Introduction: Glenohumeral abduction with external humeral rotation is a characteristic position for the development of glenohumeral instability. Limitations in external rotation are also often seen in patients. Although many studies have investigated the glenohumeral ligaments as restraints to glenohumeral translation, few studies have investigated the ligamentous restraints to external rotation, and no studies have investigated the effects of the rotator cuff muscles and biceps on limiting external rotation. The purpose of this study was to determine the effects of ligamentous restraints to external rotation in the neutral and abducted positions in a displacement-controlled model, which permits separation of effects of forces and calculation of individual force contributions. Our hypotheses included the following: 1.) The inferior glenohumeral ligament would act as a significant restraint to external rotation, particularly in the abducted shoulder. 2.) The subscapularis would act as a significant restraint to external rotation. 3.) The external rotators would significantly decrease the force required to externally rotate the shoulder.

Methods: Fifteen unpaired shoulders (8 male, 7 female; average age 56 ± 19 years) were dissected leaving the glenohumeral and coracohumeral ligaments, rotator cuff and biceps tendons, scapula, and humerus intact. The scapula was mounted in a custom fixture which allowed adjustments in glenohumeral abduction and application of loads to the subscapularis, supraspinatus, combined teres minor and infraspinatus using weights and pulleys. The biceps was loaded with a pneumatic cylinder. The humerus was mounted to a sliding universal joint in series with a servohydraulic torsion testing machine. Specimens were preconditioned for each test. Standard loads of 22N were applied to each rotator cuff and biceps tendon. A reference position was established as that rotational position obtained with 113 Nm of torque (a value which pilot studies showed reproducibly locates the toe-region of the torque-rotation curve). Testing for each specimen was carried out at 1°/second over the range of -70° to +20° of external rotation from the reference position. Individual muscle effects were tested by varying the force in each test tendon through a range of 0%, 50%, 100% and 200% of the standard load. In each specimen, a single randomly chosen ligament was cut – coracohumeral (CHL), combined superior and middle glenohumeral (S+M), entire inferior glenohumeral (IGHL), anterior band of IGHL (IGHL – A), or the posterior capsular (PC). Every specimen was tested in both neutral and abduction, examining the effect of different forces in each cuff muscle and the biceps tendon, both before and after ligament cutting. Analysis of the muscle effects was carried out over the first 70° of motion. Torque data for the capsule was analyzed through the entire range of motion. However, only peak torque is reported for this abstract. Specifically, peak torque at ±20° will be reported to assess the effects of sectioning the ligaments. A residual maximum likelihood-based repeated measures model (mixed effect model) was used to statistically analyze muscle effects. Ligament effects were analyzed using ANOVA with Tukey post hoc correction for multiple comparisons.

Results: The use of a displacement-controlled model (as opposed to a torque-controlled model) allows for the separation of the contribution of each ligament or tendon to the rotational stability of the joint. In the neutral position, the IGHL and CHL had significantly greater effects at limiting external rotation than the PC (Figure 1). Force on the subscapularis acted as a restraint to external rotation throughout the shoulder’s entire range of motion. The external rotators decreased the torque required to passively externally rotate the shoulder only during the first half of its range of motion (35°–80°). The supraspinatus acted as a weak external rotator during the shoulder’s mid-range (65°–110°). Force on the long head of the biceps decreased the torque required for external rotation during the first 30° of external rotation (35°–65°). In the abducted shoulder, the IGHL provided the greatest restraint to external rotation and had a significantly greater effect than the CHL, S+M, and PC (P < .02). The subscapularis acted as a restraint to external rotation throughout the entire range. The external rotators reduced the torque required to passively externally rotate the shoulder during the range of 35°–95°. Loads applied to the long head of the biceps increased the torque required for external rotation during the late phases of external rotation (95°–125°). The supraspinatus had no significant effect on the forces required to rotate the abducted shoulder.

Conclusions: The IGHL is by far the most important static restraint to external rotation in the abducted shoulder. These results suggest that in the abducted position, excessive external rotation alone may be sufficient to cause injury to the IGHL, without the necessity for glenohumeral dislocation or subluxation. The internal rotator (subscapularis) and the external rotators behave predictably in stabilizing against or destabilizing toward external rotation, respectively. The supraspinatus is surprisingly inefficient at affecting rotation, considering its very strong effect in stabilization against glenohumeral translation, shown in prior experiments. In the neutral position the biceps acted as a weak external rotator in the early range of rotation. In abduction, the changing line of action of the long head of the biceps, as the bicipital groove moves with humeral rotation, explains its role as a restraint to external rotation in the later ranges.

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