Contribution of the Pubofemoral Ligament to Hip Stability: A Biomechanical Study

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Purpose: To determine the isolated function of the pubofemoral ligament of the hip capsule and its contribution to hip stability in external/internal rotational motion during flexion greater than 30° and abduction. **Methods:** Thirteen hips from 7 fresh-frozen pelvis-to-toe cadavers were skeletonized from the lumbar spine to the distal femur with the capsular ligaments intact. Computed tomographic imaging was performed to ensure no occult pathological state existed, and assess bony anatomy. Specimens were placed on a surgical table in supine position with lower extremities resting on a custom-designed polyvinylchloride frame. Hip internal and external rotation was measured with the hip placed into a combination of the following motions: 30°, 60°, 110° hip flexion and 0°, 20°, 40° abduction. Testing positions were randomized. The pubofemoral ligament was released and measurements were repeated, followed by releasing the ligamentum teres. **Results:** Analysis of the 2,106 measurements recorded demonstrates the pubofemoral ligament as a main controller of hip internal rotation during hip flexion beyond 30° and abduction. Hip internal rotation was increased up to 438.9% ($P < .001$) when the pubofemoral ligament was released and 412.9% ($P < .001$) when both the pubofemoral and teres ligament were released, compared with the native state. **Conclusions:** The hypothesis of the pubofemoral ligament as one of the contributing factors of anterior inferior hip stability by controlling external rotation of the hip in flexion beyond 30° and abduction was disproved. The pubofemoral ligament maintains a key function in limiting internal rotation in the position of increasing hip flexion beyond 30° and abduction. This cadaveric study concludes previous attempts at understanding the anatomical and biomechanical function of the capsular ligaments and their role in hip stability. **Clinical Relevance:** The present study contributes to the understanding of hip stability and biomechanical function of the pubofemoral ligament.

To date, the proper biomechanical contribution of the pubofemoral ligament to hip stability is not understood. The anatomic structure and origin of the capsular ligaments, both visually and arthroscopically, have been studied.[1-7] The stabilizing functions of the iliofemoral and ischiofemoral ligaments have been well documented.[1,5-9] Subsequent studies have reported on the function of the ligamentum teres in limiting hip rotation.[10,11] A complete understanding of the isolated function of the pubofemoral ligament contributing to hip instability is required.

The capsule enclosing the hip joint significantly contributes to stability during dynamic and static motions. There are 4 ligaments that comprise the hip capsule: medial and lateral arms of the iliofemoral, ischiofemoral, and pubofemoral ligament. The fibers of the 4 primary ligaments are longitudinally oriented and insert anteriorly and posteriorly along the acetabulum. The fibers continue distally around the femoral neck and are inserted along the intertrochanteric line, and they partially cover the posterior portion of the femoral neck.[1,6] A shallow layer of circularly oriented fibers known as the zona orbicularis exists within the capsule. These fibrous structures work in conjunction with the labrum and osseous structures to create a stable hip joint during motion.[9]

The pubofemoral ligament runs from 3:30 to 5:30 using an acetabular clock-face reference system.[4] In comparison to the iliofemoral and ischiofemoral ligaments, the pubofemoral ligament has the smallest

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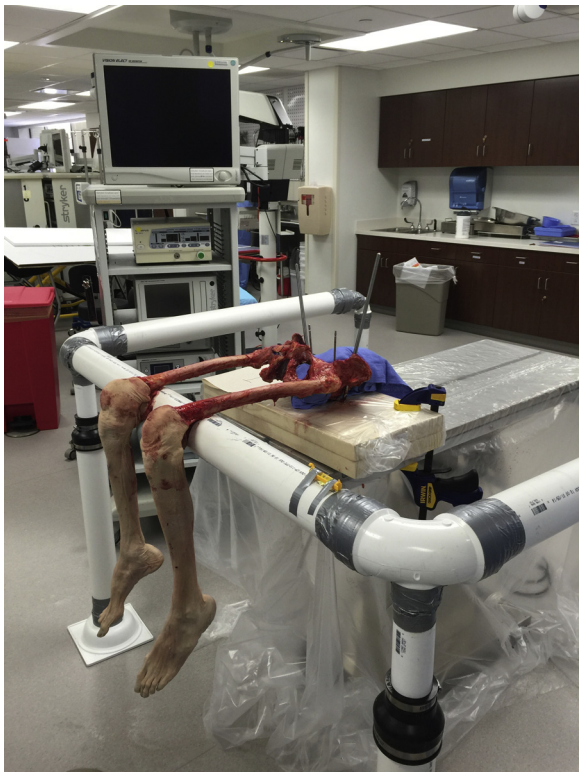

Fig 1. Cadaver testing setup. The cadaveric specimens placed in the supine position with the pubic symphysis on the same horizontal plane as both anterior superior iliac spines and secured with 4 holding pins placed through the ilium.

origin on the acetabulum.[2] From the origin, the pubofemoral ligament is described to wrap around the femoral neck inferiorly, as a sling.[1] Distally the pubofemoral ligament blends with the medial iliofemoral ligament anteriorly, and the ischiofemoral ligament posteriorly.[3] Previous cadaveric studies demonstrated the role of the pubofemoral ligament as a controller of external rotation in hip flexion below 30° and extension.[1]

The purpose of this manuscript is to determine the isolated function of the pubofemoral ligament of the hip capsule and its contribution to hip stability in external/internal rotational motion during flexion greater than 30° and abduction. The hypothesis states that the pubofemoral ligament is one of the contributing factors of anterior inferior hip stability by controlling external rotation of the hip in flexion beyond 30° and abduction.

Methods

Specimens

Thirteen hips from 7 fresh-frozen pelvis-to-toe cadaveric specimens were skeletonized from the lumbar spine to the distal femur, preserving the hip capsular ligaments. The specimens were thawed to room temperature prior to experiments. Physical examinations of the hip, pelvis, and spine were performed by a hip preservation fellowship-trained orthopaedic surgeon (J.G.H.) with 2 years in practice, to ensure no occult pathologic state existed. Computed tomographic (CT) imaging was performed prior to experiments for anatomic measurements. Exclusion criteria include deformities that restrict motion, including signs of arthrosis, osseous pathology, or surgical intervention. Hips were then examined arthroscopically by the same orthopaedic surgeon to assess the integrity of the ligamentum teres.

CT Imaging Evaluation

Axial and sagittal CT scan sequences (General Electric Medical Systems LightSpeed RT16 XTRA; GE Healthcare, Waukesha, WI) of the pelvis and lower limbs were performed on all cadavers prior to testing to ensure no pathologic state exists and to assess bone anatomy. The feet were fixed in a neutral position with 0° abduction during the imaging assessment.

Images were analyzed in GE MediaViewer (GE Healthcare) to determine the McKibbins index and anatomic measures, including femoral neck version, acetabular version measured at the 3-o'clock position, femoral neck shaft angle, knee varus/valgus angle, and

Fig 2. Pubofemoral ligament release sequence. The pubofemoral ligament release sequence is identified by the blue line. Specifically, the pubofemoral ligament was released at the inferior border, through the zona orbicularis, and adjacent to the labrum to the border of the iliofemoral ligament. Specimen shown is right hip.