The Effect of Rotator Cuff Tear Size on Shoulder Strength and Range of Motion

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Study Design: Prospective cohort study.
Objectives: To determine the effect of rotator cuff tear size on shoulder strength and range of motion.
Background: Patients with rotator cuff pathology typically present with weakness and motion loss in various motions. The extent to which the presence of a rotator cuff tear and the size of the tear affect strength and range of motion is not well understood.
Methods and Measures: Sixty-one patients scheduled for surgery, with a diagnosis of a rotator cuff tear and/or subacromial impingement, underwent examination for shoulder pain, function, range of motion, and strength. The extent of rotator cuff pathology was documented during subsequent surgery (presence of tear, tear size, tear thickness).
Results: There were 10 massive tears, 15 large tears, 13 medium tears, 12 small tears, and 11 rotator cuffs without a tear. Patients had marked weakness in abduction strength at 90° and 10° of abduction, in external rotation strength at 90°, and in the "full can" test (all, $P<.0001$). Marked range of motion losses in shoulder flexion and external rotation at 0° and 90° abduction (all, $P<.001$) were also observed. Abduction strength deficit at 10° was affected by rotator cuff tear size ($P<.0001$). Twenty of 25 patients with large or massive tears had deficits greater than 50%, compared with only 1 of 11 patients with no tear, 2 of 12 patients with a small tear, and 5 of 13 patients with a medium tear ($P<.0001$). Other strength and range of motion deficits or indices of pain and function were unaffected by tear size.
Conclusions: Weakness of greater than 50% relative to the contralateral side in shoulder abduction at 10(of abduction was indicative of a large or massive rotator cuff tear. *J Orthop Sports Phys Ther 2005;35:130-135.*

Key Words: *handheld dynamometer, shoulder muscle strength*

The clinical presentation of patients with rotator cuff tears displays wide variability. While some patients with acute injury may have profound functional limitations secondary to pain, motion loss, and weakness, others may present with minimal impairments.[3,4,8,9,25-28] The extent to which weakness and motion loss are affected by rotator cuff tear size is not well understood. Previous studies examining the relationship between strength, range of motion (ROM), and pain and rotator cuff pathology have reported somewhat conflicting findings. Weakness in shoulder external rotation[9,28] and abduction strength tested at 90° of abduction (assessed manually)[9] was found to be associated with larger tears. Conversely, Kirschenbaum et al[16] found no significant difference in isokinetic shoulder flexion, abduction, and external rotation strength between patients with large or massive tears as compared with patients with small or medium tears. Of note, the strength tests were made following a lidocaine injection. Bryant et al[2] found that a clinical examination including manual assessment of weakness in internal and external rotation had poor predictive value for tear size. Cofield et al[4] concluded that shoulder strength and ROM loss were associated with larger cuff tears; however, this relationship was not specifically quantified. Weakness in both the "full can" and "empty can" test was shown to discriminate between full and partial thickness tears, but was not examined in regard to tear size.[15] Rokito et al[30] assessed isokinetic shoulder strength in patients with full thickness tears prior to under-

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This study was approved by the Lenox Hill Hospital Institutional Review Board.
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going rotator cuff repair and found that the greatest deficits were in abduction, followed by flexion and external rotation. However, the effect of tear size was not examined. With respect to ROM, Hawkins et al[9] reported no correlation between tear size and active or passive shoulder ROM. Conversely, Post et al[28] reported that decreased active elevation was associated with larger tears.

Previous studies have utilized isokinetic[16,30] or manual[9,28,15] strength tests to examine shoulder weakness in patients with rotator cuff pathology. Isokinetic strength testing is time consuming, requires the use of expensive equipment, and may not be feasible in the typical clinical setting. Conversely, manual strength testing is inherently subjective and has questionable reliability.[10] Strength testing with the use of a handheld dynamometer provides an objective test that is easy to administer in a clinical setting. Handheld dynamometry has been shown to be sensitive in detecting small but significant side-to-side differences in shoulder strength in professional baseball pitchers[7,18] and is a viable option for testing patients with rotator cuff pathology. Handheld dynamometry has been shown to have similar reproducibility to isokinetic testing for shoulder abduction strength.[19]

The purpose of this study was to determine to what extent rotator cuff tear size affects shoulder strength (assessed using a handheld dynamometer) and shoulder ROM.

METHODS

Sixty-one patients (46 males [mean age ± SD, 51 ± 16 years] and 15 females [mean age ± SD, 57 ± 15 years]) with a rotator cuff tear and/or subacromial impingement, as diagnosed by an orthopedic surgeon, participated in this study. The average (±SD) duration of symptoms was 22 ± 42 months. Twenty-two patients had a gradual onset of symptoms and 39 patients had a sudden onset associated with a specific injury. The dominant arm was involved in 42 patients while the nondominant arm was involved in 19 patients. The exclusion criteria were the following: prior surgery to either shoulder, a history of a neuromuscular, neurovascular, or musculoskeletal condition involving either upper extremity or cervical pathology within the past year. All subjects were nonsymptomatic and had no history of rotator cuff pathology on the contralateral side. The rights were protected and informed consent was received from all patients. The protocol for the study was approved by the Lenox Hill Hospital Institutional Review Board.

All patients were evaluated by 1 of 2 physical therapists prior to undergoing arthroscopic evaluation. Both therapists had more than 8 years of experience in an orthopedic setting at the initiation of this study. Subject assessment of shoulder function was performed using the patient self-evaluation section of the American Shoulder and Elbow Surgery rating scale.[29] This provided a measurement for pain, function with activities of daily living (ADL), and overall shoulder function (0%-100%). Active shoulder ROM was measured with a plastic goniometer for abduction, flexion, and external rotation with the patient in a standing position. External rotation was tested with the shoulder positioned at both 0° and 90° of shoulder abduction. Shoulder strength was then measured for each patient with a handheld dynamometer (Lafayette Instruments, Lafayette, IN). Strength tests included resisted elevation in the scapular plane at 90° of abduction with the humerus externally rotated (full can test), resisted external rotation with the shoulder at 90° of abduction, and resisted abduction with the shoulder positioned at both 90° and 10° of abduction (palm facing down). All measurements were taken while subjects were in the standing position. The average of 2 trials for each strength test was recorded. ROM measurements were made prior to strength measurements. For strength testing, abduction strength was tested first, followed by the full can test and external rotation. The order of testing shoulder abduction strength at 90° and 10° of abduction was alternated for each patient to minimize any potential systematic abduction fatigue effects. Considering that there were only 2 trials per test, fatigue effects should have been minimal. All strength and ROM tests were repeated on the contralateral shoulder. For ROM, side-to-side differences were reported in degrees. For strength measures, the percent deficits were computed ([noninvolved − involved/noninvolved] × 100). Goniometric range of motion[20] and handheld dynamometry strength tests[19] have been shown to have good reliability in the upper extremity.

Arthroscopic evaluation was subsequently carried out by 1 of 2 orthopedic surgeons. The surgeons were blinded to the results of the strength and ROM testing. Tear size was quantified using the classification introduced by DeOrio and Cofield,[5] which categorizes tear size according to greatest diameter: small, less than 1 cm; medium, 1 to 3 cm; large, 3 to 5 cm; and massive, greater than 5 cm. Any coexisting pathologies, including the presence of calcium deposits, acromioclavicular arthritis, a type II or III acromion (hooked acromion), or a tear of the biceps and/or labrum were recorded. Details regarding the thickness of the tear and extent of retraction were documented as well.

Statistics

One-way analysis of variance was used to examine the effect of rotator cuff tear size on strength deficits, loss of ROM, pain, function, and self-assessment. Post hoc pairwise comparisons were made with Tukey's test. Chi-square analysis was used to compare strength

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deficits (dichotomizing patients into 2 groups) between patients with larger and massive rotator cuff tears and the rest of the patients.

RESULTS

Ten patients had a massive rotator cuff tear, 15 patients had a large tear, 13 patients had a medium tear, 12 patients had a small tear, and 11 patients did not have a tear (requiring only a subacromial decompression). Full-thickness tears were seen in 3 of 12 small tears, 11 of 13 medium tears, and all large and massive tears. The rotator cuff tear was retracted in 1 of 12 small tears, 7 of 13 medium tears, 13 of 15 large tears, and all 10 massive tears. Twenty-one patients had a rotator cuff tear in just the supraspinatus (11 had a small tear, 6 had a medium tear, 3 had a large tear, and 1 had a massive tear). All other tears involved 2 or more tendons. Twelve patients had a labral tear (2 had no rotator cuff tear, 5 had a small tear, 4 had a medium tear, and 1 had a large tear). Eight patients had acromioclavicular joint arthritis (4 had a small rotator cuff tear, 1 had a medium tear, and 3 had a large tear). Five patients had a medial spur (3 had a small rotator cuff tear, 1 had a medium tear, and 1 had a massive tear). Four patients had a type II or III acromion (2 had no rotator cuff tear, 1 had a medium tear, and 1 had a large tear).

The patient sample as a whole had marked strength deficits, as compared to the contralateral side, in all tests ($P<.0001$): abduction strength at 90°

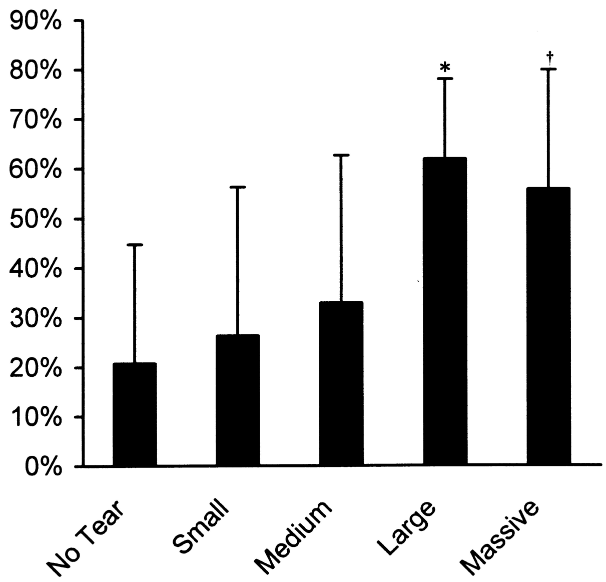

FIGURE 1. Relationship between rotator cuff tear size and abduction strength deficit at 10° abduction. Bars are mean ±SD for percent deficit as compared to the asymptomatic contralateral shoulder. Main effect of tear size ($P<.0001$). Strength deficits in patients with large (*$P<.01$) and massive (†$P<0.05$) tears were greater than the deficits in patients with no tear or small tears.

(mean ± SD, 53% ± 36%), full can test (48% ± 32%), abduction strength at 10° (40% ± 29%), and external rotation strength at 90° (31% ± 78%). Only abduction strength deficit at 10° was affected by rotator cuff tear size ($P<.0001$, Figure 1). Tear size did not affect strength deficits in abduction at 90° ($P = .07$), full can test ($P = .14$), or external rotation at 90° ($P = .17$) (Table 1). Abduction strength deficit at 10° was also affected by tear thickness ($P<.05$). Patients with full thickness tears had a mean (±SD) deficit of 47% ± 27% compared to 35% ± 35% in patients with partial thickness tears and 21% ± 24% in patients with no tear. Abduction strength deficits at 10° ($P<.01$) and 90° ($P<.05$) were affected by the retraction of the rotator cuff tear: for abduction at 10°, patients with retracted tears had a mean (± SD) deficit of 52% ± 23% compared to 32% ± 34% in patients with nonretracted tears and 21% ± 24% in patients with no tear (the corresponding mean [±SD] deficits at 90° were 64% ± 34% for patients with retracted tears, 41% ± 41% for patients with nonretracted tears, and 44% ± 20% for patients with no tear). Abduction deficit at 10° was also affected by the number of tendons involved in the rotator cuff tear ($P<.001$): patients with more than 1 tendon involved had a mean (±SD) deficit of 54% ± 27% compared to 31% ± 27% in patients with 1 tendon involved and 21% ± 24% in patients with no tear. No other strength deficits were affected by rotator cuff tear thickness, retraction, or number of tendons involved.

The patient sample as a whole had shoulder ROM losses ($P<.001$) in flexion (mean ± SD, 26° ± 33°), external rotation at 90° (mean ± SD, 21° ± 25°) and external rotation at 0° (mean ± SD, 16° ± 17°) when compared to the contralateral side. Loss of external rotation at 0° of shoulder abduction was affected by tear size ($P<.05$, Figure 2), but tear size did not affect loss of external rotation ROM at 90° of abduction ($P = .39$) or loss of flexion ROM ($P = .82$). Patients with massive tears had a mean (±SD) loss of external rotation ROM at 0° of 27° ± 24°, while patients with a small tear only had a loss of 5° ± 9° ($P<.05$). However, the mean (±SD) external rotation ROM loss was 14° ± 15° in patients with no tear. ROM losses were unaffected by rotator cuff tear thickness, retraction, or number of tendons involved.

Rotator cuff tear size did not affect pain ($P = .17$), function with ADL ($P = .71$), overall function ($P = .99$), or chronicity of injury ($P = .54$). Tear size was affected by patient age ($P<.001$). Patients who did not have a rotator cuff tear were significantly younger than the other patients ($P<.05$): no tear mean (± SD) age, 36 ± 14 years; small tear mean (± SD) age, 56 ± 13 years; medium tear mean (± SD) age, 51 ± 16 years; large tear mean (± SD) age, 57 ± 15 years; massive tear mean (± SD) age, 62 ± 9 years. The mechanism of injury (gradual onset versus sudden

TABLE 1. Effect of rotator cuff tear size on strength deficits (mean ± SD) and range of motion (ROM) deficits (mean ± SD) for the tests with nonsignificant effects ($P>.05$). Strength and ROM deficits are expressed compared to the asymptomatic contralateral shoulder.

	Strength Deficits (%)			ROM Deficits (deg)	
Tear Size	Abduction at 90°	Full Can Test	External Rotation at 90°	Flexion	External Rotation at 90°
No tear	43.9 ± 20.3	39.0 ± 34.8	37.3 ± 30.9	21 ± 35	24 ± 22
Small	47.7 ± 31.8	40.9 ± 32	33.9 ± 27.5	21 ± 25	18 ± 22
Medium	37.2 ± 47.1	36.9 ± 32.9	24.7 ± 39.4	22 ± 33	11 ± 22
Large	63.0 ± 36.3	56.0 ± 29.4	39.3 ± 55.0	30 ± 31	24 ± 25
Massive	75.0 ± 22.4	65.3 ± 23.5	70.6 ± 27.8	35 ± 45	31 ± 32
Effect of tear size	P = .07	P = .14	P = .17	P = .39	P = .82

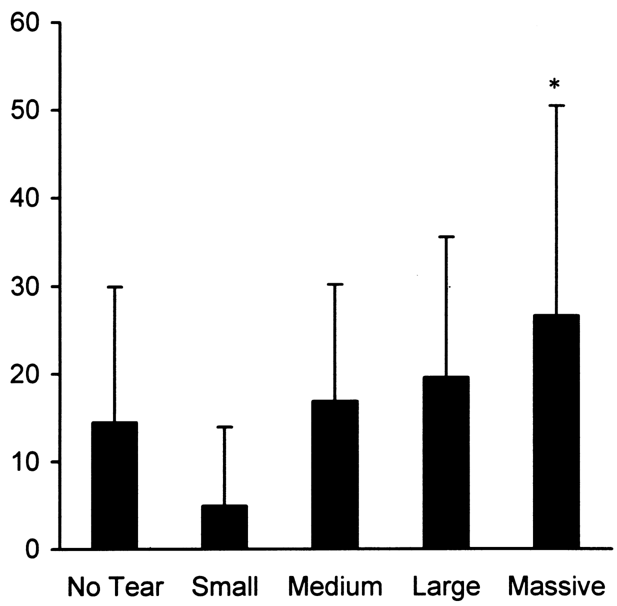

FIGURE 2. Relationship between rotator cuff tear size and loss of external rotation range of motion (ROM). Bars are mean ±SD for ROM loss as compared to the asymptomatic contralateral shoulder. Main effect of tear size ($P<.05$). ROM loss in patients with massive tears was greater (*$P<.05$) than the ROM loss in patients with small tears.

onset) was unaffected by tear size (P = .51). Pain, function with ADL, and overall function were also unaffected by rotator cuff tear thickness, retraction, or number of tendons involved.

There were no differences in strength or ROM deficits between men and women (P = .52-.90) and rotator cuff tear sizes were not different between men and women (P = .79).

A receiver-operating characteristic curve (Figure 3) was created to determine whether the abduction strength deficit at 10° was a useful test for identifying patients with large or massive rotator cuff tears. The true positive and false positive rates were computed for deficits from 10% to 90% in 10% increments. The strength deficit that yielded the smallest error ([100 – true positive rate] ± false positive rate) was 50%. Six of 10 patients with massive tears and 14 of 15 patients with large tears had deficits in abduction strength at 10° that were greater than 50%. By comparison, only 1 of 11 patients with no tear, 2 of 12 patients with a small tear, and 5 of 13 patients with a medium tear had deficits that were greater than 50% (Mantel-Haenszel chi-square test [$P<.0001$]). Using a deficit of 50% to categorize patients, the abduction strength test at 10° of abduction had a sensitivity of 80%, a specificity of 78%, a positive predictive accuracy of 71%, and a negative predictive accuracy of 85%.

DISCUSSION

In the present study, the only strength measurement affected by rotator cuff tear size was shoulder abduction tested at 10° of abduction. Twenty of 28 patients with a deficit greater than 50% (compared to the asymptomatic contralateral side) had a large or massive tear compared with 5 of 33 patients with a

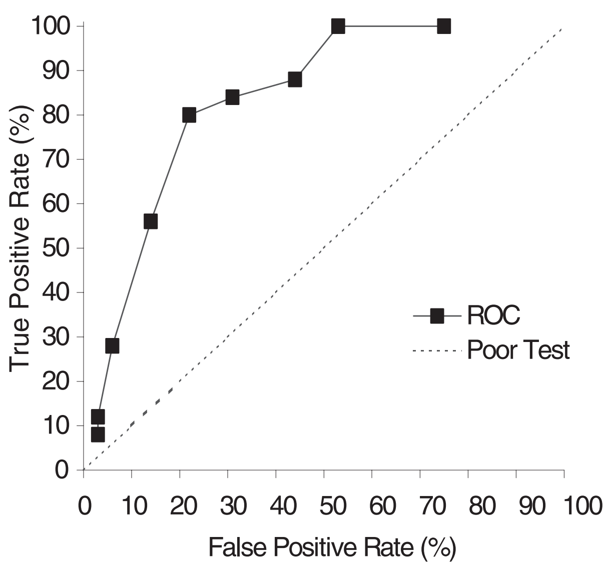

FIGURE 3. The receiver-operating characteristic (ROC) curve for the shoulder abduction strength test at 10° of abduction. True and false positive rates are calculated for identifying large and massive rotator cuff tears based on the percent strength deficit. True and false positive rates are plotted for strength deficits from 10% to 90% in 10% increments.

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deficit that was 50% or less. The lack of effect of tear size on the other tests may be attributable to the test positions. The other 3 strength tests involved positioning the arm in 90° of shoulder elevation (full can test) or 90° of shoulder abduction (external rotation and abduction tests). Impingement symptoms during testing in these positions may have contributed to the measured weakness and obscured differences due to rotator cuff tear size. Ben-Yishay et al[1] effectively demonstrated improved shoulder abduction strength following subacromial lidocaine and bupivacaine injection in patients with impingement.

The only other factors that were affected by tear size were age and loss of shoulder external rotation motion compared to the contralateral side. Age has long been recognized as a diagnostic indicator in this patient population. McLaughlin et al[21] in 1951 reported an average age of 57 years for patients with massive tears and 41 years for patients with incomplete tears. The decrease in active external rotation motion in patients with massive tears may reflect an external rotation lag sign.[11] However, the range of motion loss was not progressively worse with increasing tear size. Patients with no tear actually had greater (nonsignificant) loss of motion than patients with a small tear.

The fact that reliability was not documented for the strength and ROM tests is a limitation in this study. The lack of an effect of some of the strength and ROM tests on rotator cuff tear size may in part be attributable to measurement error. However, previous studies have shown good reliability in the upper extremity for goniometric range of motion[20] and handheld dynamometry strength tests.[19] Additional limitations were that the study sample was limited to those patients who were scheduled for surgery and had unilateral symptoms. While the abduction strength deficit at 10° of abduction may be useful in identifying large and massive tears, this finding is based on a patient population of those patients who had either failed nonsurgical treatment or for whom nonsurgical treatment was not considered. Therefore, the usefulness of this test in patients having nonsurgical treatment for a rotator cuff injury remains to be determined. The exclusion of patients with bilateral symptoms was necessary to assess the effect of tear size on strength and ROM deficits. However, it is common for patients with rotator cuff pathology to have bilateral symptoms and the current results would not be applicable to such patients.

Severe weakness in the initiation of shoulder abduction in patients with large and massive rotator cuff tears is consistent with the findings of McLaughlin,[22] who stated, "No patient who had complete or massive avulsion of the cuff from the humerus was able to initiate abduction of the arm against gravity in any position." While all patients in the present study were able to generate some force against the dynamometer at 10° of abduction (range, 1 to 25 N for patients with a massive tear), 8 patients were unable to abduct their arm to 90° for testing in that position. A deficit of 100% was recorded for those tests. With a handheld dynamometer it is possible to objectively quantify weakness at the initiation of abduction first noted by McLaughlin.[22]

The biomechanical reason for the effect of rotator cuff tear size on abduction strength at 10° is unclear. Some authors have suggested that the supraspinatus is responsible for the initiation of abduction.[6,12,17,25,30] Conversely, McLaughlin[22] had previously claimed that supraspinatus function was not necessary for the initiation and maintenance of abduction. Because abduction weakness at 10° increased with both the size of the tear and the number of tendons involved, this weakness could not be solely attributed to supraspinatus disruption. In this regard, the current findings support the contention of McLaughlin.[22]

The gold standard for noninvasive diagnosis of rotator cuff tears is magnetic resonance imaging (MRI). Ianotti et al[14] reported that MRI had excellent sensitivity, specificity, and positive and negative predictive accuracy in differentiating full-thickness tears, partial thickness tears, and intact tendons. However, the accuracy of MRI in detecting tear size was not reported. Motamedi et al[24] reported the accuracy of MRI in quantifying tear size in patients with recurrent tears. Based on their sample of 33 shoulders, MRI had a sensitivity of 79%, a specificity of 85%, a positive predictive accuracy of 90%, and a negative predictive accuracy of 69% for the detection of large and massive rotator cuff tears. The abduction strength test at 10° of shoulder abduction used in the present study had similar sensitivity (80% versus 79%), lower specificity (78% versus 85%), lower positive predictive accuracy (71% versus 90%), and higher negative predictive accuracy (85% versus 69%). A negative predictive accuracy of 85% indicates that, if a patient has a strength deficit of less than 50% in shoulder abduction at 10° of abduction, it is likely that the patient does not have a large or massive rotator cuff tear. However, it is important to note that this test does not rule tears of a smaller magnitude.

The receiver-operating characteristic curve for abduction strength deficit at 10° of shoulder abduction captures 84% of the area under its curve. Generally, tests capturing 90% to 100% of the area under the curve are considered excellent, and those capturing 80% to 90% are considered good.[23] The combination of shoulder abduction deficit at 10° of abduction and patient age decreased the area under the receiver-operating characteristic curve to 70%, indicating that the combination of variables did not improve the detection of large or massive rotator cuff tears.

CONCLUSION

Weakness of greater than 50% relative to the contralateral side in shoulder abduction at 10° of abduction was indicative of a large or massive rotator cuff tear. Other shoulder strength tests were not affected by tear size. Because patients with large and massive rotator cuff tears are thought to have a poor prognosis for nonoperative treatment,[31] any clinical test that can identify large and massive tears would be valuable to physical therapists. The abduction strength test at 10° of abduction may be a useful adjunct to the clinical exam in patients with suspected rotator cuff pathology.

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