Hip Laxity Measurements for Intact, THA, and Muscle-Resected Hips in Lower-Limb Cadaveric Specimens

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INTRODUCTION: Hip joint stability after total hip arthroplasty (THA) is affected by surgical and patient factors including implant positioning and the surrounding hip capsule and musculature. Previous studies have investigated interactions between implant positioning and tension in the hip capsule due to its role in preventing dislocation [1-3]. Musculature surrounding the hip, including the gluteus medius and external rotators, also play a role in hip stability. Studies have shown that gluteus medius and hip abductor deficiencies are associated with increased risk of revision after THA [4]. However, the passive contributions of hip musculature to hip joint stability have not been quantified. Measuring the passive contributions of these muscles has implications for surgical approach and arthrotomy repair and could also be used for calibration of computational tools that predict dislocation risk. The objective of this study was to experimentally measure torque-rotation behavior of the hip in cadaveric specimens under native, THA, and muscle-resected conditions to investigate the passive muscle contributions to joint stability.

METHODS: Five hips from pelvis-to-toe specimens were tested (2M, 3F; Age 62.8±6.3 yrs, BMI 28±4) that had intact extremities without prior surgery or evidence of osteoporosis or arthritis. Specimens were thawed for 48 hours before testing, then positioned supine on a Hana table (Mizuho OSI) with custom fixturing to constrain the pelvis at prescribed hip flexion angles. A 6 DoF piezoelectric load cell was integrated with the leg spar to acquire force and torque data applied through the leg (9306A, Kistler) (Fig 1). Optical tracking arrays were rigidly attached to the pelvis, femur, tibia, and load cell to track kinematics (Optotrak Certus, Northern Digital Inc.) (Fig 1). Kinematics and loading were synchronized and sampled at a rate of 100 Hz. Internal and external (IE) laxity tests were performed to a 5 Nm torque limit at neutral hip ab/adduction for 0, 30, 60, 90° flexion as well as hyperextension for three conditions: 1) intact native hip 2) after anterolateral approach THA, and 3) after resection of the gluteus medius and external rotators from their insertions on the greater trochanter. All hips were implanted with CORAIL® femoral stems and PINNACLE® acetabular cups (DePuy Synthes Inc.) by the same surgeon. After testing, fiducial markers were placed in the pelvis and femurs and digitized relative to the motion capture system. The bones were then denuded and optically scanned for registration to the kinematic data. Anatomic coordinate systems were established for the pelvis, femurs, and tibiae using CT-based segmentations to calculate hip kinematics [5]. Torque values were discretized at ½ Nm increments and IE rotation angles were compared across hips for the intact, THA, and muscle-resected conditions at each flexion angle.

RESULTS: Hip IE laxity increased after THA and then again after muscle resection (Fig. 2). The native hip's mean internal and external rotations at 5 Nm were 29.7±3.8° and 20.6±2.3°, respectively, across all flexion angles. After THA, the mean internal laxity increased by 29% or 8.5±1.9° while the external laxity increased by 22% or 4.6±4.5°. Hip external rotation at 90° flexion was the only hip laxity that did not increase after THA. A larger increase in laxity was observed after muscle-resection, with hip rotations increasing by 11.9±2.6° and 11.4±5.5° for internal and external laxity, respectively. Hip laxities were consistently smaller at hyperextension and 90° hip flexion but were largest at 0° and 30° hip flexion.

DISCUSSION: These results demonstrate increased hip laxity after gluteus medius and external rotator resection in implanted hips. The primary function of these muscles are hip abduction and external rotation, so the increased internal laxity after muscle-resection was expected. However, a similar increase in external hip laxity was also observed indicating the muscles contributed to stability in both directions. THA increased hip laxity across most flexion angles, likely due to the capsule arthrotomy and smaller diameter implanted femoral head. Future work will use this experimental data to develop and calibrate passive muscle structures for modeling dislocation of the implanted hip.

SIGNIFICANCE/CLINICAL RELEVANCE: This study demonstrated that the passive constraint provided by the gluteus medius and the external rotators play a significant role in stabilizing the hip and must be considered when quantifying the risk of hip impingement and dislocation.

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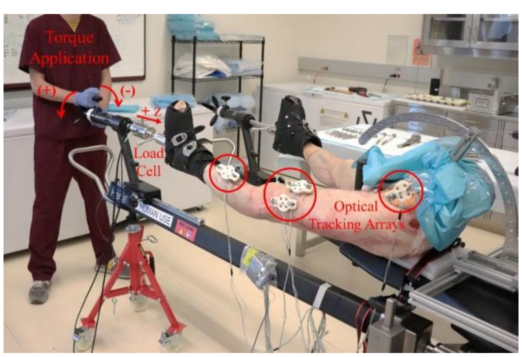

Fig 1. Specimen secured on the Hana table with optical tracking arrays attached to the pelvis, femurs, tibias, and load cell. Torque is applied manually at the distal end of the leg.

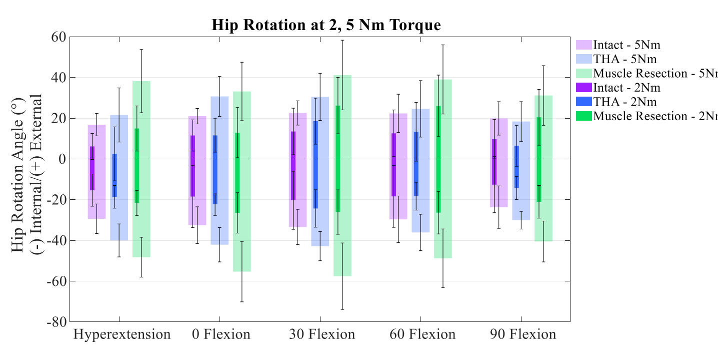

Fig 2. Average (±1SD) hip IE rotation angles at 2 and 5 Nm torque levels for all hips.