Electromyographic activities of the biceps during arm elevation in shoulders with rotator cuff tears

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We investigated electromyographic activities of the biceps in 40 shoulders with full-thickness tears of the rotator cuff and 40 asymptomatic shoulders, with a normal rotator cuff on MRI, to determine the role of the biceps in cuff-deficient shoulders. Using surface electrodes, biceps activities were recorded during arm elevation in the scapular plane with and without a 1-kg load. The percentages of integrated electromyograms to the maximum voluntary contraction (%MVC) were obtained at 30°, 60°, 90°, and 120° of elevation. In the normal shoulders, %MVC of the biceps was always less than 10% through the arc of elevation both with and without load. Among 40 shoulders with rotator cuff tears, 14 showed increased activities of the biceps more than 10% in %MVC ($p < 0.0001$), whereas the remaining 26 shoulders had activities similar to the normal shoulders. The biceps activities in these 14 shoulders increased with load application and at higher angles of elevation. The muscle strength tended to be weaker in shoulders with increased biceps activities than in those without. Our findings suggest a potential supplemental function of the biceps in shoulders with rotator cuff tears.

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The function of the biceps brachii muscle in the shoulder joint as a mover and stabilizer has been investigated both in cadaveric (Kumar and Balasubramaniam 1989, Itoi et al. 1993, 1994, Rodosky et al. 1994) and clinical studies (Glousman et al. 1988, Warner and McMahon 1995). In shoulders with massive rotator cuff tears, the long head of the biceps often becomes widened and hypertrophic, suggesting a substitution of the biceps for the functional deficit caused by rotator cuff tears (Skinner 1937, Burkhead 1990, Itoi et al. 1995). The function of the biceps in cuff-deficient shoulders has been studied by use of electromyography (EMG) (Ting et al. 1987, Yamaguchi et al. 1997), but the results were debatable. Ting et al. (1987) reported that the biceps EMG activities increased during arm elevation in 4 of 5 shoulders with massive rotator cuff tears, whereas Yamaguchi et al. (1997) observed no activities of the biceps in 14 shoulders with rotator-cuff tears. These conflicting results prompted us to conduct the present EMG study to determine the function of the biceps in cuff-deficient shoulders.

Subjects and methods

During June 1994–1997, 52 patients with rotator cuff tears diagnosed either by arthrography or by magnetic resonance imaging (MRI) were referred to our institute. Among them, 40 shoulders of 37 patients who had full-thickness tears of the rotator cuff and who were able to elevate their arms more than 120° were enrolled in this study (cuff-tear group). There were 23 men and 14 women having an average age of 61 (39–79) years. As controls, 40 asymptomatic shoulders with normal rotator cuff on MRI were studied: 28 contralateral shoulders of 28 patients with unilateral involvement in the cuff-tear group and 12 contralateral shoulders of 12 patients with unilateral shoulder pathology, other than rotator cuff tears. There were 35 men and 5 women with an average age of 50 (17–79) years. Physical examination was performed by the senior author (EI) and the range of motion, impingement sign, and the muscle strength assessed by manual muscle testing (Daniels and Worthingham 1980) were recorded, prior to the EMG examination.

Dynamic electromyography

EMG activities of the biceps during arm elevation in the scapular plane were recorded with 2 silver-silver chloride surface electrodes (Blue sensor, Medicotest A/S, Denmark) attached at a 2-cm interval to the anterior surface of the arm, at the level of the biceps muscle belly. Light-reflecting markers were attached to the elbow and acromion, so that an EMG-synchronized video camera connected to the motion analysis system (Quick-Mag, OKK Inc, Tokyo, Japan) could monitor the real-time motion of the arm. Sitting on a chair, the patients were asked to elevate their arm with the elbow extended and the forearm pronated (palm down). The arm was elevated from the hanging arm position (starting position) up to the maximum elevation and then depressed down to the starting position in the scapular plane at a voluntary speed (2–3 seconds for elevation). This elevation-depression cycle was repeated twice at an interval of a few seconds. Then, a 1-kg weight was wrapped around the wrist and the protocol was repeated the same way as the previous cycles. After these motion cycles with and without the load, maximum voluntary contraction of the biceps was obtained with the elbow flexed at 90° and forearm supinated (Daniels and Worthingham 1980). Since 23 patients (24 shoulders) in the cuff-tear group complained of motion pain during the test, 10 mL of 1% lidocaine was injected into the glenohumeral joint to eliminate pain.

Repeat testing

The influence of local anesthetic on EMG activities of the biceps was studied by repeat testing of 10 shoulders in 5 volunteers, aged from 19 to 23 years, with no history of shoulder pain, using the same protocol as described above. The measurements were repeated twice before and once after 10 mL of 1% lidocaine had been injected into the glenohumeral joint.

Data recording

The raw EMG data from the surface electrodes were acquired using a receiver (Multi Telemeter 511X; Nihon Denki Sanei Co, Tokyo, Japan) and recorded with a portable data recorder (SR-50; TEAC, Tokyo, Japan). The recorded EMG data, which were sampled at 1000 Hz, were integrated using a wave-analyzing system (Hyper Wave; Kissei Comtec Co, Nagano, Japan) with a time constant of 0.05. Finally, combined with the data from the motion analysis system, the integrated EMG of the biceps at 30°, 60°, 90°, and 120° of elevation were obtained and expressed as percentages of the maximum voluntary contraction (%MVC) (Kronberg et al. 1991). The EMG data from the second cycle of elevation were analyzed.

Table 1. Test-retest repeatability

Elevation angle (degrees)	Repeat testing without block		Repeat testing before and after the block	
	no load	1-kg load	no load	1-kg load
30	1.65	3.09	1.41	2.68
60	2.65	2.90	1.33	3.19
90	3.45	4.24	2.69	3.72
120	3.80	3.08	4.05	3.34

Values are the repeatability coefficients (%) (Bland and Altman 1986).

Statistics

With the %MVC as a trial factor and the measurement conditions (with/without load, four angles of elevation) as within-subject factors, a 2-way within-subjects analysis of variance (ANOVA) was used in each group. The %MVC was also compared with use of a between-within univariate ANOVA with the two groups as a between-group factor and the loading condition as a within-subject factor at each angle of elevation. When there was a significant interaction between the factors, the effect of each factor was separately analyzed with a 1-way between-group or within-subject ANOVA. Test-retest repeatability was assessed with a repeatability coefficient, defined as two standard deviations of the differences between repeated measurements (Bland and Altman 1986). Statistical significance was set at the 5% level.

Results

Repeat testing

Repeat testing before and after the block showed the same repeatability as in repeat testing without the block (Table 1).

Dynamic electromyography

In the control group, %MVC of the biceps was always less than 10% both with and without load, regardless of the elevation angle (Figure 1). The %MVC increased with the increase in elevation angle ($p = 0.02$), but there was no significant effect of loading ($p = 0.06$) on the %MVC. In the cuff-tear group, 14 of 40 shoulders showed a %MVC greater than 10%, without load (Figure 2), which increased after load application ($p = 0.006$; Figure 2). The elevation angle had a significant effect on the %MVC in these 14 shoulders ($p < 0.0001$): the %MVC increased with the increase in elevation angle. As a result of the increased %MVC in 14 cuff-tear shoulders, the differences between the cuff-tear and control groups were

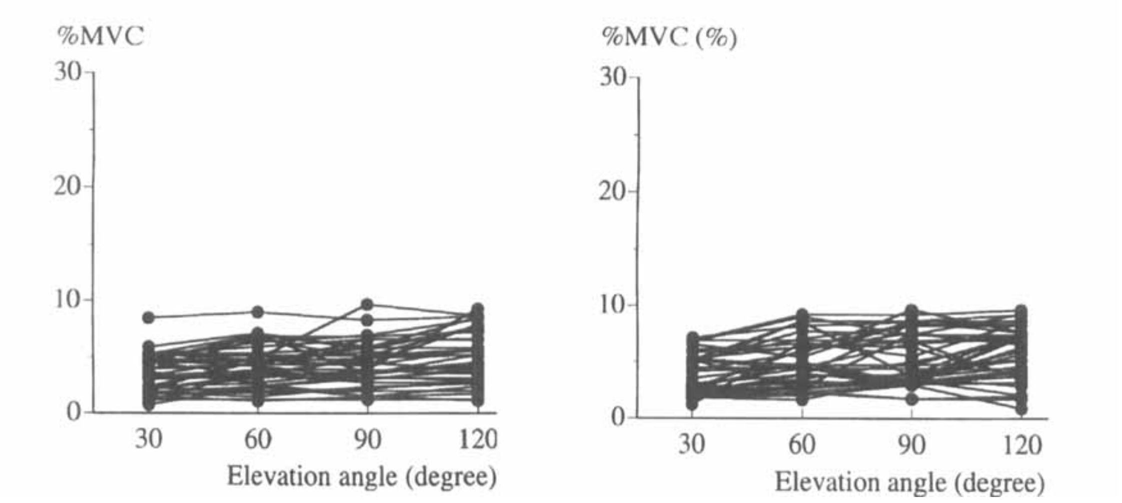

Figure 1. %MVC (maximum voluntary contraction) in normal shoulders, without load (left) and with 1-kg load (right). The %MVC was less than 10% regardless of elevation angle.

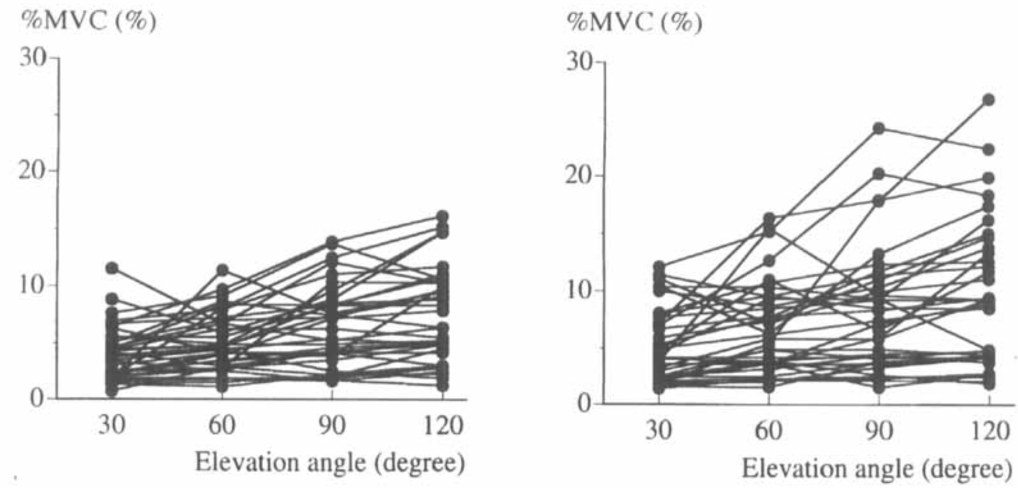

Figure 2. %MVC (maximum voluntary contraction) in cuff-tear shoulders, without load (left) and with 1-kg load (right). The %MVC increased more than 10% in 14 of 40 shoulders. It increased at higher angles of elevation ($p < 0.0001$) and with load application ($p = 0.006$).

statistically significant at 30° ($p = 0.05$), 60° ($p = 0.04$), and 90° ($p = 0.01$) of elevation with loading. Even greater differences were observed between the 14 shoulders with increased biceps activities and the remaining 26 cuff-tear shoulders ($p < 0.0001$) or the normal shoulders ($p < 0.0001$). However, there were no significant differences between the 26 cuff-tear shoulders and the normal shoulders.

Comparison between the high- and low-activity groups

Further analyses were performed in the cuff-tear group. Demographic parameters such as age, gender, and duration of symptoms were similar in those with increased activities of the biceps (high-activity group) and in those without (low-activity group) (Table 2). The tear size measured during operation (28 shoulders) or on MRI (12 shoulders) and the physical find-

Table 2. Gender, age, and duration of symptoms in the cuff-tear group

	Biceps activities	
	high	low
Gender (male/female)	6/8	18/8
Age (yr)	61 (5.4)	60 (11)
Duration of symptoms (mo)	30 (41)	22 (23)

Age and duration of symptoms are mean (SD).

Table 3. Tear sizes and muscle strength in the cuff-tear group

	Biceps activities		
	high	low	p-value
Tear size			
large/medium/small	2/9/3	4/13/9	0.7 [b]
Range of motion			
Abduction (°) [a]	138 (43)	130 (35)	0.6 [c]
External rotation (°) [a]	36 (27)	35 (21)	0.9 [c]
Impingement sign (+/-)	11/3	22/4	0.6 [b]
Strength by manual muscle testing			
Abduction (N,G / F,P)	1/13	9/17	0.06 [b]
Ext. rotation (N,G / F,P)	3/11	13/13	0.08 [b]

[a] Values are mean (SD)
[b] Chi-square test
[c] Two-sample t-test
Tear size: large (>3 cm); medium (1–3 cm); small (<1 cm)
N normal, G good, F fair, and P poor.

ings were also compared (Table 3). Among these parameters, the muscle strength assessed by the manual muscle testing tended to be weaker in the high-activity group, but the differences did not reach the statistically significant level ($p = 0.06$ in abduction, $p = 0.08$ in external rotation).

Discussion

The functioning of the biceps in shoulders with rotator cuff tears has been debated (Ting et al. 1987, Yamaguchi et al. 1997). We found that one third of the cuff-tear shoulders showed increased EMG activities of the biceps during arm elevation, whereas the remaining two thirds showed low activities, like those in the normal shoulders.

Comparisons of various parameters revealed that shoulders with increased activities of the biceps tended to show less strength in abduction and external rotation although not statistically significant. The biceps EMG activities also increased with load application. These findings suggest that the biceps may have supplemented the strength deficit caused by rotator cuff tears (Itoi et al. 1997). As an elevator of the shoulder (Basmajian and Latif 1957, Furlani 1976, Bassett et al. 1990), the biceps seems to contribute to shoulder elevation when a load beyond the strength of the deltoid and the cuff is applied. In normal shoulders, no increase in biceps activity occurred because elevator strength was far greater than 1 kg. In some shoulders with rotator cuff tears, the weight of the arm was already greater than the capacity of the elevators other than the biceps. In such cases, the biceps showed activities without load and a further increase in activities with an increase in load. It is theoretically possible that the weight of the arm and an additional 1-kg load exceed the strength of the elevators. However, none of the shoulders in this series showed this pattern.

Rotator cuff tear causes not only muscle weakness, but also instability in the shoulder: the humeral head cannot be maintained in the center of the glenoid fossa during arm elevation in cuff-tear shoulders (Poppen and Walker 1976, Haza 1988, Yamaguchi et al. 1997). Here is another possible explanation of increased activity of the biceps: to centralize the humeral head during arm elevation which was otherwise unstable, due to cuff deficiency.

Local anesthetic was used to eliminate pain in some patients. The influence of local anesthesia on EMG activities of the biceps as well as the repeatability of dynamic EMG measurements were assessed with use of the repeatability coefficient (Bland and Altman 1986). The coefficients were small enough for us to be confident that this method of measurement provides useful clinical data and the use of local anesthesia did not affect EMG activities of the biceps.

In massive rotator cuff tears when the torn edges of the cuff tendons cannot be approximated, the long head of the biceps may be used to close the defect by changing its course and suturing it to the adjacent cuff tendons (Bush 1975, Post 1978). It may affect the function of the biceps slightly, but as long as the origin is kept intact, the contraction force is transmitted to the glenoid, and thus biceps function seems to be mostly preserved. If the long head of the biceps is torn with the rotator cuff tendons, the residual stump of the biceps tendon may be resected and used as a free graft to cover the defect (Ellman 1991). This does not affect the function of the biceps. However, sectioning the intact long head of the biceps as a free graft (Neviaser 1971) should be the last resort because it partly or totally sacrifices the muscle function. We recommend that the intact long head of the biceps be preserved in reparative procedures of rotator cuff tears.

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