ISOKINETIC STRENGTH AFTER TEARS OF THE SUPRASPINATUS TENDON

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We measured the isokinetic strength of abduction, adduction, internal rotation, and external rotation in ten patients with full-thickness tears of the supraspinatus and ten with partial-thickness tears. The measurements were repeated after intra-articular or intrabursal injection of local anaesthetic.

Pain blocks produced significant increases in strength in both full and partial-thickness tears. After the block, the strength in full-thickness tears compared with the opposite side was 67% to 81% in abduction and 67% to 78% in external rotation, both significantly smaller than those on the uninvolved side ($p = 0.0064$, $p = 0.0170$). In partial-thickness tears the strength after the block ranged from 82% to 111%, with no significant differences between the involved and uninvolved sides.

The decreases in strength of 19% to 33% in abduction and 22% to 33% in external rotation after full-thickness tears appear to represent the contribution of supraspinatus to the strength of the shoulder.

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The function of a muscle can be assessed in patients either after paralysis by a nerve block, which evaluates loss of force generation, or when the tendon is ruptured, when loss of force transmission can be measured. The abduction strength of the shoulder after a suprascapular nerve block is one method of assessing the function of supraspinatus and infraspinatus.[1-4] The average decrease in abduction strength is approximately 50% which indicates the combined contribution of supraspinatus and infraspinatus. The function of the supraspinatus alone, however, cannot be isolated. Measurement of isokinetic strength in shoulders with tears of the rotator cuff, and hence loss of force transmission, has been reported to show that the strength of the involved shoulder was between 37% and 70% of the normal side[5,6] and that pain contributed significantly to the weakness,[7] but none of these studies specified the size and location of the tear.

We have studied the decrease in the strength of the shoulder caused by isolated tears of the supraspinatus tendon which were confirmed at operation.

PATIENTS AND METHODS

Since 1993 we have measured preoperatively the isokinetic strength of the shoulder in 49 consecutive cases of tearing of the rotator cuff. Isolated tears of the supraspinatus were present in 23. Three of these were excluded because of incomplete data, leaving 20 patients (20 shoulders) available for study. Their mean age was 56 years (34 to 77) and none had a history of shoulder pain on the contralateral side. The diagnosis of full-thickness tears and articular side tears was established before operation by arthrography. If the arthrograms were normal MRI was performed to assess further the presence of bursal side or intratendinous tears.

All patients had surgical repair of the cuff. During operation it was confirmed that the tears were confined to the supraspinatus tendon, and that both the rotator interval capsule anteriorly and the infraspinatus tendon posteriorly were intact. The width and the length of the tears were measured and their size assessed by multiplying the width by the length. The patients were grouped according to the degree of tear; ten had full-thickness (mean age 59 years) and ten had partial-thickness tears (mean age 51 years). Of the partial-thickness tears, seven were on the articular side and three on the bursal side of the tendon.

Isokinetic strength testing. We measured the isokinetic strength of abduction/adduction and internal/external rotation of both shoulders using the Cybex 340 isokinetic dynamometer (Cybex, Division of Lumex, Ronkonkoma, New York). The strength of internal and external rotation was tested with the subject standing with the arm at the side and the elbow flexed to 90°[8,9] and was carried out between 45° of internal and 45° of external rotation at angular velocities of 60°/s and 180°/s. A preliminary session consisting of four repetitions was followed by three maximum

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efforts at 60°/s. After sufficient rest, another session of four repetitions followed by four maximum efforts at 180°/s was performed.

The strength of abduction and adduction was measured with the patients seated on an upper body exercise and testing table with the trunk supported in a reclined position 40° from the vertical.[8] The test was carried out in the scapular plane between 0° and 110° of abduction at angular velocities of 60°/s and 180°/s using a similar regime to that for rotational strength.

To relieve pain we then injected 10 ml of 1% lidocaine into the glenohumeral joint for full-thickness and articular side tears as demonstrated on arthrograms and 5 ml into the subacromial bursa for bursal side tears with normal arthrograms. After confirming that pain on movement against resistance had been abolished the measurements on the involved side were repeated.

Repeat testing. Test-retest repeatability and the influence of local anaesthetic on strength were studied by repeat testing of a group of five volunteers, aged from 22 to 23 years with no history of shoulder pain, using the same protocol as described above. The measurements were repeated after 10 ml of 1% lidocaine had been injected into the glenohumeral joint of the right shoulder.

Data analysis. The peak torque is the highest torque value seen from all repetitions and all points in the range of movement. The total work indicates the work performed by the subject in the best work repetition or the repetition which produced the greatest value. The average power is obtained by dividing the total work in the best work repetition by the actual contraction time. These were recorded and expressed as percentages of those of the contralateral side. Torque at each 10° increment during abduction was determined from the recorded torque-angle curves. The data were subjected to detailed statistical analysis as noted in the tables.

RESULTS

Test-retest repeatability. The repeatability coefficients[10] in repeat testing of the right shoulders before and after the block and of left shoulders without any block are summarised in Table I. Repeat testing with the block showed

Table I. Test-retest repeatability in the right shoulder before and after pain block and in the left shoulder without a block. Values are the repeatability coefficients[10]

	Angular velocity			
	Right shoulder		**Left shoulder**	
	60°/s	**180°/s**	**60°/s**	**180°/s**
Abduction				
Peak torque (Nm)	7.9	5.4	11.5	10.0
Total work (J)	6.7	6.2	5.8	8.6
Average power (W)	7.4	9.7	9.0	8.4
Adduction				
Peak torque (Nm)	16.9	16.8	12.2	17.1
Total work (J)	11.4	11.4	14.3	14.3
Average power (W)	11.2	15.1	12.9	18.6
Internal rotation				
Peak torque (Nm)	4.6	4.6	7.4	7.8
Total work (J)	7.0	6.3	5.2	7.0
Average power (W)	4.8	7.0	9.4	6.8
External rotation				
Peak torque (Nm)	4.1	6.8	4.0	5.4
Total work (J)	3.7	2.6	3.6	3.9
Average power (W)	2.4	4.8	2.3	7.4

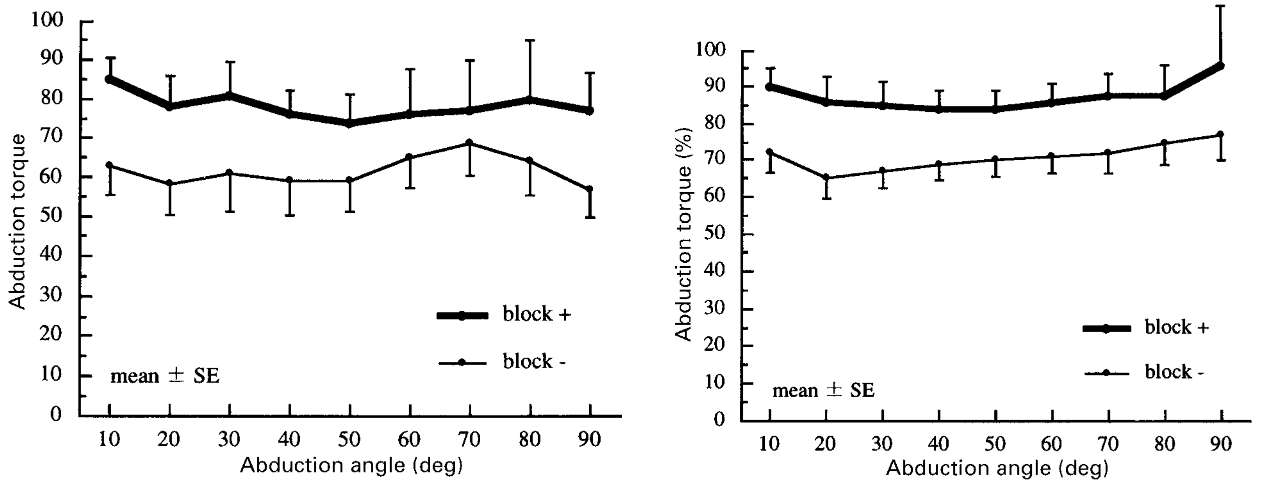

Fig. 1a

Fig.1b

Percentage abduction torques in patients with full-thickness (a) and partial-thickness tears (b). In full-thickness tears they increased after the block ($p = 0.0346$), but they were still significantly smaller than those of the contralateral shoulder (100% level) ($p = 0.0064$). The torque did not change significantly with the change of abduction angle ($p = 0.69$). In partial-thickness tears the percentage abduction torques increased after the block ($p = 0.0231$). As a result, the torques after the block were not significantly smaller than those of the contralateral shoulder ($p = 0.0776$) and the torque did not change significantly with the change of abduction angle ($p = 0.96$).

similar repeatability as in the contralateral shoulders without the block.

Abduction strength (Table II). In both groups all the measurements in abduction strength showed significant increases after the pain block except for the total work in the full-thickness group (p = 0.0549). The strength after the block in full-thickness tears was 67% to 81% of the contralateral side as against 82% to 102% in the partial-thickness group. Thus, abduction strength after the block was still 19% to 33% reduced in the full-thickness group and 0% to 19% weaker in the partial-thickness group than the contralateral side. The abduction strength after the block was significantly larger in the full-thickness group than in the partial-thickness group except for the total work at 60°/s (p = 0.15). The angular velocities had a significant effect on all the measurements except the total work in the full-thickness group; the strength at 180°/s was closer to the opposite side than at 60°/s.

For both groups the percentage abduction torques through an arc of 10° to 90° of abduction before and after the block are shown in Figure 1. In both groups, the torques increased after the block (p = 0.0346 and p = 0.0231, respectively), but in the full-thickness group after the block were still smaller than those of the contralateral shoulder (100% level) (p = 0.0064). In the partial-thickness group the torques after the block were not significantly smaller than those of the contralateral shoulder (p = 0.0776). They did not change significantly with the change in abduction angle in either group (p = 0.69 and 0.96, respectively).

Adduction strength (Table II). The adduction strength showed significant increases only in the peak torque in both groups; in the full-thickness group it was 94% to 118% of the contralateral side and in the partial-thickness group 86% to 111%. There was no significant difference in adduction strength after the block between the two groups. There was also no significant difference between the strength after the block and that of the contralateral side. The effect of angular velocity was significant only in the peak torque measurement (p = 0.0330).

Internal rotation strength (Table III). Pain block had a significant effect on the measurement of the strength of internal rotation in both groups. After the block the strength was 83% to 100% of the contralateral side in the full-thickness group and 87% to 98% in those with a partial-thickness tear, showing no significant difference between the groups. There was also no significant difference between the strength after block and of the contralateral side. The measurements at 180°/s were closer to the contralateral side than those at 60°/s.

External rotation strength (Table III). Pain block produced significant increases in all measurements of the strength of external rotation except the peak torque at 180°/s. After the block the strength ranged from 67% to 78% in the full-thickness group and from 87% to 96% in the partial-thickness group. The strength after the block was 22% to 33% weaker in the full-thickness group (p = 0.0170) and 4% to 13% weaker in the partial-thickness group (p = 0.54) than on the contralateral side. The total work at 180°/s in the partial-thickness group was greater than that in the full-thickness group (p = 0.0288). The angular velocity had no significant effect.

Tear size and strength. The width, length, and area of the full-thickness tears were 17.5 ± 4.9 mm (mean ± SD), 16.3 ± 3.5 mm, and 28.3 ± 9.5 mm^2 respectively. The Pearson correlation coefficients (r) between the area of the tear and the strength are given in Table IV. In adduction, there was a mild degree of correlation which was not statistically significant.

DISCUSSION

Previous attempts to measure the strength of shoulders with rotator-cuff tears have shown considerable variability with a decrease in abduction strength ranging from 37% to 70%. Some measurements were carried out without a pain block[5] and others did not specify the size and location of the tear.[6,7] We have isolated the contribution of the supraspinatus to shoulder strength in vivo. Shoulders with full-thickness tears had significant weakness in abduction and external rotation even after the pain block and this loss of power represents the contribution of the supraspinatus to shoulder strength. Those with partial-thickness tears had no significant weakness after the block since the force generated by the muscle is partially transmitted to the humerus through the remaining tendon fibres.

In assessment of repeatability, correlation coefficients between repeated measurements have been widely used, but the use of correlation is misleading. We have used the repeatability coefficient instead, which is defined as two standard deviations of the differences between repeated measurements.[10] These varied among the measurements but were small enough for us to be confident that this method of measurement of isokinetic strength provided useful clinical data. The repeatability before and after the block was similar to that in contralateral shoulders without the block, showing that the use of local anaesthesia did not affect the isokinetic strength.

The contribution of supraspinatus to the strength of shoulder abduction was 19% to 33%. The combined contribution of the supraspinatus and infraspinatus is known to be approximately 50%[2-4] and the two muscles must therefore have an almost equal contribution to shoulder abduction. Although the supraspinatus was thought to be an important abductor among the cuff muscles,[11,12] recent studies in vitro have demonstrated that the infraspinatus and subscapularis contribute as much to abduction as the supraspinatus[13-15]; our observations support this view.

The supraspinatus deficit decreased the strength of external rotation by 22% to 33%. Until recently, supraspi-

Table II. Pre- and postinjection mean (± SD) (percentage) abduction and adduction strength for ten observations in both groups

	Full-thickness				p values for block effect	Partial-thickness				p values for block effect	p values for types of tear	p values for angular velocity
	Pre-inj		Post-inj			Pre-inj		Post-inj				
	60°/s	180°/s	60°/s	180°/s		60°/s	180°/s	60°/s	180°/s			
Abduction*												
PT	58.8 ± 18.6	71.6 ± 20.5	75.6 ± 18.2	80.7 ± 17.5	0.0029	70.9 ± 18.3	77.1 ± 14.5	90.3 ± 17.8	102.2 ± 17.3	0.0001	0.0144	0.0615
AP	49.6 ± 24.3	58.8 ± 23.2	69.7 ± 22.2	73.1 ± 24.3	0.0358	72.0 ± 14.9	74.5 ± 15.2	85.5 ± 17.5	99.8 ± 20.7	0.0294 (60°/s)† 0.0063 (180°/s)†	0.0377	0.0010
TW	43.1 ± 21.7	51.9 ± 29.1	67.4 ± 20.0	68.8 ± 24.5	0.0549	64.7 ± 14.9	68.2 ± 17.3	81.5 ± 21.0	96.8 ± 24.8	0.0356 (60°/s)† 0.0088 (180°/s)†	0.15 (60°/s)‡ 0.0286 (180°/s)‡	0.44 (F)§ 0.0003 (P)§
Adduction												
PT	82.6 ± 24.7	86.6 ± 38.8	97.6 ± 18.9	108.5 ± 29.1	0.0268	81.6 ± 20.2	88.6 ± 38.8	95.6 ± 21.1	107.5 ± 25.0	0.0359	0.58	0.0330
AP	82.8 ± 24.7	85.9 ± 47.2	95.2 ± 20.3	117.7 ± 43.7	0.0806	79.7 ± 16.1	72.5 ± 24.5	88.7 ± 21.7	109.1 ± 47.6	0.0669	0.45	0.0538
TW	79.9 ± 25.0	85.9 ± 43.5	93.7 ± 20.2	111.8 ± 37.5	0.0600	72.8 ± 17.0	65.9 ± 25.0	86.4 ± 32.7	110.5 ± 73.6	0.11	0.76	0.0645

* PT, peak torque; AP, average power; TW, total work

† One-way within-subject ANOVA for comparison of pre- and postinjection strength

‡ One-way between-group ANOVA for comparison of postinjection strength

§ F, full-thickness; P, partial thickness

Table III. Pre- and postinjection mean (± SD) (percentage) internal and external rotation strength for ten observations in both groups

	Full-thickness				p values for block effect	Partial-thickness				p values for block effect	p values for types of tear	p values for angular velocity
	Pre-inj		Post-inj			Pre-inj		Post-inj				
	60°/s	180°/s	60°/s	180°/s		60°/s	180°/s	60°/s	180°/s			
Internal rotation*												
PT	73.6 ± 22.5	77.9 ± 21.8	82.9 ± 33.2	100.2 ± 25.2	0.0045	66.5 ± 16.8	68.7 ± 25.5	87.3 ± 19.0	92.4 ± 22.8	0.0005	0.85	0.0461
AP	68.5 ± 23.3	74.6 ± 20.9	86.1 ± 30.6	97.6 ± 24.0	0.0012	64.9 ± 17.7	70.0 ± 24.6	88.4 ± 20.2	96.8 ± 24.4	0.0010	0.94	0.0222
TW	68.0 ± 24.6	75.1 ± 22.3	86.8 ± 32.0	98.7 ± 25.4	0.0007	63.4 ± 17.6	68.7 ± 26.4	88.9 ± 22.7	98.3 ± 25.3	0.0012	0.84	0.0079
External rotation*												
PT	53.5 ± 17.6	66.7 ± 22.6	78.2 ± 16.6	74.8 ± 15.6	0.0027 (60°/s)† 0.20 (180°/s)†	71.8 ± 15.2	70.6 ± 22.3	88.8 ± 25.8	86.8 ± 24.8	0.0053	0.21	0.48
AP	50.2 ± 25.5	51.4 ± 27.5	75.9 ± 21.5	71.3 ± 17.4	0.0105	70.6 ± 15.8	74.2 ± 27.0	92.4 ± 24.4	93.5 ± 30.1	0.0057	0.0734	0.57
TW	49.5 ± 26.9	46.8 ± 29.1	75.6 ± 23.5	67.1 ± 17.8	0.0129	69.5 ± 19.0	70.9 ± 30.3	91.7 ± 26.1	96.3 ± 34.6	0.0077	0.16 (60°/s)‡ 0.0288 (180°/s)‡	0.0832 (F)§ 0.29 (P)§

* PT, peak torque; AP, average power, TW, total work

† One-way within-subject ANOVA for comparison of pre- and postinjection strength

‡ One-way between-group ANOVA for comparison of postinjection strength

§ F, full-thickness; P, partial-thickness

Table IV. Correlation between tear size and strength in patients with full-thickness tears

	Angular velocity			
	60°/s		180°/s	
	r	p values	r	p values
Abduction				
Peak torque	0.131	0.736	-0.089	0.819
Total work	-0.254	0.509	-0.393	0.295
Average power	-0.084	0.830	-0.253	0.512
Adduction				
Peak torque	0.403	0.282	0.399	0.287
Total work	0.193	0.618	0.300	0.432
Average power	0.496	0.174	0.385	0.306
Internal rotation				
Peak torque	0.092	0.814	0.186	0.631
Total work	0.013	0.974	0.057	0.885
Average power	0.006	0.987	0.076	0.847
External rotation				
Peak torque	0.058	0.881	-0.286	0.455
Total work	-0.163	0.675	-0.266	0.490
Average power	-0.097	0.805	-0.261	0.497

natus had been thought to be an abductor not an external rotator, but Kuechle[16] has shown that the supraspinatus functions as an external rotator through the entire arc of rotation. Otis et al[14] reported that the function of the anterior portion of the supraspinatus changes from an internal rotator to an external rotator as the arm is extremely rotated whereas the posterior portion functions constantly as an external rotator.

Decrease in shoulder strength is due to a loss of force transmission to the humerus. We found no significant correlation between the size of the tear and the strength, suggesting that other factors may be involved. Even although the insertion of the supraspinatus is completely torn, the force produced by the muscle may be partially transmitted to the humerus by means of load distributed along the edge of the torn cuff, like the force distributed along the span of a suspension bridge.[17] The tears may have involved part of the infraspinatus tendon since the posterior portion of the supraspinatus intermingles with the oblique fibres of the tendon of infraspinatus[18] and the main tendinous portion of the infraspinatus covers the posterior half of the supraspinatus tendon.[19] In particular, the strength of external rotation may be affected by involvement of the infraspinatus. A tear in the supraspinatus tendon may also cause the tendons of the infraspinatus and subscapularis to separate and shift inferiorly along the humeral head changing their direction of pull. Shoulder strength may also be affected by muscle atrophy. Even in shoulders with small tears of the supraspinatus atrophy is also seen in the infraspinatus and subscapularis.[20]

We used the strength of the contralateral shoulders as a normal comparison.[3,4] Although there is no statistical difference between dominant and non-dominant shoulders, there is a consistent pattern of greater strength in the dominant shoulder.[21-23] In addition, the contralateral shoulder may have a tear without clinical symptoms.

Does this decrease in strength affect the activities of daily living? Wuelker et al[24] and McMahon et al[25] have shown in cadaver studies that neither shoulder movement nor glenohumeral kinematics are significantly affected by a simulated paralysis of the supraspinatus. Loss of the supraspinatus in activities of daily living is compensated for by increased deltoid function, but in sport and heavy labour, in which a force close to the maximum is required, operative repair is indicated.

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