Introduction: The hip joint has long been considered a ball-in-socket joint with inherent bony stability. However, there have been few studies evaluating normal hip kinematics. Particularly, there is a lack of evidence as to whether the joint is truly a ball in a socket with a constant center of rotation. Further, the contribution of the soft tissues, including the labrum, to joint stability has not been extensively studied.

Capsular laxity or injury has been proposed as a mechanism of injury to the acetabulum. If the labrum and soft tissues are important contributors to joint stability, laxity may lead to labral tears, a condition which may lead to further translations of the femoral head (FH) within the acetabulum. This increased motion of the FH within the acetabulum may result in degeneration of the joint by the application of shear forces to articular cartilage resulting in premature hip osteoarthritis.

The objectives of this study were to (1) assess hip kinematics with all the soft tissues intact using a novel computer assisted navigation system, (2) assess the relative contributions of the soft tissues to hip stability, and (3) assess the relative contribution of periarticular soft tissues to hip motion.

Materials and methods: We used 4 normal cadaveric hemicorpse specimens, while pelvis to distal femur (femoral condyles), for a total of 8 hip specimen acquisitions. The specimens were from 3 males and 1 female (avg age = 72 yrs). A software for intra-operative kinematic assessment (KLEE, Orthokey, Delaware), based on an optoelectronic localizer, was used to acquire the data regarding the relative motion between femur and pelvis. The anatomical reference system was identified through the palpation of anatomical landmarks. The surgeon involved in the study repeated the motions 3 times. There were 12 passive kinematic tests in 3 different limb conditions (‘intact’, ‘no-skin-no-muscle’, ‘labral tear’) to explore the whole kinematic range specific of the limb at maximum load. The no-skin, no muscle condition allowed for the labrum and capsular-ligamentous complex to remain intact, while in the last scenario involved cutting of the joint capsule and ligaments. The FH centroid and ranges of motion were evaluated in 36 positions. Each hip specimen was passively taken through the following motions:

<table>
<thead>
<tr>
<th>Flexion – Extension</th>
<th>Abduction-Adduction</th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Extension (FE)</td>
<td>Abd, N, &amp; Add</td>
<td>IR, NR, ER</td>
</tr>
<tr>
<td>Zero Degrees Extension (0E)</td>
<td>Abd, N, &amp; Add</td>
<td>IR, NR, ER</td>
</tr>
<tr>
<td>90 Degrees Flexion (90F)</td>
<td>Abd, N, &amp; Add</td>
<td>IR, NR, ER</td>
</tr>
<tr>
<td>Full Flexion (FF)</td>
<td>Abd, N, &amp; Add</td>
<td>IR, NR, ER</td>
</tr>
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We analysed the differences in flexion / extension (F/E), abduction / adduction (Abd/ADD), internal / external rotation (IR/ER) ranges introduced by the 3 different limb conditions, using the reference point as 0E, neutral flexion-extension and NR. Statistics included Wilcoxon’s Signed Ranks Test.

Results: The kinematic analysis revealed the following passive range of motion: (1) the F/E range was 115.7 ± 2.4° (12.9 ± 1.0° in ext / 101.7 ± 3.0° in flex) in ‘intact’ limb, 139.2 ± 10.8° (14.7 ± 2.7° in ext / 120.7 ± 8.6° in flex) in ‘no-skin-no-muscle’ condition, and 174.3 ± 34.1° (25.3 ± 0.5° in ext / 147.4 ± 35.4° in flex) in ‘capsule cut’ condition; all the ranges were statistically different (p < 0.05); (2) the Abd/ADD range was 44.5 ± 13.7° (35.4 ± 1.5° in abd / 101 ± 13.4° in add) in ‘intact’ limb, 59.2 ± 18° (38.5 ± 3.2° in abd / 21.7 ± 0.7° in add) in ‘no-skin-no-muscle’ condition, and 82.0 ± 6.5° (57.4 ± 2.5° in abd / 25.6 ± 6.8° in add) in ‘capsule cut’ condition; all the ranges were statistically different (p < 0.05); (3) the IR/ER range was 52.2 ± 10.5° (32.0 ± 11.9° in IR / 25.1 ± 10.5° in ER) in ‘intact’ limb, 59.2 ± 1.8° (36.1 ± 14.1° in IR / 26.5 ± 1.2° in ER) in ‘no-skin-no-muscle’ condition, and 116.4 ± 54.4° (58.2 ± 16.1° in IR / 55.6 ± 36.3° in ER) in the ‘capsule cut’ condition; all the ranges were statistically different (p < 0.05), except the ranges of intact condition and no-skin-no-muscles (p = 0.37).

The centroids of the FH moved in all situations with the soft tissues intact at all hip positions, as compared to the resting position of 0E, neutral Abd/ADD and NR. When internally rotating, the centroid moved medially in all situations, while the FH centroid moved laterally in all positions when in ER, except for hip flexion (90F or FF) in abduction, where there was slight medial movement (0.2mm), and nearly no motion in FF with neutral F/E with either rotation. In 0E and FE, the centroid moved medial-lateral most, moving medially 1mm while the extremity was in IR, while in ER, the centroid moved 0.9mm laterally. With the soft tissues intact, the centroid moved anteriorly in FF and 90F an average of 1.6mm, but not at 0E and FE, regardless of IR/ER or Abd/ADD. In flexion (90F and FF), there was also 1.4mm of distal translation in both ER and in IR. However in 0E and FE, there was negligible distal translation when the soft tissues were intact.

The center of the FH moved more when the skin and muscles were removed as compared to intact state anteriorly and distally in IR, but not medial-laterally. The centroid moved medially when the extremity was IR, regardless of other positioning, however this more pronounced in flexion (90F & FF) as well as 0E in neutral abduction-adduction and adduction. The centroid also moved medially with ER when in flexion with abduction, and less so in FF with neutral abduction-adduction. Otherwise, the centroid moved laterally in other positions in ER. In 0E the centroid moved medially 1.1mm while the extremity was in IR and 0.8mm laterally in ER, while in FE the centroid moved 0.5mm medially in IR and 0.4mm laterally in ER. In 90F the centroid moved medially 1.7mm while in IR and 0.4mm laterally in ER, and lastly, the centroid moved 1.7mm medially in IR and 0.1mm in ER while in FF. Anterior translation was also increased as compared to the intact state when the skin and muscles were removed, though this occurred primarily in flexion (90F and FF). In ER, anterior translation was greater than the intact state when the skin and muscles were removed, though this occurred primarily in flexion (90F and FF). In FF, anterior translation was greater than the intact state and no-skin no-muscles condition.

Discussion: The study of the three different conditions that we analyzed highlights the critical role of the soft tissues in hip stability and kinematics. This study shows that the hip is not a true ball in socket joint. It is clear the femoral head moves within the acetabulum in the normal state, with passive joint motion mediolaterally, anteriorly and distally. Further, we have shown that the soft tissues do provide stability – both in limiting hip range of motion as well as limiting translation of the femoral head within the acetabulum. This finding has important clinical implications in the understanding of the contribution of the acetabular labrum, periarticular muscles, joint capsule and ligaments to hip joint kinematics.