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ORIGINAL ARTICLE

Mapping glenohumeral laxity: effect of capsule tension and abduction in cadaveric shoulders

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Background: Shoulder capsular plication aims to restore the passive stabilization of the glenohumeral capsule; however, high reported recurrence rates warrant concern. Improving our understanding of the clinical laxity assessment across 2 dimensions, capsular integrity and shoulder position, can help toward the standardization of clinical tools. Our objectives were to test and describe glenohumeral laxity across 5 capsular tension levels and 4 humeral position levels and describe tension-position interplay.

Methods: We tested 14 dissected cadavers for glenohumeral laxity in 5 directions: anterior, posterior, and inferior translation, and internal and external axial rotation. Laxity was recorded across capsule tension (baseline, stretched, 5 mm, 10 mm, and 15 mm of plication) and position (0°, 20°, 40°, 60° of scapular abduction). Repeated-measures analysis of variance with post hoc contrasts tested the effect of tension, position, and composite tension × position on laxity.

Results: Capsule tension, position, and composite interplay had a statistically significant, although unequal, effect on laxity in each direction. Laxity was consistently overconstrained in 15-mm plication and was overall greatest in 20° and lowest in 60°. Restoration occurred most in 10 mm, but this depended on the position. The composite effect was significant for external and internal rotation and inferior laxity, but laxity at the middle range (20° or 40°) was different than at the end range (0° or 60°) for all directions.

Conclusions: On average, laxity was restored to baseline tension after 10-mm plication, but this determination varied depending on shoulder position. Middle-range laxity behaved differently than end-range laxity across plication tensions. This information is useful in understanding the unstable shoulder as well as for standardizing clinical laxity assessment.

Level of evidence: Basic Science Study; Biomechanics

Keywords: Multidirectional instability; plication; clinical laxity test; glenohumeral capsule; translational laxity; rotational laxity; restoration; differential engagement

The glenohumeral joint is the primary articulation in the shoulder. A properly controlled and stable joint allows for normal function required in daily life[4] through balanced forces from active and passive structures surrounding the shoulder.[28] However, an inherent lack of bony restraint puts the

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glenohumeral joint at risk for aberrant translation, and the passive tissues play a key role in constraining excessive motion. The basic function of the glenohumeral capsule is to passively limit motion in rotation and translation near end-range positions.[1,3] Capsular tightening limits shoulder range of motion (ROM) and protects against hyper-rotation, subluxation, and other injury. However, the extent of the native capsule's restraint on ROM depends on joint position. The capsule's role during functional activities is crucial as a passive stabilizer at the end ROM when active agonist-antagonist stabilization is not effective but does not typically contribute to stability in mid-ROM tasks.[3,23] Individuals whose activity chronically challenges the extremes of available shoulder ROM, and thus the check-reign capabilities of the capsule, put demanding strain on these tissues. Hyperlaxity threatens normal stabilization and control of the shoulder, sometimes leading to discomfort and pain. Competitive young overhead athletes may acquire hyperlaxity over time or have congenital factors that increase the risk of developing shoulder pathology.

A common yet difficult shoulder pathology to manage is excessive symptomatic laxity in more than 1 direction, generally labeled multidirectional instability (MDI). It was first described by surgeons Neer and Foster as instability in multiple directions.[13] The clinical signs of a nontraumatic unstable shoulder can be very subtle, and the literature suggests that no one clinical laxity test has good diagnostic value.[9,24] Clinical laxity can be marked when dislocation occurs or more subtle with mild pain as the chief complaint, secondary to muscles one overuses in an attempt to control the joint. When conservative nonsurgical treatment is ineffective, surgical treatment may be indicated, commonly a capsular plication or other capsulorrhaphy procedure. Arthroscopic plication attempts to restore passive capsular stabilizing properties, but with a prognosis that is debated.[7,10,15]

Capsular plication is a common surgical intervention for MDI, and arthroscopy has been increasingly used to treat various degrees of this pathology. But, we have limited understanding how surgical alteration of capsular tissue affects the loading environment of the glenohumeral joint. Also, how surgery can be optimized intraoperatively to appropriately restore the tension properties to an intact condition remains unknown. Current knowledge relates a narrow range of clinical shoulder tests and objective biomechanical measurements, which limits our understanding of plication efficacy intraoperatively.

Therefore, the purpose of this study was to investigate and describe the interplay of capsule tension and shoulder position on passive glenohumeral capsular laxity. The research objectives were to report capsular laxity at different levels of capsule tension (baseline, stretched, and 5-mm, 10-mm, and 15-mm plication) and report capsule tension behavior across different glenohumeral positions (0°, 20°, 40°, and 60° scapular abduction). We hypothesized that laxity would differ significantly with the level of capsule tension, the level of shoulder position, and both compositely. We also hypothesized that laxity in plicated (5 mm, 10 mm, 15 mm) tension levels would be significantly different between middle-range positions (20° or 40°) and end-range positions (0° or 60°).

Materials and methods

This was a cross-sectional experimental study of shoulder laxity in dissected cadaveric shoulders.

Cadaver preparation

We procured 14 fresh-frozen shoulder (scapula and humerus) models from an anatomic donation organization (Anatomy Gifts Registry; Hanover, MD, USA). The deceased donors (9 men and 5 women) were an average age of 56 ± 11 (range, 33 to 66) years. While frozen, all specimens were scanned with computed tomography and evaluated for any signs of osteoarthritis. Each specimen was kept at –35°F and then thawed for 24 hours to room temperature before experimental testing. Then, all specimens were tested for ROM by the study orthopaedic surgeon.

All periarticular tissues were dissected by a single experienced orthopedic surgeon. Care was taken not to violate the capsule by leaving the rotator cuff tendinous insertion intact. All capsules were vented at the rotator interval and then sutured using 2-0 Vicryl (Ethicon Inc., Bridgewater, NJ, USA). Retroreflective motion tracking marker clusters were rigidly attached to the humerus and scapula. Humerus and scapula bony landmarks were manually identified and registered with a markered wand. A circumduction trial was used to calculate the effective glenohumeral joint center of rotation.

The bones were cut and rigidly set in aluminum potting fixtures: the humerus was resected midshaft, and the proximal aspect was set in a cylindrical frame; the scapular inferior angle and superior border were resected, and the scapula was set in a square frame. Plaster of paris was poured into each potting frame around the bone and allowed to harden. The humeral and scapular fixtures were attached to a glenohumeral laxity testing device with multiple degrees of freedom, designed to test glenohumeral translation and axial rotation in multiple positions (Fig. 1). Cluster marker trajectories were recorded with a calibrated motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA) accurate to ±0.2 mm and ±0.3°. An attached multiaxis load cell (MC3-6-1000; AMTI, Watertown, MA, USA) measured applied torque.

Capsule laxity testing

Each shoulder underwent glenohumeral translational and rotational laxity testing in 4 fixed levels of scaption (abduction in the scapular plane), referred to as "position": 0°, 20°, 40°, and 60°. Accuracy was confirmed with real-time 3-dimensional (3D) kinematic feedback. For all tests, a constant 22-N force was applied to the humerus and aligned to compress into the glenoid face.

Translational tests

Translational laxity tests were done in neutral fixed flexion and axial rotation; a 44-N load was applied cyclically 5 times along anterior, posterior, and inferior directions, selected randomly. The load was applied manually to the scapula potting frame with a calibrated spring scale. Each load cycle started with the humeral head centered