach et al. [3] found that hip adduction reduces the ability to detect a pivot shift as compared to abduction. It was observed that the combination of hip abduction and tibial external rotation consistently yielded the most pronounced pivot shift. It remains to be determined, though, the angle of hip abduction at which the pivot shift test should be performed.

In the current study, computer navigation was used to quantify the effect of the IT band, and of the hip abduction angle, on the magnitude of the pivot shift. Our working hypotheses were that removal of the IT band would decrease the magnitude of the pivot shift and that abduction at the hip would increase the magnitude of the pivot shift.

Materials and methods

Six fresh-frozen whole lower limb specimens (hip-to-toes) were used for this study. All specimens were examined prior to testing, and integrity of the joint surface, the menisci and the ligaments was confirmed. The limits of knee motion were determined using previously described techniques [15, 28]. Specimens were thawed overnight for 48 h at room temperature before testing. Each specimen was laid in the supine position on an operating table, ensuring unrestricted motion at the hip and knee joints.

A surgical navigation system with ACL-specific software and with an accuracy of 1 mm and 1° (Surgetics, Praxim Inc., Grenoble, France) was used for kinematic data acquisition as previously described [6, 11]. Reflective reference arrays were attached to the femur and the tibia, 15 cm above and below the joint line, using two pairs of 4-mm Schanz pins. A medial parapatellar arthrotomy was performed to digitize the reference landmarks within the knee joint. Care was taken to preserve the meniscal attachments and to not damage the capsule beyond the trajectory of the incision. Instrumented laxity testing consisted of the Lachman and the pivot shift tests. For the Lachman test, the knee was flexed to 30° and an anterior pulling force of a mean 120 N [21] was applied using a handheld pull-type spring scale attached to the tibia through an eyelet screw fixed to the anterior tibial crest, 7 cm below the joint line. In order to reduce test–retest variability and ensure more accurate examinations [16, 26], a mechanized pivot shifter developed at our institution was used to perform the pivot shift manoeuvres [9, 27]. A valgus force of 40–50 N was applied 5 cm below the joint line on the lateral side of the proximal third of the leg.

Tibiofemoral translation in the Lachman test was defined as the range in translation from the tibiofemoral resting point at the beginning of each trial to the maximum anterior position of the tibia in the sagittal plane, in each of the lateral and medial compartments. The pivot shift was assessed by comparing the motion path of the pivot shift compared with the motion path during a reference flexion–extension cycle. The maximum amount of anterior tibial translation (ATT) in the medial and lateral compartment during the pivot shift manoeuvre compared to the reference motion path was recorded as previously described [10, 19, 29]. This ATT represents coupled rotational and translational movements induced by the motion path of the pivot shift manoeuvre and, for this reason, is reported as the coupled ATT. In addition, the flexion angle at which the maximum translation occurred was recorded [30].

Lachman and pivot shift tests were performed for each of three conditions: intact, ACL deficient and ACL and IT band deficient. Additionally, three different hip abduction angles were tested in the ACL deficient and ACL and IT band-deficient states. Three trials of both the Lachman and pivot shift tests were performed at each tested condition. After testing the intact knee, a #15 blade was used to resect the ACL, in which visual and tactile confirmation was performed by two examiners. Once testing in the ACL-deficient state was completed, the IT band was detached from its distal insertion at Gerdy's tubercle and peeled back 5 cm to ensure that it was no longer functionally active (Fig. 1). This was confirmed once again by two examiners. There was an average difference of 0.27 mm (SD = 0.29 mm) between trials, with an intraclass correlation coefficient of 0.99.

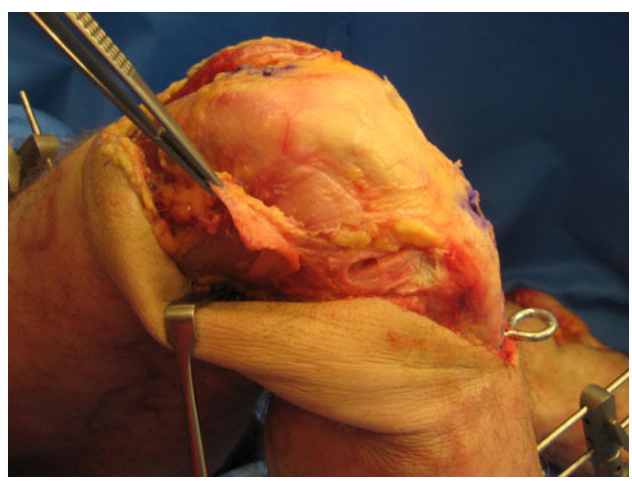

Fig. 1 The IT band after it was carefully detached from Gerdy's tubercle

Statistical analysis

The study was powered based on data from previous research and with the aim of detecting a difference in translation of at least 3 mm between conditions. Repeated-measures analysis of variance (rmANOVA) was used to model the effect that sectioning the ACL and the IT had on ATT during the Lachman test. In addition to ACL and IT band sectioning, the hip abduction angle was included in the rmANOVA model for coupled ATT during the pivot shift test. Bonferroni correction was used for all pairwise comparisons. Statistical significance was set to $\alpha = 0.05$. All statistical analyses were performed using Stata/SE 12.0 (StataCorp LP, College Station, TX).

Results

Lachman test

Mean ATT for the lateral compartment in the intact knee was 4.4 mm (95 % CI = 2.2, 6.6). After sectioning the ACL, mean ATT increased by 4.78 mm (95 % CI = 1.1, 8.5) to a mean 9.2 mm (95 % CI = 7.0, 11.3) ($P = 0.012$). When the IT band was sectioned in addition to the ACL, mean ATT further increased by 5.0 mm (95 % CI = 1.3, 8.6) to 14.11 mm (95 % CI = 11.9, 16.3) ($P = 0.01$).

For the medial compartment, mean ATT in the intact knee was 2.8 mm (95 % CI = 1.3, 4.4). After sectioning the ACL, mean ATT increased by 4.1 mm (95 % CI = 1.4, 6.7) to a mean 6.9 mm (95 % CI = 5.3, 8.5) ($P = 0.004$). When the IT band was sectioned in addition to the ACL, mean ATT further increased by 3.0 mm (95 % CI = 0.3, 5.7) to 9.9 mm (95 % CI = 8.3, 11.5) ($P = 0.028$).

Pivot shift test

Lateral compartment coupled ATT in the intact knee was a mean 0 mm (95 % CI = −0.5, 0.5). When the ACL was sectioned, coupled ATT increased to 8.1 mm (95 % CI = 7.8, 8.3) ($P < 0.0001$). Additional sectioning of the IT band resulted in a 2.8 mm increase in translation from the ACL-deficient state to a mean 10.8 mm (95 % CI = 10.6, 11.1) ($P < 0.0001$). The mean angle at which the maximum ATT occurred in the lateral compartment increased from 15.3° to 20.5° ($P < 0.05$) after the IT band was sectioned.

Changes in hip abduction angle did not result in significant changes in coupled ATT in the lateral compartment in the ACL-deficient state (n.s.). Mean ATT at 0° was 7.5 mm (95 % CI = 6.9, 8.1); at 15°, it was 8 mm (95 % CI = 7.4, 8.6); and at 30°, mean ATT was 8.7 mm (95 % CI = 8.1, 9.2). With both the ACL and the IT band sectioned, there was no significant difference in ATT at 0° or 15° (mean ATT = 10.33 mm; 95 % CI = 9.8, 10.9) (n.s.). There was a small increase in translation at 30° (mean ATT = 11.8 mm, 95 % CI = 11.3, 12.4) ($P = 0.017$).

Coupled ATT in the medial compartment for the intact knee was a mean 6.7 mm (95 % CI = 6.3, 7.1). After sectioning the ACL, coupled ATT increased by 1.8 mm (95 % CI = 1.3, 2.3) to a mean 8.4 mm (95 % CI = 8.2, 8.7) ($P < 0.0001$). Concomitant sectioning of the ACL and the IT band resulted in a 1.5 mm (95 % CI = 1.1, 1.9) increase in translation to a mean 9.9 mm (95 % CI = 9.7, 10.2) ($P < 0.0001$). There was no change in the flexion angle at which the maximum ATT was recorded with sectioning of the IT band.

According to the angle of hip abduction, mean coupled ATT was 10.2 mm (95 % CI = 9.8, 10.6) at 0°, and 9.8 mm (95 % CI = 9.4, 10.3) at both 15° and 30° (n.s.).

Discussion

The most important finding of this study was that the magnitude of ATT during the pivot shift and the Lachman tests increases as the constraint of the IT band is removed. Additionally, the hip abduction angle at which the pivot shift test was performed did not significantly affect the magnitude of ATT in this cadaveric model.

The pivot shift is a mulitplanar manoeuvre that involves two main components: translation (the anterior subluxation of the lateral tibial plateau followed by its reduction) and rotation (the rotation of the tibia relative to the femur) [7, 8]. Previous research by our group focused on deconstructing the pivot shift into its component elements. Lateral compartment translation, but not medial compartment translation, has been demonstrated to correlate tightly with the clinical grade of the pivot shift [19]. These studies suggest that a requisite amount of lateral compartment translation is necessary to produce various grades of the pivot suggesting that lateral compartment control may be a key goal of ACL reconstruction. Indeed, tension of the lateral soft tissues may be an important secondary restraint to anterolateral rotatory laxity in the ACL-deficient knee. This concept is supported by our previous finding that lateral meniscectomy, but not medial meniscectomy, resulted in increased magnitude of the pivot shift [25], as well as by the work from Ferretti et al. [24] that demonstrated the importance of the anterolateral femoral tibial ligament (ALFTL) in limiting tibial translation and rotation in the ACL-deficient knee.

The IT band is positioned directly superficial to the anterolateral capsule and is a major lateral compartment structure that would be predicted to limit anterior translation and internal tibial rotation in the ACL-deficient knee.

This study is the first to directly quantify the effect of the IT band on the pivot shift and the Lachman in the ACL-deficient knee. Previous research has shown that lateral compartment translation correlates well with the grade of the pivot shift [4]. The data from the current study suggest that sectioning the IT band results in a significant increase in lateral compartment translation during the pivot shift manoeuvre. The increase in lateral compartment translation averaged approximately 3 mm. In comparison, a previous study found that complete lateral meniscectomy increased lateral compartment translation, an average of 6–7 mm in the ACL-deficient knee during pivot shift testing [25]. Clinically, it appeared that 5–7 mm of translation is needed to increase the pivot shift one clinical grade [4]. As such, sectioning of the IT band caused a significant but modest increase in lateral compartment translation in the ACL-deficient knee during pivot shift testing.

With Lachman testing, ATT increased by 3–5 mm in the ACL-deficient knee. This is similar to the increase in ATT previously found after removing the medial meniscus in the ACL-deficient knee [25]. However, taking into consideration previous research, the IT band does not appear to have a greater impact than other lateral structures (such as the lateral meniscus and the lateral collateral ligament) in the prevention of ATT during the pivot shift test.

It is important to note that the role of the IT band in the pivot shift is debated. Many authors have suggested that the IT band is instrumental in guiding the reduction portion of the pivot shift [12, 22, 31, 32]. Indeed, Losee [20] found that the pivot shift reduction disappeared after detachment from Gedy's tubercle.

Other authors, however, demonstrated that IT band sectioning resulted in higher subjective pivot shift grade [13]. Bach et al. [3] found that cutting the IT band eliminates the effect of hip position on the pivot shift results. Yamamoto et al. [32] found the IT band to be an ACL agonist as it decreased in situ forces in the ACL by 23–40 %.

According to these data, sectioning the IT band increases the magnitude of anterior translation but it is not firmly established whether the velocity or 'abruptness' of the reduction felt during the pivot shift manoeuvre is affected. Indeed, the kinematics of the pivot shift did change with IT band sectioning, as the maximum anterior translation occurred in a greater degree of knee flexion. This suggests that the knee stays subluxed longer.

No effect of hip position on the pivot shift was seen in the current study. Bach et al. [3] reported on 37 patients with ACL injuries and graded the pivot shift subjectively in various positions of hip abduction/adduction and internal and external rotation. They noted that hip abduction produced the greatest degree of pivot shift and reasoned that the IT band is most relaxed in this position. We could not substantiate that hip abduction has a direct role on the pivot shift; however, our data support the concept that relaxing the IT band (either by directly sectioning it in a cadaver or by abducting the hip in a patient) will exaggerate the pivot shift phenomenon.

There are several limitations to this research. First, the study involved time zero cadaveric specimens without the typical injury patterns sustained in ACL trauma. Indeed, complete detachment of the IT band is not associated with any clinically recognized injury patterns. However, the goal of this research was to study an important lateral structure of the knee, that is, IT band and try to quantify its contribution to the occurrence of the pivot shift phenomenon. Thus, attenuation or incompetence of the lateral structures, including the IT band, may be an important factor in producing recurrent knee instability in the ACL-deficient or reconstructed knee. Another potential limitation is the small number of cadaver specimens used. The study was powered and its sample size calculated based on previous research that has shown a difference in ATT of 3 mm or more to be clinically significant. This was successfully captured in our statistical model, as differences in ATT greater than 3 mm were deemed to be statistically significant. Third, the study focused on the magnitude of translation that occurred during the pivot shift, not on quantifying the abruptness or acceleration of the reduction phenomenon in the ACL-deficient knee with and without the IT band. Previously, it was demonstrated that the magnitude of lateral compartment translation correlated tightly with the clinical grade of the pivot shift; however, this study was performed in knees with competent IT bands. Loss of the IT band may affect the abruptness of the reduction phenomenon. Subjectively, a change in the abruptness of the pivot shift was not detected after sectioning the IT band in the cadavers for this study; however, this was not quantified and we cannot comment conclusively on whether the IT band affects the feel of the reduction as the anteriorly subluxed tibia reduces during knee flexion. Future research employing electromagnetic or accelerometer-based technology could help elucidate how velocity is affected by different conditions during the pivot shift [1, 2, 16].

Conclusion

An increase in the magnitude of the pivot shift and the Lachman was observed as the constraint of the IT band was removed. Additionally, it was shown that the hip abduction angle at which the pivot shift test was performed did not significantly affect the magnitude of ATT in this cadaveric model. It has been previously shown that control of the lateral compartment is important in eliminating the pivot shift and that lateral meniscectomy results in higher grade pivots in the ACL-deficient knee [4]. The results from the current study are clinically relevant as they emphasize the relative competence of the lateral soft tissue envelope as a key determinant in the magnitude of the pivot shift in the ACL-deficient knee.

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