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BASIC SCIENCE

# The role of negative intraarticular pressure and the long head of biceps tendon on passive stability of the glenohumeral joint

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**Background:** The purpose of this study was to determine the effect of intraarticular pressure and the long head of biceps (LHB) tendon on passive translations of the glenohumeral (GH) joint. Tenotomy or tenodesis of the LHB are common procedures but the consequences on shoulder stability are unclear.
**Methods:** A novel shoulder laxity testing rig permitting six degrees of freedom of motion was used to test passive translations in anterior, posterior, superior, and inferior directions in 10 cadaveric shoulders. Specimens were tested in neutral rotation with 0°, 30°, 60°, or 90° of GH abduction in the scapular plane. Translation loads up to 30N were applied, and displacements measured in an intact joint, vented joint and with the biceps tendon loaded (20N).
**Results:** The GH joint was most lax at 30° GH abduction. Venting of the joint increased translations in all positions and directions (mean ± standard error of the mean), the greatest difference was 12.5 (3.9) mm in the anterior–posterior direction and 7.5 (3.9) mm in the SI direction. Loading the LHB tendon with 20N decreased translations in all directions. The largest difference was observed in the anterior direction, 13.9 (2.8) mm ($P < .0005$) and inferior direction, 12.0 (2.8) mm ($P < .0005$).
**Conclusion:** Negative intraarticular pressure and the LHB contribute significantly to overall passive stability of the GH joint. Surgical division or transfer of the LHB tendon may impact on joint stability and function.
**Level of evidence:** Basic Science Study, Biomechanical Study.
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**Keywords:** Biceps; tenotomy; biomechanics; kinematics; stability; glenohumeral joint

Based on its incongruent bony morphology, the glenohumeral (GH) joint is inherently unstable, and a complex interaction of additional static and dynamic factors is required to maintain stability. Static factors include capsuloligamentous structures, the glenoid labrum, and negative intraarticular joint pressure. Lesions that lead to capsular disruption may result in the alteration of the relationship between negative intraarticular pressure and congruency of the joint surfaces under load. The relative contribution of intraarticular pressure to glenohumeral joint stability has been previously investigated; however, various different testing conditions and protocols makes meaningful comparisons and clinical interpretation difficult.[5,6,10]

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Dynamic stability is due primarily to the rotator cuff muscles forming an envelope around the proximal humerus that compresses the head, centers it onto the glenoid, and provides a force to resist the shear loading due to deltoid. The long head of biceps (LHB) tendon is unique in its intraarticular origin, and there is much interest in its role in both normal and pathological joints; but, the exact contribution of the tendon to glenohumeral stability is poorly defined. Previous biomechanical studies have indicated that the biceps tendon restricts passive translations in the anterior and superior axes.[7,8,17,21,23] Previous studies have used a variety of testing conditions and GH joints were often constrained in 1 or more axes, which does not simulate the clinical situation. The aim of this study was to comprehensively define whether: 1) venting the GH joint to atmospheric air had any effect on the passive translations of the GH joint in any direction; and 2) loading the biceps tendon reduced passive translations of the GH joint in any direction.

## Materials and methods

Ten fresh-frozen unpaired human shoulder girdles (5 male, 5 right; mean age 73 years; range, 31-84) were used in this study. Specimens were stored at −20°C and then defrosted at room temperature for a minimum of 12 hours before preparation and testing.

## Specimen preparation

The skin and underlying muscles were carefully removed from each cadaveric shoulder girdle using a scalpel. The LHB tendon was maintained in its sheath in the bicipital groove, but was dissected free at the distal musculotendinous junction. Care was taken to preserve the glenohumeral capsuloligamentous complex, leaving the joint intact. Specimens were kept moist by regularly spraying with normal saline.

Three bony landmarks were used to standardize the scapular position in the potting jig: the inferior angle, the most medial protuberance of the scapular border, and the supraglenoid tubercle. Excess scapular bone was trimmed and specimens were set in the aluminium casting box jig using polymethylmethacrylate bone cement, as detailed previously by Southgate et al.[16] The intramedullary canal of the proximal humerus was reamed and cross-drilled to prevent rotation of cement within the canal, and an 8 mm stainless steel rod was cemented in situ. The distal portion of the long head of biceps tendon was wrapped in cotton cloth and loops of 1 polydioxanone suture were passed through the tendon and cloth to permit loading of the tendon to simulate passive tension in the muscle.

Following polymerisation of the bone cement, specimens were removed from the potting jig and placed in the 6° of freedom Shoulder Laxity Testing System (Fig. 1). In this rig, the humerus may be oriented in any position relative to the scapula. The scapular mount itself is placed upon 3 slide-beds so that translation loads can be applied along orthogonal axes in the anterior-posterior (AP), medial-lateral (ML), and superior-inferior (SI) axes. Axial rotation of the humerus was achieved by loading a rotational pulley applied to the stainless steel rod. A separate loading fixture was added to the system to allow loading of the biceps tendon, using a cable and pulley mechanism in a physiological direction, as seen in Figure 1.[16]

## Loading protocol

The testing protocol was set to permit active translation of 1 slide at a time, with unconstrained motion also recorded in the remaining 2 directions. Compressive loads were not applied to the glenohumeral joint, because the goal of the experiment was to investigate effects based only on the capsule; it was also possible that restraint due to concavity compression would have confounded the results.

Each glenohumeral joint capsule was preconditioned at 30° GH abduction in the scapula plane, using a predetermined protocol of 10 cycles of 0.5 Nm torque in external and internal rotation. 0.5 Nm torque has previously been demonstrated as the moment required to reach the stiffer, linear region of the loading curve, without causing damage to the joint capsule; 10 repetitions were sufficient to reach a plateau in displacement at this level of torque.[16] The specimen was then re-positioned and abduction was restricted at 0° in the scapular plane without any translational load, and the instrumentation was zeroed.

5N incremental loads were applied to the pulleys up to 30N so that any subtle effects on translations may be observed with the relatively small loads. In the absence of any other applied loads that may affect joint stability (eg, loading the cuff muscles), in certain joint positions a transitional load of 30N was sufficient to dislocate the joint; therefore, loads higher than 30N were not tested. The linear displacement of each slide-bed represented translations at the joint, which were measured using linear variable differential transformers (LVDTs; Solartron Metrology, Bognor Regis, UK) for anterior, posterior, superior, and inferior directions. Loads were applied in a quasi-static manner at an approximate loading rate of 1N/s. The loading protocol was repeated with the humerus repositioned at different degrees of abduction in the scapular plane, with readings taken at 0°, 30°, 60°, and 90° GH abduction. Internal or external rotation of 1 Nm was achieved by applying 1 kg mass to the axial rotation pulley, and subsequent rotation was locked during testing (Fig. 1). The instrumentation was set to 0 at each testing position prior to loading.

The entire protocol was conducted for 3 different testing conditions in the following sequence:

1) **Intact joint capsule.** Care was taken to ensure that the capsule was not damaged during testing to preserve any negative intra-articular pressure.

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