STABILISING FUNCTION OF THE BICEPS IN STABLE
AND UNSTABLE SHOULDERS

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We studied the contributions of the long and short heads of the biceps (LHB, SHB) to anterior stability in 13 cadaver shoulders. The LHB and SHB were replaced by spring devices and translation tests at 90° abduction of the arm were performed by applying a 1.5 kg anterior force. The position of the humeral head was monitored by an electromagnetic tracking device with or without an anterior translational force; with 0 kg, 1.5 kg or 3 kg loads applied on either LHB or SHB tendons in 60°, 90° or 120° of external rotation; and with the capsule intact, vented, or damaged by a Bankart lesion.

The anterior displacement of the humeral head under 1.5 kg force was significantly decreased by both the LHB and SHB loading in all capsular conditions when the arm was in 60° or 90° of external rotation. At 120° of external rotation, anterior displacement was significantly decreased by LHB and SHB loading only when there was a Bankart lesion.

We conclude that LHB and SHB have similar functions as anterior stabilisers of the glenohumeral joint with the arm in abduction and external rotation, and that their role increases as shoulder stability decreases. Both heads of the biceps have been shown to have a stabilising function in resisting anterior head displacement, and consideration should therefore be given to strengthening the biceps during rehabilitation programmes for chronic anterior instability of the shoulder.

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In the stable shoulder the long head of the biceps (LHB) was thought to be a depressor of the humeral head (Lucas 1973; Saha 1983; Kumar, Satku and Balasubramaniam 1989). Glousman et al (1988), however, were the first to consider it as an anterior stabiliser. They reported that during throwing, the EMG activity in the biceps was greater in patients with chronic anterior instability than in those with stable shoulders and they speculated that the biceps helped to compensate for anterior instability. Itoi et al (1982) investigated the stabilising function of the LHB in cadaver shoulders with intact capsuloligamentous structures, and concluded that it contributed to anterior, posterior, and inferior stability. This contribution decreased when the shoulder was in a tight position, and they therefore speculated that it increased when the shoulder became unstable. The short head of the biceps (SHB) has EMG activities similar to those of the LHB (Basmajian and Latif 1957; Furlani 1976), and may also contribute to stability of the shoulder.

Our study was designed to determine the contributions of the LHB and the SHB to anterior stability of the glenohumeral joint when it was in various degrees of instability.

MATERIAL AND METHODS

Specimens. Thirteen previously frozen cadaver shoulders with no radiological evidence of glenohumeral osteoarthritis were obtained. A fibreglass rod 60 cm in length and 9.6 mm or 12.6 mm in diameter, depending on the size of the humerus, was cemented into the medullary canal of the proximal humerus. An anterior/posterior fibreglass pin 3.2 mm in diameter was then inserted at the level of the insertion of the latissimus dorsi to allow application of anterior translation forces. A stainless-steel pin 4.0 mm in diameter was placed parallel to this pin 2 cm above the end of the intramedullary rod and used to control rotation of the humerus during tests.

All muscles except the rotator cuff and biceps were removed. The LHB was divided at its proximal musculotendinous junction, and a spring attached between the tendon end and a sliding device on the intramedullary rod so that any given load could be applied. The SHB was also sectioned at its proximal musculotendinous junction approximately 8 cm from the coracoid origin, and the same method used to apply loads in the direction.
of muscle force. The joint capsule, ligaments, and articular integrity remained intact. The scapula was mounted on a Plexiglas fixator, which was inclined at 30°, with the distal tip of the humeral intramedullary rod placed through a small hole in a vertical Plexiglas plate to maintain the humerus in the horizontal position. The position simulated that of the glenohumeral and scapulothoracic joints when the arm was abducted to 90° (Poppen and Walker 1976). The stainless-steel pin enabled the arm to be adjusted to positions of 60°, 90° and 120° of external rotation (ER). We chose abduction and external rotation because these are the positions in which anterior dislocation or subluxation occurs in an unstable shoulder and are therefore clinically important (Stevens 1926; DePalma 1970; Matsen, Thomas and Rockwood 1990). The location of the tip of the intramedullary rod in a small fixed hole prevented any abduction/adduction or flexion/extension of the arm, while still allowing anterior/posterior or superior/inferior movement of the humeral head in the course of the experiments (Fig. 1).

Experimental apparatus. A spring is attached to the cut end of the LHB and the SHB by nylon thread fixed to the tendon by Bunnell's method. The other end of the spring is attached to the intramedullary rod, by a collar which can be slid distally to provide 1.5 kg or 3 kg loading. The scapula is inclined at 30° and the humerus is horizontal to simulate a clinical position of 90° abduction. The anterior force to the proximal humerus is applied through a pulley system.

Experiments. The experiments were performed in each of 90 permutations of the following conditions:
1) with or without 1.5 kg or 3 kg loads applied on the LHB or the SHB;
2) with the arm in 60°, 90° or 120° ER;
3) before and after applying a 1.5 kg anterior force to the proximal humerus; and
4) with the capsule intact, vented, or with the antero-inferior capsule sectioned to simulate a Bankart lesion.

Data collection. The three-dimensional kinematics of the humerus relative to the scapula were monitored by an electromagnetic tracking device, the 3Space Tracker System (Polhemus, Colchester, Vermont), which allows measurement of the three-dimensional position and the orientation of a sensor relative to a source with six degrees of freedom. The accuracy of this system has been demonstrated (An et al 1988; Nahass, Madson and Walker 1991). With the source and sensor attached to the scapula and humeral shaft, respectively, the relative location and orientation of the humerus with respect to the scapula can be monitored at all times.

After the experiments, the glenohumeral joint was disarticulated and a number of anatomical landmarks on the humerus and scapula were digitised. From these a coordinate system was established and the geometrical centre of the humeral head was calculated as previously described (Itoi et al 1992).

Statistical analysis. Statistical analysis was performed using SAS Version 6.06 (SAS Institute Inc, Cary, North Carolina). We found that there was a significant interaction between the effect of biceps loading and that of arm rotation (p < 0.0001), so that the effect of biceps loading and the effect of external rotation on anterior stability in each of the three different capsular conditions could be analysed separately using a one-way repeated measures analysis of variance. The stabilising effect of the LHB and the SHB were compared together with the effect of external rotation using a two-way repeated measures analysis of variance. If this was significant, the Student-Newman-Keuls multiple comparisons procedure was used to determine which set of data showed the significant difference. Statistical significance was set at the 5% level.

RESULTS

The position of the humeral head with the capsule intact is shown in Figure 2. In 90° and 120° of ER, loading the LHB caused an anterior shift of the humeral head (p = 0.0005, p < 0.0001 respectively), and the distance the humeral head moved after applying the 1.5 kg translation force with varying forces on the tendon is shown in Figure 3. With no LHB loading, the anterior displacement produced by 1.5 kg was the greatest at 60° ER, intermediate at 90°, and smallest at 120° (p < 0.0001). The effect of LHB loading on anterior displacement was significant at both 60° and 90° ER: the displacements were smaller with than without LHB loading at 60° ER (p < 0.0001) and at 90° ER (p = 0.0011). At 120° ER, there were no significant changes in the small amount of displacement between the three different loading conditions.

After venting the capsule, the position and displacement data showed the same trends as those observed with an intact capsule. Creation of a Bankart lesion produced the same trends (Fig. 4), but anterior displacement was significantly decreased by LHB loading at 60° ER (p < 0.0001), 90° ER (p < 0.0001), and 120° ER (p < 0.0001).

The stabilising function of the SHB was also assessed. With the capsule intact, the position of the head was more posterior at 120° ER than at the other rotations,
DISCUSSION

Our study showed clearly that tension on the LHB and the SHB significantly stabilised the humeral head for anterior translation with the arm in abduction and external rotation. This was observed at 60° and 90° ER for all three capsular conditions. At 120° of ER there was significant stabilisation only after the creation of a Bankart lesion. This is probably due to the tightening of
the capsuloligamentous structures at 120° ER, when the glenohumeral joint is close to the limit of external rotation. This makes the capsule extremely tight and stabilises the joint, causing the effects of the LHB and the SHB to be less obvious.

What is the mechanism of stabilisation? In general, there are four possibilities for dynamic stabilisation by muscles: 1) passive tension from the bulk effect of the muscle itself; 2) contraction causing relative compression of the articular surfaces; 3) joint motion that secondarily tightens the passive ligamentous constraints; and 4) the barrier effect of the contracted muscle (Morrey and An 1990).

At the glenohumeral joint, biceps tendon force can be considered in two components; one perpendicular and the other transverse to the glenoid surface. Force in the transverse direction will provide direct resistance to movement of the humeral head in the opposite direction. In addition, any compressive force normal to the glenoid surface will also induce a transverse shear force due to the slope of the articulating surface (Flatow et al 1991). This induced shear force will also provide constraint to humeral head displacements in a transverse direction (Vanderhooft et al 1982). The relative importance of the compressive constraint and the direct barrier effect depends on two factors: joint orientation, which determines the direction of the line of action of the biceps tendons, and the exact location of glenohumeral contact, which determines the slope of the articulating surface.

In our study, with the arm in 90° abduction, the tendon of LHB is superior to the humeral head in 60° ER (Fig. 5a) and becomes located and orientated more posteriorly with increase in external rotation (Figs 5b and 5c). This anatomical relationship suggests that the barrier effect may be an effective stabiliser when external rotation of the arm is less than 60° but not in the greater rotations that we tested. The tendon of SHB is always anterior to the humeral head and its barrier effect may be the main mechanism of stabilisation when the head moves anteriorly and comes into contact with the tendon. When external rotation is greater than 60° the main stabilising mechanism of both LHB and SHB would seem to be the shear force induced by compression into the glenoid socket.

The exact contribution of the LHB and the SHB to the dynamic stability of the shoulder during activities of daily living or sport depends on the level of contraction of these muscles. An EMG study by Furlani (1976) showed that both the LHB and SHB were active in forward flexion of the arm, and that both were silent in

![Fig. 5a](image1)
![Fig. 5b](image2)
![Fig. 5c](image3)

Relationship between the humeral head and the LHB in various positions of rotation, seen from above. At 60° ER (a), the LHB tendon is superior to the humeral head, and neutral in the anterior/posterior plane. At 90° and at 120° ER (b and c), the tendon is posterior to the humeral head. The SHB is anterior to the centre of the humeral head regardless of the rotational position. The arrow indicates the anterior direction, and an asterisk indicates the LHB tendon; G = glenoid; H = humeral head; S = supraspinatus tendon.
other movements except adduction, in which only the SHB was active. Bassett et al (1990) reported that the physiological cross-sectional areas of these muscles were almost the same, as were their moment arms: the maximum forces produced by each of the two heads were calculated to be almost the same. These studies indicate that both heads of the biceps are usually activated simultaneously, and both can exert almost the same force. There are no data available for the activity of these muscles during specific actions such as throwing.

Our study has shown, however, that their stabilising effect at 120° ER became significant in the presence of a Bankart lesion: stabilisation by the biceps became obvious when the shoulder was unstable. This supports the speculation by Glousman et al (1988) that the biceps can help to compensate for the instability of a damaged shoulder, even if it is less important in a stable shoulder.

Advice on the rehabilitation of patients with anterior shoulder instability has emphasised the importance of strengthening the internal and external rotators (Rockwood, Burkhed and Brna 1986; Matsen et al 1990) but little attention has been paid to the biceps. Our study has shown that the long and the short heads of the biceps are effective stabilisers of the glenohumeral joint in positions of abduction and external rotation, especially when there is anterior instability. Biceps strengthening may benefit patients with anterior instability; this should be taken into consideration during rehabilitation.

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REFERENCES


