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# Effects of Biceps Loading and Arm Rotation on the Superior Labrum in the Cadaveric Shoulder

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PRADHAN, R.L., ITOI, E., KIDO, T., HATAKEYAMA, Y., URAYAMA, M. and SATO, K. *Effects of Biceps Loading and Arm Rotation on the Superior Labrum in the Cadaveric Shoulder*. Tohoku J. Exp. Med., 2000, **190** (4), 261-269 —— Effects of loading the long head of the biceps brachii (LHB) and arm rotation on the strain of the superior labrum (anterior and posterior) in 10 fresh frozen cadaveric shoulder joints were studied. Loads were applied to the rotator cuff muscles to stabilize the humeral head. The strain of the anterior and posterior portions of the labrum with the biceps loaded with 0.42 kg, 1.36 kg, and 2.31 kg were measured using linear transducers. The humerus was rotated externally (30, 45, 60, and 90°) and internally (30, 45, and 60°) with the arm elevated 60° at glenohumeral joint (simulated 90° elevation of arm to the trunk). The strain increased with an increase in the weight of the load to LHB and with increase in rotation angle both internally and externally. Since the strain in the posterior portion was larger than that of the anterior portion it seems likely that the labrum, especially the posterior portion, is subject to large strain during biceps loading and arm rotation. ——— superior labrum; SLAP lesion; biceps loading; strain © 2000 Tohoku University Medical Press

The role of the biceps-superior labrum complex in the stability of the glenohumeral joint in various directions has been recently stated (Andrews et al. 1985; Rodosky et al. 1994; Pagnani et al. 1995). Many of the anatomical studies have revealed that the posterior portion of the superior labrum is mostly an extension of the long head of the biceps (LHB) tendon while the anterior portion receives the fibers but from the capsular ligaments (superior, middle and inferior glenohumeral ligaments) (Cooper et al. 1992; Vangsness et al. 1994; Huber and Putz 1997). With increasing use of arthroscopy, lesions occuring at the superior glenoid have been recognized more often. One such lesion is that in which the injury begins posteriorly and extends anteriorly, stopping at or above the mid-glenoid notch and termed "SLAP" (superior labrum from anterior to posterior) by

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Snyder et al. (1990). Various types of SLAP lesions have been recognized, with Type II (avulsion of the superior labrum and biceps anchor) being the most common (Snyder et al. 1990). The lesion is commonly observed as a result of fall on the outstretched arm (Snyder et al. 1990) or in athletes involved in overhead activities, especially baseball pitchers (Andrews et al. 1985). Morgan et al. (1998) noted that posterior Type II SLAP lesions were more common in overhead and throwing athletes. The humerus rotates through an arc of more than 160° through external to internal rotations during the throwing motion from cocking to follow through phases (Fleisig et al. 1995). A recent study (Itoi et al. 1999) has shown the significant changes of moment arm of the LHB during arm rotation. Thus, our first hypothesis was that the greater the biceps load, the greater the strain of the superior labrum. Our second hypothesis was that arm rotation would affect the strain of the superior labrum. As demonstrated by Andrews et al. (1985), the superior labrum lifted off the glenoid when the biceps brachii was electrically stimulated, hence, indicating that tension is directly transmitted to the superior labrum. Grauer et al. (1992) reported that the strain in the superior labrum increased with abduction and external rotation of the arm with a constant loading of 20 pounds (9.09 kg) to the biceps. In this study we determined the effect of various loadings to LHB tendon with various arm rotations on the strain of the superior labrum.

## MATERIALS AND METHODS

### *Preparation of specimens*

Thirteen specimens of fresh frozen shoulders with no radiological evidence of glenohumeral osteoarthritis were obtained from cadavers, 53 to 82 years old (mean, 64 years old). There were 8 right shoulders and 5 left shoulders from 5 male and 4 female cadavers. The specimens were received as forequarter amputations with scapula sectioned from the thorax and the humerus transected below the deltoid insertion. The specimens were thawed overnight at room temperature (24°C). All soft tissues were removed except for the rotator cuff muscles, which were elevated from the scapula and carefully dissected from the capsule distally. The humeral attachment of the supraspinatus muscle was elevated and the biceps labral complex visualized. Two of the specimens had thin anterior labrum, where the strain gauge could not be attached, and one had fragmentation of the intra-articular portion of LHB. These three specimens were excluded from the study, leaving 10 specimens in total. The tendons of the subscapularis and infraspinatus were sectioned and cables were attached to the remnant portions of tendons to apply load. An acrylic plate was attached parallel to the medial border of the scapula and fixed with screws and polymethylmethacrylate. An intramedullary rod (10 mm in diameter) was inserted into the humerus and was fixed with polymethylmethacrylate. The scapula was attached to a custom shoulder positioner (Fig. 1) that allowed the humerus to be placed in a given plane

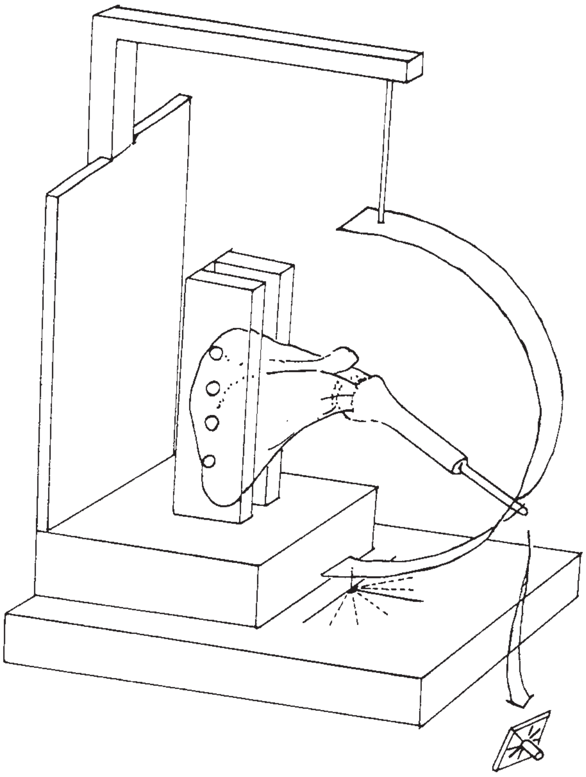

Fig. 1. Shoulder positioning device.

of elevation (such as scapular or coronal plane), a given angle of glenohumeral elevation (0° to 100°), and a given angle of humeral rotation (external and internal). A force of 2.25 kg (22 N) was applied through the cables attached to the subscapularis and infraspinatus tendons to keep the humeral head centered into the glenoid fossa during the entire test (Warner et al. 1992). The LHB was cut at the musculotendinous junction and a Bunnell stitch was attached to apply various loads. A spring was attached to the cut end of the LHB tendon with a sliding device on the intramedullary rod to apply predetermined loads. The specimen was kept moist with a spray of saline solution every 5 to 10 minutes during the test, which was performed at room temperature (24°C).

### *Measurement device*

Two three-mm stroke differential variable reluctance transducers (DVRT; MicroStrain, Burlington, VT, USA) were attached to the anterior and posterior portions of the superior labrum 5 mm from the biceps-labral complex without interfering with the free movement of the transducers (Fig. 2). We had adequate space to attach linear transducers in the precise location in each specimen and made sure that the transducers were attached on the superior aspect of labrum such that the transducers would not interfere the free movement of the humeral head. The insertion length was accurately measured twice each time by two individuals. The transducer had two stainless-steel barbed points that enabled us to firmly place it without changing the initial length. Each individual transducer had its own characteristic output and was calibrated to linear displacement

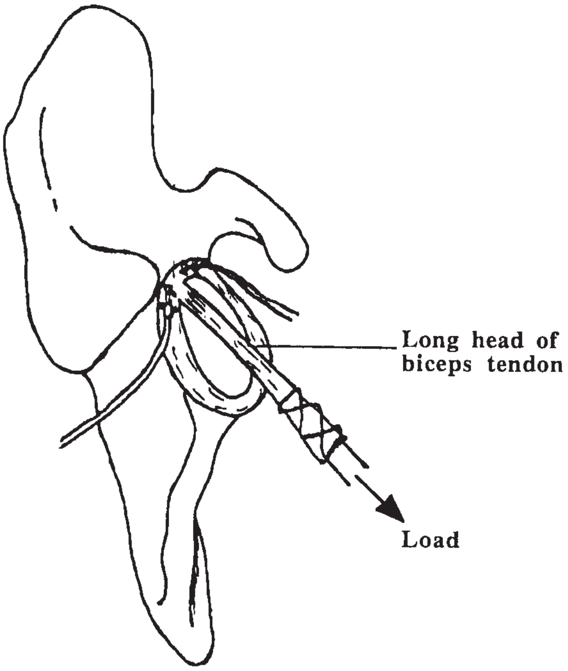

Fig. 2. Attachment of the DVRT in the anterior and posterior portions of superior labrum.

by the manufacturer. The transducers were connected to a chart-recorder (MB-STD; MicroStrain) to record the displacement data during the test, and on to a strip chart recorder (Polygraph, Nippon Kohden, Tokyo).

*Arm positioning*

Initially goniometric readings were obtained and the neutral position was determined by the following method. According to Matsen and Kirby (1982), the biceps groove points in the anterior direction when the humerus is in 10° of internal rotation. We then determined the anteroposterior direction of the humerus and inserted a screw that referred to the neutral position in reference to the scapular plane. The scapulohumeral rhythm indicates that the glenohumeral and scapulothoracic joints rotate in approximately 2 : 1 ratio, thus elevation of the arm to 90° corresponds to 60° of glenohumeral elevation (Poppen and Walker 1976). We chose this position because the arm position relative to the trunk is approximately 90° to 100° of abduction for all throwing activities and remains in this position during the entire delivery of the throw (Atwater 1980).

The force applied to the biceps corresponds to the muscle activity of the biceps as % maximum voluntary contraction (%MVC) at various stages of the throwing motion as detected by DiGiovine et al. (1992) and calculated according to the physiological cross-sectional area of the LHB (Bassett et al. 1990). The loads corresponding to the biceps activities in wind up, early cocking, and deceleration phases of pitching were thus calculated to be 0.42 kg, 1.36 kg, and 2.31 kg respectively. These three loads were chosen arbitrarily to see the difference in loading the LHB on superior labrum strain and various arm rotations. At the elevated position the arm was manually rotated from the neutral rotation to a desired position of rotation and back to the neutral before proceeding to the next rotation. The strain was measured with the arm in 30°, 45°, and 60° of internal rotation and 30°, 45°, 60°, and 90° of external rotation.

### *Collection and analysis of data*

A series of procedures were performed to determine the effect of loading to the LHB on the strain in the anterior and posterior portions of the superior labrum. We collected the strain data with the humerus rotated at 90° of elevation under the three loading conditions. With the strain (%) as a trail factor and the measurement conditions (different loads, various degrees of arm rotation, and anterior and posterior portions) as within-subjects, a 3-way within-subject analysis of variance (ANOVA) was used. There was a significant interaction between these parameters, therefore, the effects of these were separately analyzed using a one-way repeated measures ANOVA. When there was a significant effect, Scheffe's multiple comparisons procedure was used to compare between each factor. Statistical significance was set at the 5% level.

## RESULTS

The strain in both anterior and posterior portions of the superior labrum increased with the increase in the loads to the LHB tendon as well as with the increase of external and internal rotations. The difference was more prominent in

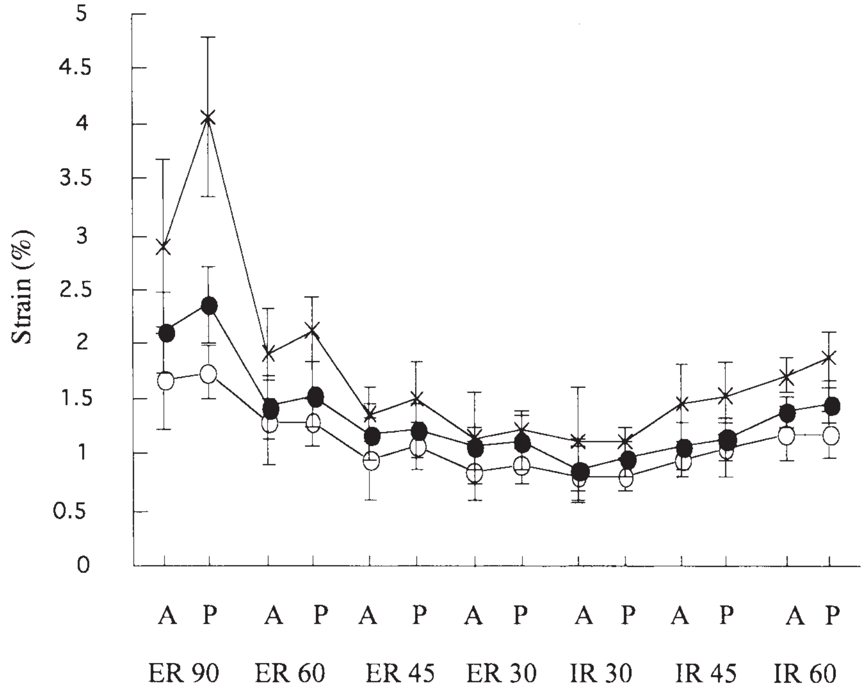

Fig. 3. Strain in the anterior and posterior superior labrum in arm rotations and various loads. Values are mean±s.d. IR, internal rotation; ER, external rotation; A, anterior; P, posterior.
—○—, load=0.42 kg; —●—, load=1.36 kg; —×—, load=2.31 kg.

the posterior portions than in the anterior portion in 90° external rotation (Fig. 3).

### *Anterior portion*

In the anterior portion, the strains under three different loads did not differ significantly at 30° of external and internal rotations. At 45° the strain was significant in external ($p<0.05$) and internal ($p<0.01$) rotations while comparing between the wind-up and deceleration loads. At 60° of external rotation the difference in strain was significant between the wind-up and deceleration loads ($p<0.01$) and between the early cocking and deceleration loads ($p<0.05$), and in internal rotation the significance was also between the wind-up and deceleration loads ($p<0.001$) and between the early cocking and deceleration loads ($p<0.01$). In 90° external rotation the increase in strain in the anterior portion between the wind-up and deceleration loads ($p<0.001$) and between the early cocking and deceleration loads ($p<0.05$) were also significant. The stain was significantly larger for 90° external rotation as compared with 45° in both early cocking (1.36 kg) and deceleration load (2.41 kg) ($p<0.01$) and 30° in both 1.36 kg and 2.41 kg load ($p<0.001$). There was only significant difference between 60° and 30° of internal rotation in 2.41 kg load ($p<0.05$).

### *Posterior portion*

In the posterior portion, the strain under the deceleration load was significantly greater than the strain under the wind-up load in all the rotations tested ($p<0.01$ for external rotation, $p<0.001$ for internal rotation). In addition, there were significant differences between the strain under the early cocking load and deceleration load in 60° and 90° of external rotation ($p<0.001$) and in 45° and 60° of internal rotation ($p<0.01$). In 90° of external rotation, there was also a significant difference between the strains under the wind-up and early cocking loads ($p<0.05$). The strain was significant for 90° external rotation compared with 45° (early cocking $p<0.05$, deceleration $p<0.01$) and 30° in all the three loads tested ($p<0.001$). There was, however, significant difference between 60° and 30° of internal rotation in early cocking and deceleration loads ($p<0.01$).

### *Comparison between the anterior and posterior portions*

There was no statistically significant difference in the strain when comparing between the anterior and posterior portions of the superior labrum in all the rotations tested except in 90° of external rotation under the deceleration load, where the strain of the posterior portion was significantly greater than in the anterior portion ($p<0.01$).

## DISCUSSION

In our study, the strain in the anterior and posterior portions of the superior labrum significantly increased as the load to the biceps increased, especially in the position of 90° of external rotation, more notably so in the posterior superior labrum. Our findings are in accordance with the study carried out by Grauer et al. (1992) but they carried out their study under the single loading condition to the biceps and speculated that the strain would be proportional to the load applied to the biceps. The anatomy of the glenoid labrum has been extensively studied by Cooper et al. (1992) and Huber and Putz (1997). The glenoid consists mostly of fibrous tissue rather than cartilage and the superior portion resembles a meniscus with loose attachment to the glenoid process. In previous studies (Habermeyer et al. 1987; Pal et al. 1991; Cooper et al. 1992; Vangsness et al. 1994) and in a recent study (Huber and Putz 1997) have reported that the posterior superior labrum mainly consists only of extended periarticular fibers of the LHB. The LHB joins with the fibers of the anterior portion only in 5-24% of the cases. Since the posterosuperior labrum consists of fibres from the LHB, the load to the biceps tendon would be transmitted more to the posterior portion than the anterior portion (Morgan et al. 1998). It is possible that the relatively low strain of the anterior superior labrum is due to the attachment of the fibers of superior, middle and maybe the inferior glenohumeral ligaments (Cooper et al. 1992) to the anterior superior labrum, which may share the load to the labrum through the biceps tendon (Pagnani et al. 1996), thus reducing the strain of the anterior superior labrum. Malicky et al. (1996) and Blasier et al. (1997) stated that in internal rotation the biceps placed a posteriorly directed force on the humerus, while in external rotation the transverse force of the long head of biceps was directed anteriorly.

In the recent kinematic moment arm study (Itoi et al. 1999), found that the moment arm changes with the change of arm rotations and were significant for the long head of the biceps than any other muscles crossing the glenohumeral joint. They found that the change in moment arm in abduction was $12.2 \pm 3.5$ mm and concluded that the abductor, flexor, and horizontal adductor functions of the long head of the biceps were significantly affected by arm rotation. This means that the biceps tendon shifts from one side of the center of rotation to another with the rotation of the arm. The change of the moment arm or the change of the anatomical location of the tendon relative to the center of the motion may explain the difference in the strain of the anterior and posterior portions. Although the transmission of strain and mechanism of the injury caused by tension from the long head of the biceps to the superior labrum is obscure, the above mentioned reasons may possibly act discretely or in conjunction with one another. Pagnani et al. (1995) reported that without destabilizing the insertion of the biceps posteriorly, there was no significant anteroposterior or superoinferior translation of the humeral head. The increase in strain seen in the posterior superior portion may be in agreement with this anatomical stabilizing factor of the biceps attachment.

A possible source of error could arise because of the difficulty in placement, and of movement of the DVRT during higher degrees of manual rotations.

We noted that the strain was greater in the posterior superior labrum in the position simulating the late cocking phase. The final burst of biceps activity during deceleration could significantly contribute to the increased strain present in the posterior superior labrum. We thus believe that with repeated greater degrees of external rotation, the posterior superior labrum is at greater risk of being avulsed from the glenoid rim in people involved in throwing and overhead activities. Dynamic studies closely simulating the in vivo muscle force and rotations may be necessary for future studies.

## Acknowledgments

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