Iliotibial Band Tension Reduces Patellar Lateral Stability

Azhar M. Merican,1,2 Farhad Iranpour,2 Andrew A. Amis2,3

1Department of Orthopaedic Surgery, University Malaya Medical Centre, 50603 Kuala Lumpur, Malaysia, 2Musculoskeletal Surgery Department, Imperial College London, Charing Cross Hospital, London, United Kingdom, 3Biomechanics Section, Mechanical Engineering Department, Imperial College London, London, United Kingdom

Received 14 December 2007; accepted 15 July 2008
Published online 16 October 2008 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/jor.20756

ABSTRACT: This study investigated the effect of loading the iliotibial band (ITB) on the stability of the patellofemoral joint. We measured the restraining force required to displace the patella 10 mm medially and laterally (defined as medial and lateral stability, respectively) in 14 fresh-frozen knees from 0 to 90° knee flexion. The testing rig allowed the patella to rotate and translate freely during this displacement. The quadriceps was separated into five components and loaded with 175 N total tension. Testing was performed at 0 to 90 N ITB tension. With no ITB tension, the lateral restraining force ranged from 82 to 101 N across 0 to 90° flexion. Increasing ITB tension caused progressive reduction of the lateral restraining force. The maximum reduction was 25% at 60° flexion and 90 N ITB tension. Medial restraining force increased progressively with increasing knee flexion and increasing ITB loads; it ranged from 74 N at 0° knee flexion and 0 N ITB tension to 211 N at 90° knee flexion and 90 N ITB tension. The maximum effect was an increase of medial restraining force of 50% at 90° flexion and 90 N ITB tension. © 2008 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. J Orthop Res 27:335–339, 2009

Keywords: patella; patellofemoral joint; stability; iliotibial band; tension

Patellofemoral joint stability depends on the complex interaction of several factors, including the extensor mechanism, the retinacular restraints, the articular geometry, and limb alignment, but their individual contributions are difficult to quantify because of their interactions. For example, there are interactions between the dynamic and static stabilizers, such as the force of the vastus medialis obliquus acting on the medial patellofemoral ligament.1,2 On the lateral side, although less investigated, a similar effect can be expected, because of the interconnections of the iliotibial band (ITB) to the patella that provide lateral retinacular restraint to the patella.3–6

Previous studies have shown a significant effect of the ITB on tibiofemoral7–9 and patellofemoral kinematics and contact areas.8 The current study measured patellar stability, defined in the objective engineering sense, as the “restraining force” required to oppose patellar displacement from the equilibrium position10,11. This provided a more direct method of quantifying patellar stability than indirect measures, such as changes in joint contact patterns or changes in patellofemoral kinematics. This measurement of restraining force was not the same as the clinical symptom of instability, although these might be related. There has been clinical evidence that tightness of the ITB may contribute to patellar maltracking and instability12,13. Despite this evidence suggesting a role of the ITB in patellar stability, there has not been objective measurement of this effect. The aim of our study was to test the hypothesis that because the ITB pulls posteriorly/laterally on the patella, an increase in ITB tension would decrease the restraining force of the patella against lateral displacement and, conversely, increase the restraining force against medial displacement.

MATERIALS AND METHODS

Fourteen fresh-frozen cadaveric knees with no prior history of knee surgery or disease were used in this study [mean age 66 (SD = 14) range 41–85, M:F 7:7]. These were obtained from the International Institute for the Advancement of Medicine (Jessup, PA). The institute undertook screening and consent to use the knees for research. Ethical permission for the study was obtained from the Riverside Research Ethics Committee. The knees were stored at −20 °C and thawed a day prior to experimentation.

The skin and subcutaneous tissue were removed. The deep fascia, retinaculae, and ITB were preserved. The femur and tibia were cut approximately 20 and 15 cm above and below the knee, respectively. The head of the fibula was transfixed to the tibia by two bone screws to maintain its anatomical position and then the distal part excised. Using polymethylmethacrylate and after preparation of the medullary cavity, an intramedullary sleeve and a rod were cemented into the femur and tibia, respectively. The sleeve in the femur was aligned to the central axis of the femur by the use of rubber spacers and an outrigger alignment rod. A polyethylene socket was cemented into the patella, centered over the median ridge and 10-mm deep to the anterior (superficial) surface. This was taken to be the geometric centre of the patella. The quadriceps was separated into five components: rectus femoris (RF) and vastus intermedius (VI), vastus lateralis longus (VLL), vastus lateralis obliquus (VLO), vastus medialis longus (VML), and vastus medialis obliquus (VMO).

The stability testing rig was composed of two parts. A fixed part (for mounting the femur) was attached to the base of an Instron materials testing machine (Instron Ltd., Buckinghamshire, England) and the moving part (for displacing the patella) was a 3 degrees of freedom mounting attached to the Instron load cell on the moving crosshead (Fig. 1). The knee was mounted sideways (lateral aspect upward) in the fixed part of the stability rig by locating the cemented femoral sleeve onto a horizontal rod, so the anatomic axis of the femur was perpendicular to the load cell axis. The femoral sleeve allowed the femur to be rotated until the most posterior aspects of the femoral condyles were aligned vertically in a distal–proximal view. When this was achieved it was locked to the mounting device.

To connect the patella to the moving crosshead of the test machine, the lower end of the 3 degrees of freedom
mounting was snap-fitted into the polyethylene patellar socket to form a ball and socket joint (Fig. 1). The mounting allowed for patellar mobility in a sagittal plane: linear bearings allowed anterior–posterior and proximal–distal translations and a rotary bearing on the loading axis allowed flexion-extension rotation. Thus, the patella could move freely in 5 degrees of freedom while it was moved medially or laterally by the crosshead motion.

The components of the quadriceps were each loaded with hanging weights using cables and pulleys. A total load of 175 N was applied to the muscle groups.10 This was done according to the directions and physiological cross-sectional areas (PCSAs) of the muscles14 relative to the femoral axis: VLL 14° lateral and 0° anterior; VLO 35° lateral and 33° posterior; VML 15° medial and 0° anterior; VMO 47° medial and 44° posterior; and RF † VI 0° lateral and 0° anterior. The quadriceps tension distribution was: RF † VI 35%, VLL 33%, VLO 9%, VML 14%, and VMO 9%. The direction of pull of the ITB was 0° lateral and 6° posterior.7

The knee was tested at 0, 20, 30, 60, and 90° of tibiofemoral flexion. It was flexed against the muscle tension and at the chosen test angle a vertical rod was placed anterior to the tibial rod to block knee extension. The interface was greased so the tibia was free to rotate and translate during testing. At each test angle, the ball joint at the center of the patella was displaced cyclically 10 mm laterally and medially at 100 mm/min from its stable neutral position. The fourth load versus displacement curve was recorded. The 5 degrees of freedom within the displacing apparatus allowed the patella to translate and rotate in response to the loads acting on it from the joint surface and soft tissues attached to it. Although potentially of interest, these secondary coupled motions were not measured.

The medial stability was the restraining force recorded by the load cell when the patella was displaced medially by 10 mm and similarly, lateral stability was the restraining force acting when the patella had been displaced 10 mm laterally from its stable neutral position, as defined in previous studies.10,11 This displacement-limited test protocol was used because of prior experience, which showed that ±10 mm patellar medial–lateral displacements did not cause irreversible changes in the surrounding tissues. We chose not to use a force-limited displacement test because we did not have evidence to support a choice of the limiting load that would not induce irreversible changes across the arc of knee flexion. The following loads were applied to the iliotibial band by hanging weights: 30 N, 60 N, and 90 N. At these loading conditions, the restraining force measurement was repeated.

The restraining force acting on the patella when it was displaced 10 mm from its stable position with no ITB tension was compared, across the range of knee flexion angles, using a one-way repeated-measures analysis of variance. If there was a significant difference overall, Bonferroni post hoc tests were used to determine the knee flexion angles between which the differences in restraining force had occurred. The restraining force acting on the patella when it was displaced 10 mm from its stable position was compared, across the range of knee flexion angles and across the range of ITB tensions, using a two-way repeated measures analysis of variance. If there was a significant difference overall, Bonferroni post hoc tests were used to determine in which ITB loading conditions and knee flexion angles this occurred. Differences were taken to be significant for \( p < 0.05 \).

**RESULTS**

With the ITB unloaded, patellar lateral restraining force was greater at 0 and 90° knee flexion than at intermediate angles, varying from 101 N at 0°, to 82 N at 20° and back to 100 N at 90° (Fig. 2, Table 1). The medial restraining force increased with knee flexion (\( p < 0.0001 \)), from 74 N at 0° to 142 N at 90° knee flexion.

With increasing tension in the ITB, the lateral restraining forces decreased and the medial restraining forces increased (Fig. 2). The medial restraining force increase was larger, in comparison to the lateral, and this increase was accentuated at higher flexion angles. There were significant differences in the medial and lateral restraining forces after the ITB was loaded. With 30 N ITB tension, lateral restraining force was decreased on average by 7 N (SD = 4) between 20 and 60° of flexion. At 60 and 90 N of ITB tension, there was a significant reduction at all joint angles. This was maximal at 60° flexion, with a reduction of 15 N (SD = 6) and 21 N (SD = 6) for 60 and 90 N, respectively. The medial restraining force increased progressively with increasing knee flexion and increasing ITB tension. At 30 N ITB tension, the increase in medial restraining force was statistically significant from 20 to 90° knee flexion. By 60 N ITB tension, the increase in medial restraining force was statistically significant from 0 to 90° knee flexion. The largest effects resulted from 90 N ITB tension, which

**Figure 1.** The experiment setup showing the knee in the muscle loading rig secured to the Instron materials testing machine. The load cell is attached to a 3 degrees of freedom mounting with its lower end connected to the patella via a snap-fit ball and socket joint (inset). The socket is made of polyethylene and is cemented into the patella; its center corresponds to the geometric center of the patella.
caused the medial restraining force to increase by 49% at 90° knee flexion (Table 1).

DISCUSSION
The results of this study supported our hypothesis. It showed that increasing tension in the ITB caused a reduction in patellar lateral restraining force and an increase in patellar medial restraining force (measures of mechanical stability). Extrapolating these results to the physiological state, the data showed that ITB relaxation reduced patellar medial stability, a phenomenon similar to the documented link between lateral retinacular release and patellar medial instability.15

This is the first quantitative study in the literature to have investigated the effect of loading the ITB on the mechanical stability of the patella; that was defined by measuring the restraining forces needed to displace the patella a fixed distance medially or laterally from its equilibrium position. The lateral retinaculum contributed 10% of the lateral restraining force at 20° knee flexion in one study16 and 1917 in another. However, most studies have concentrated on the medial retinaculum.

Table 1. The Medial and Lateral Restraining Force for the Patellofemoral Joint when the Iliotibial Band (ITB) is Unloaded (0 N) and the Change Thereof when the ITB is Loaded to 30, 60, and 90 N

<table>
<thead>
<tr>
<th>ITB Load</th>
<th>0 N</th>
<th>30 N</th>
<th>60 N</th>
<th>90 N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Restraining Force</td>
<td>Change in Restraining Force from 0 N</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Knee flexion angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0°</td>
<td>101 N (23)</td>
<td>–3 (5)**</td>
<td>–6 (3)***</td>
<td>–10 (6)***</td>
</tr>
<tr>
<td>20°</td>
<td>82 N (22)*</td>
<td>–5 (4)***</td>
<td>–10 (4)***</td>
<td>–13 (7)***</td>
</tr>
<tr>
<td>30°</td>
<td>85 N (19)b</td>
<td>–7 (4)***</td>
<td>–11 (4)***</td>
<td>–16 (7)***</td>
</tr>
<tr>
<td>60°</td>
<td>88 N (19)</td>
<td>–9 (6)***</td>
<td>–15 (6)***</td>
<td>–21 (6)***</td>
</tr>
<tr>
<td>90°</td>
<td>100 N (23)</td>
<td>–2 (7)ns</td>
<td>–7 (8)***</td>
<td>–13 (9)***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0°</td>
<td>74 N (22)</td>
<td>+4 (5)**</td>
<td>+8 (5)**</td>
<td>+12 (8)***</td>
</tr>
<tr>
<td>20°</td>
<td>89 N (14)</td>
<td>+7 (6)*</td>
<td>+14 (9)***</td>
<td>+23(11)***</td>
</tr>
<tr>
<td>30°</td>
<td>87 N (19)</td>
<td>+10 (5)***</td>
<td>+24 (7)***</td>
<td>+36(10)***</td>
</tr>
<tr>
<td>60°</td>
<td>109 N (24)c</td>
<td>+21 (5)***</td>
<td>+41 (7)***</td>
<td>+61(13)***</td>
</tr>
<tr>
<td>90°</td>
<td>142 N (21)c</td>
<td>+30(10)***</td>
<td>+54(15)***</td>
<td>+70(19)***</td>
</tr>
</tbody>
</table>

**not significant. *p < 0.01 versus 0° and 90°. **p < 0.05 versus 0° and 90°. ***p < 0.001 versus 0°. *p < 0.05. **p < 0.001. ***p < 0.0001 Bonferroni post hoc test.
The medial patellofemoral ligament has been identified as the primary passive soft tissue restraint, and it is generally accepted that it provides most restraint at 0–20° of knee flexion.10,16–20

The general pattern of the restraining force versus knee flexion angle in the knee with the ITB unloaded (Fig. 2) was similar to previous reports.10,11,17,20 The medial and lateral restraining forces of the patellofemoral joint were comparable at 0° flexion. Then, the medial restraint progressively increased as the knee was flexed to 90°. The lateral restraint, on the other hand, dropped at 20° flexion, then rose thereafter but to a lesser degree than the medial restraint. It is generally thought that the trochlear groove deepens in flexion and that the lateral facet is steeper and more prominent than the medial,21 so the contrasting data in this study suggested an important role for the soft tissues in restraining patellar medial–lateral translations.

This study found that increasing ITB load increased the medial stability of the patellofemoral joint, especially with increasing knee flexion. The iliotibial band is connected to the lateral patella via the retinaculum so an increase in ITB load increased the posterior–lateral pull on the patella. This made it more difficult to displace the patella medially. In this regard, as the knee flexes to 90°, the ITB falls posteriorly, tightening the lateral retinaculum further. At this angle of knee flexion the proximally directed line of pull of the ITB acted more directly on the patella, rather than passing alongside it. In addition, the pull on the tibia in flexion rotates it externally and increases the Q angle that again increases the lateral force on the patella.

The findings reported in this study must be interpreted in the light of the limitations of the method used. This was a study on elderly knees in vitro. Although care was taken to tense the individual heads of the quadriiceps in a physiological manner, the relative contributions vary from knee to knee. The overall tension in the quadriceps was limited by the desire to avoid tearing the muscle fibres in these elderly specimens. Although appropriate physiological loading of the ITB is unknown, the tension that was used was in line with published evidence. These limitations, however, are unlikely to affect the overall conclusions of this work. Finally, we note that further information might be available relating to the behavior of the retinacula, if the patellar kinematics were also measured during stability tests.

The force in the ITB in vivo is unknown, and publications vary with regard to the forces used in cadaveric experiments.9 The rationale for selecting 30 N for the iliotibial force was based on past work.7,8 At least 30 N is required experimentally to produce a positive pivot shift in an anterior cruciate ligament (ACL) deficient knee.7 Because pivoting commonly occurs in patients with an ACL deficient knee, at least 30 N should be physiological. Kwak and colleagues8 used 89 N based on physiological cross sectional area of the muscle, with a quadriiceps tension of 534 N, a similar ratio to this study.

The ITB tension had a significant effect on the mechanical stability of the patellofemoral joint, quantified in terms of the restraining force acting at a fixed displacement medial or lateral from the equilibrium position. This can help explain the clinical observation of patellar problems related to ITB tightness. Also of importance, biomechanical experiments should load the ITB when studying patellar stability and kinematics.

ACKNOWLEDGMENTS
A.M.M. was supported by the University of Malaya Medical Centre, Kuala Lumpur, and the Arthritis Research Campaign (ARC). The ARC donated the Instron machine, and the cost of materials and knee specimens was funded by a grant from the ARC. We also thank Philip Wilson for his technical support.

REFERENCES


