Supraspinatus Fatty Infiltration Correlation with Handgrip Strength, Shoulder Strength, and Validated Patient-Reported Outcome Measures in Patients with Rotator Cuff Tears

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ABSTRACT

Introduction. The purpose of this study was to investigate the relationships between supraspinatus atrophy on magnetic resonance imaging (MRI) and other objective parameters in patients with rotator cuff tears. It was hypothesized that high-grade supraspinatus fatty infiltration would be correlated negatively with handgrip strength, shoulder strength, and patient-reported outcome measures (PROMs).

Methods. Patients with MRI-proven rotator cuff tears treated by a single sports medicine fellowship-trained orthopaedist at a single institution underwent comprehensive preoperative evaluation including bilateral handgrip and shoulder strength measurements with dynamometers and multiple online questionnaires from the Surgical Outcomes SystemTM (Arthrex, Naples, FL). Available shoulder MRIs were reviewed to grade supraspinatus fatty infiltration severity according to the 5-tier Goutallier system and an alternate 3-tier classification scheme. Difference analysis and Spearman (rho) rank order correlation were applied to the collected data to define the relationships between supraspinatus fatty infiltration and key variables including handgrip strength, shoulder strength, and scores derived from the shoulder PROMs.

Results. Ninety of the 121 patients enrolled in the study had shoulder MRIs available for review. There was no correlation found between supraspinatus fatty infiltration and handgrip strength, shoulder abduction strength, or any of the seven common shoulder PROM scores evaluated. There was statistically significant, albeit weak, correlation between MRI-derived fatty infiltration and shoulder external rotation strength.

Conclusions. Contrary to the hypothesis, high-grade supraspinatus fatty infiltration is largely unrelated to and should not be considered predictive of handgrip strength, shoulder strength, or common shoulder PROM scores. ***Kans J Med 2022;15:155-159***

INTRODUCTION

Shoulder pain is one of the most frequent musculoskeletal complaints seen by general practitioners and specialists.[1-6] Subacromial impingement is the most common shoulder disorder[6,7] and has been associated significantly with rotator cuff tendinopathy.[2,6-10] About 20 years ago, rotator cuff tears accounted for 4.5 million annual physician visits and 40,000 inpatient surgeries.[11] Now, over 300,000 rotator cuff repair procedures are performed annually and there has been a dramatic shift from open surgeries on inpatients to arthroscopic procedures in the outpatient setting.[9,12] Being able to diagnose patients with shoulder pain correctly through inquiry, physical exam findings, and imaging is crucial for orthopaedists to recommend proper treatment.

In a previous study, we examined the correlation of handgrip and shoulder strength with patient-reported outcomes measures (PROMs) in patients with rotator cuff tears.[13] Herein, the earlier study was extended to include fatty infiltration in the rotator cuff musculature. Historically, Goutallier et al.[14] showed on computed tomography (CT) scans that patients undergoing rotator cuff repair had greater fatty tissue infiltration within the rotator cuff compared to their normal asymptomatic counterparts. The Goutallier classification system, though originally derived from CT imaging, was found to be highly and easily reproducible on magnetic resonance imaging (MRI).[15]

The purpose of this study was to investigate the relationships between fatty infiltration of the rotator cuff found on shoulder MRI and other preoperative objective parameters of patients diagnosed with rotator cuff tears. These objective measures included absolute and percentage loss of handgrip strength, shoulder abduction strength, and shoulder external rotation strength as well as validated PROMs. It was hypothesized that increased fatty infiltration within the rotator cuff musculature would be correlated negatively with handgrip strength, shoulder strength, and shoulder PROM scores.

METHODS

Patient Enrollment. The study was approved by the local Institutional Review Board. All patients signed a consent form prior to participation in the study. One orthopaedic sports medicine fellowship-trained surgeon (DJP) enrolled patients undergoing rotator cuff repair surgery in the study from October 2018 to June 2021. Patients between the ages of 25 and 75 years who presented with shoulder pain, shoulder weakness on exam, and an MRI confirming a rotator cuff tear were included in the study. Patients were excluded if they had any history of cervical spine pathology, previous upper extremity surgery, significant upper extremity trauma, or any acute fracture of the upper extremities.

At their initial appointment, all patients underwent a complete physical exam, including bilateral handgrip and shoulder strength testing. Since there was no control group in the study, percentage loss of strength of the affected extremity was calculated as the net difference in strength of the affected extremity and the unaffected extremity divided by the strength of the unaffected extremity. These calculated values for percentage loss of handgrip strength, shoulder abduction strength, and shoulder external strength were analyzed separately from the values for absolute handgrip strength and absolute shoulder strength.

Patient-Reported Outcome Measures. All enrollees were asked to complete a set of questions which were emailed to them upon completion of their initial clinical encounter. These questionnaires were completed online as part of the Surgical Outcomes System (SOS™; Arthrex, Naples, FL, USA). The following PROMs were included within the SOS™: Simple Shoulder Test (SST), visual analog scale

(VAS), American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) function score, Single Assessment Numerical Evaluation (SANE), and Veteran RAND 12-Item Health Survey (VR-12) mental and physical health scores.

Developed to assess the functional limitations of the affected shoulder in the context of the patient's activities of daily living (ADLs), the SST has been found to be a reliable and valid test to evaluate functional gains and losses over time.[16] It consists of 12 "yes-or-no" questions inquiring about whether the injury affects his or her ability to perform a physical function.[17]

The VAS allows for communication of the patient's subjective assessment of pain through a numerical rating scale between zero and ten.[18] It has been regarded as a valid and reliable tool for measuring both acute and chronic levels of pain.[19]

As a standardized form adopted by the American Shoulder and Elbow Surgeons, the ASES index score is an equally-weighted combination of the VAS and a 10-question inquiry on ADLs (function score), which is heavily dependent on shoulder range of motion that is free from pain.[20] Specifically regarding outcome assessments for rotator cuff disease, the ASES function score demonstrated acceptable reliability and internal consistency.[21]

The SANE rating, introduced as an easier method to obtain outcomes data, is historically a written response to the following question: "How would you rate your shoulder today as a percentage of normal (0% to 100% scale with 100% being normal)?"[22] It was found to have good correlation with two well established, more prohibitive shoulder rating scores. More importantly, in regards to patients' functional changes following rotator cuff repair surgery, it showed reliability and acceptable precision.[23]

Lastly, the VR-12 is a 12-item health questionnaire developed from a more extensive survey, the VR-36.[24] The goal of the VR-12 and VR-36 is to measure the functional role of a patient and the physical or emotional problems that limit the patient's ability to fulfill that role in the social or cultural environment.[25] Modification of these surveys, from an originally dichotomized "yes-or-no" answer to a 5-point ordinal answer in selected question items, has increased the precision and validity of the physical and mental role limitation components.[26]

Grip Strength Testing Protocol. In addition to a standard physical exam, all patients underwent bilateral strength testing for handgrip, shoulder abduction, and shoulder external rotation. Difference between the affected and unaffected sides was noted. All strength measurements were obtained first on the unaffected extremity, then on the affected extremity. The handgrip strength measurements were obtained with a Dynatron hydraulic hand dynamometer (Dynatronics Corporations, Salt Lake City, UT, USA). Handgrip strength with this type of instrument has been found to be valid and reliable for healthy and ailing patients.[27-29] Procedural posture had the patient seated with the shoulder at 0° flexion, abduction, and rotation; elbow flexed at 90° and forearm and wrist in neutral rotation.[29] Of the five customizable sizing positions on the dynamometer, position two or three was used based on patient preference. Each patient underwent three measurements, requiring contraction of a full grasp for five seconds with a one-minute rest period in between each attempt. Peak force was recorded for analysis.

Shoulder Strength Testing Protocol. Shoulder abduction and external rotation strength testing with a handheld dynamometer has been found to be reliable and valid.[30-32] All strength measurements were performed with the patient in the seated position and were obtained by a digital handheld dynamometer (Lafayette Instrument Company, Lafayette, IN, USA). Method of evaluation was noted to be a "make test" with the examiner stabilizing the dynamometer on the extremity in a fixed position against which the patient would push.[33] For abduction testing, an attempt would be made to have the shoulder of interest in 90° abduction and the elbow in 90° flexion. The dynamometer was placed on the lateral aspect of the distal humerus, just proximal to the elbow. If 90° abduction could not be reached, maximum shoulder abduction was used. The patient was instructed to apply a force perpendicular to the dynamometer.

For external rotation testing, the shoulder was in a neutral position with 90° elbow flexion and 0° forearm pronation. The dynamometer was positioned on the distal portion of the dorsal forearm, just proximal to the wrist. The patient was instructed to exert a laterally directed force perpendicular to the dynamometer, while maintaining position of the elbow at the side of the body. As with handgrip strength measurements, three trials were performed bilaterally with the unaffected extremity first, followed by the affected side. Interval rest periods between shoulder trials were 30 seconds. The examiner monitored the patient for any excessive shoulder elevation, trunk bending, or pelvic weight shifting which were considered compensatory movements prompting repeat measurement. The mean value for each set of trials was used in data analysis.

MRI Fatty Infiltration Classification. The classic Goutallier classification, originally described with CT imaging, proposed five grades of muscular fatty degeneration. In Grade 0, there was no fat deposition; in Grade 1, the muscle contained some fatty streaks; in Grade 2, fatty infiltration was important, but still more muscle than fat; in Grade 3, muscle and fat were equal; and in Grade 4, more fat than muscle was present.[14] Fuchs et al.[15] found that the Goutallier classification system was as reproducible with MRI as it was with CT scans. Slabaugh et al.[34] modified the Goutallier categories and created a simplified 3-tier classification scheme, combining Grades 0-1 (normal to mild fatty infiltration) and Grades 2-3 (moderate fatty infiltration), while maintaining Grade 4 (severe fatty infiltration) in its own category.

In this study, fatty infiltration of the supraspinatus muscle belly was assessed by a senior orthopaedic resident (GMM) who reviewed the shoulder MRI of the enrolled patients. The supraspinatus muscle-tendon unit was selected for evaluation, since it is involved most commonly in patients with rotator cuff injury.[35] A T1-weighted oblique-sagittal image cut closest to the lateral border of the scapular spine and medial border of the coracoid process was selected for the grading of fatty infiltration.[36] Fatty infiltration of the supraspinatus on the available MRIs was graded according to the Goutallier classification[14] and the modified system described by Slabaugh.[34] Both data sets were used for analysis. The evaluation was blinded to the clinical and patient-reported outcome findings.

Statistical Analysis. Descriptive statistics, difference analysis, and Spearman (rho) rank order correlation were applied to the data from the two fatty infiltration classification schemes. The key variables analyzed included handgrip strength, absolute shoulder strengths, percentage loss of both handgrip, and shoulder strengths, and all scores derived from the PROMs. Relationships were reported as either positive (direct) or negative (indirect) correlations. Statistical Package for Social Sciences (SPSS, version 23; IBM®, Armonk, NY, USA) was used for all data analysis. The alpha value was set at 0.05.

RESULTS

This study of a cross-sectional cohort enrolled 121 patients, 71 males and 50 females. The average age of all patients was 59.3 years, ranging from 33 to 75. The right shoulder more often was affected. Eighty-six patients (71%) and 35 (29%) patients noted right-sided and left-sided shoulder complaints, respectively. Regarding hand dominance, 106 patients (88%) were right-handed. Dominant shoulder complaints were found in 87 patients (72%).

Handgrip, shoulder abduction, and external rotation strength data are shown in Table 1. Mean strength on the affected side was less than strength on the unaffected side for all three measures. While the differences in shoulder abduction and external rotation strengths achieved statistical significance, the side-to-side difference in handgrip strength was not statistically significant.

Table 1. Handgrip and shoulder strength of the affected and unaffected sides.

	Affected Side*	Unaffected Side*	p Value
Handgrip strength, kg	33.4 (12.7)	36.1 (12.4)	0.095
Shoulder abduction strength, kg	5.0 (4.9)	8.0 (4.1)	< 0.001[a]
Shoulder external rotation strength, kg	6.1 (3.9)	8.4 (4.4)	< 0.001[a]

*Tabulated strength values are mean (standard deviation)
[a]Statistically significant, $p < 0.05$.

Ninety of the 121 enrolled patients had shoulder MRI evaluations available for review at the time of the study. Data derived from assessment of supraspinatus fatty infiltration severity using the 5-tier Goutallier and modified 3-tier classifications schemes were analyzed in search of correlations with other preoperative measured parameters (Table 2). The negative correlations of shoulder external rotation strength and percentage loss of handgrip strength with supraspinatus fatty infiltration achieved statistical significance for both fatty infiltration classification schemes. However, the relatively low Spearman rho coefficients (≤ 0.35 in each case) indicated relatively weak, albeit statistically significant, correlations. All other correlations investigated did not achieve statistical significance.

Table 2. Supraspinatus fatty infiltration correlated with other preoperative measures.

Preoperative Measures	Goutallier Classification (0 - 4)		3-tier Classification (1 - 3)	
	Spearman's rho	p Value	Spearman's rho	p Value
Handgrip strength	-0.069	0.519	0.138	0.193
SH abduction strength	-0.143	0.117	0.024	0.823
SH ER strength	-0.348	0.001[a]	-0.214	0.042[a]
% Handgrip strength loss	-0.210	0.047[a]	-0.350	0.001[a]
% SH Abd strength loss	0.034	0.754	-0.020	0.855
% SH ER strength loss	0.183	0.084	0.145	0.174
SANE score	-0.129	0.342	-0.045	0.744
ASES function score	-0.186	0.169	-0.119	0.383
ASES index score	-0.113	0.406	-0.115	0.399
VAS score	0.050	0.713	0.110	0.419
VR-12 physical health score	-0.108	0.486	-0.092	0.552
VR-12 mental health score	0.116	0.395	0.068	0.616
SST score	-0.083	0.442	-0.030	0.780

Abbreviations: SH, shoulder; ER, external rotation; Abd, abduction; SANE, Single Assessment Numerical Evaluation; ASES, American Shoulder and Elbow Surgeons; VAS, visual analog scale; VR, Veteran RAND; SST, Simple Shoulder Test
[a]Statistically significant, $p < 0.05$.

DISCUSSION

The purpose of the study was to correlate supraspinatus fatty infiltration on MRI with measurable preoperative parameters including handgrip strength, shoulder strength, and PROMs. First, the study demonstrated a negative correlation between supraspinatus fatty infiltration and absolute shoulder external rotation strength. This finding, though statistically significant, was relatively weak regardless of which fatty infiltration classification system was used in the data analysis. Thus, as the rotator cuff musculature progressively was replaced by fat, it was found that the absolute strength of shoulder external rotation decreased as expected.

Previous studies have shown that fatty infiltration in rotator cuff musculature correlates with decreasing shoulder strength.[37-39] Gerber et al.[39] showed that supraspinatus atrophy and fatty infiltration correlated negatively with absolute contractile strength via intraoperative electric nerve stimulation, but cautioned that correlations with clinical strength measurements may be difficult secondary to rotator cuff tear pain. This may explain why supraspinatus fatty infiltration was not correlated with absolute shoulder abduction strength and only weakly correlated with absolute external rotation strength in our study.

Second, the results showed a negative correlation between supraspinatus fatty infiltration and percentage loss of handgrip strength, irrespective of whether the Goutallier or 3-tier classification data were analyzed. Thus, as the fatty infiltration increased in the affected shoulder, the relative difference between the affected and unaffected handgrip strengths decreased. This finding was contrary to the expectation. This finding may be related to overcompensation during handgrip strength testing on the affected side, but there were no data to support this hypothesis. Although ipsilateral handgrip strength and shoulder strength have been correlated in other previous studies,[40,41] including our own,[13] there was no correlation between fatty infiltration and absolute handgrip strength in the present study.

Third, no correlation between supraspinatus fatty infiltration and any standard shoulder PROM was found. In this regard, the results are contrary to other authors who investigated smaller patient cohorts. For example, Lapner et al.[42] showed a higher preoperative supraspinatus Goutallier grade was associated with a lower ASES score in a 62-patient cohort. Davis et al.[43] did not evaluate Spearman correlations between fatty muscle and PROMs, but found a significant inverse association between Goutallier grade and ASES score in a 15-patient cohort during both univariate and multivariate linear regressions. The larger sample size in our study may help to explain the difference in results of the presented study compared to these previous studies.

The presented study had several limitations. Since the sample size was derived from the practice of a single surgeon at a single location, the ability to draw conclusions for a more heterogenous demographic population was limited. High responder burden associated with completing multiple preoperative PROMs may have caused inaccurate or incomplete patient responses. Incomplete data, such as having only 75% of the shoulder MRIs available for direct review, may have reduced the power of the study to find other statistically significant correlations. Intrarater reliability was not determined for fatty infiltration grading or strength measurements, which were both done by single investigators. Lastly, no control group was available, though an attempt was made to use the unaffected extremity as a control. While the data were characterized by extremity dominance, the 0-10% difference in handgrip strength based on hand dominance published in the literature[44] was not accounted for in the data analysis.

CONCLUSIONS

In this study, no statistically significant relationships between supraspinatus fatty infiltration and specific preoperative parameters, including handgrip strength, shoulder abduction strength, and pertinent shoulder PROMs were found. For both the Goutallier and the 3-tier classification systems, statistically significant but weak negative correlations between supraspinatus fatty infiltration and absolute shoulder external rotation strength were found. Taken together, these findings indicated that, contrary to the hypothesis, high-grade supraspinatus fatty infiltration was largely unrelated to and should not be considered predictive of handgrip strength, shoulder strength, or common shoulder PROM scores.

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