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Grip and shoulder strength correlation with validated outcome instruments in patients with rotator cuff tears

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Hypothesis/Background: The ability to better define preoperatively the extent of rotator cuff (RC) dysfunction is desired. The study's purpose was to prospectively examine the relationships between absolute and percentage loss (affected compared to unaffected) of grip and shoulder strength, and RC dysfunction.
Methods: Forty-seven consecutive patients with proven RC tears participated in this study. Prior to surgery, bilateral strengths of grip, shoulder abduction, and shoulder external rotation (ER) were measured with a handheld dynamometer, and subjective outcome measures were gathered. RC tear size was determined via arthroscopy. Patient-reported outcomes were gathered on the day of the examination or via e-mail following initial evaluation. Descriptive statistics, difference analysis, and correlation coefficients (reported as either direct or negative) were used to analyze data. Grip, abduction and ER strengths, and percentage loss of grip, abduction, and ER strengths (percentage loss affected vs. unaffected), and tear size were analyzed in relation to all of the scores on selected subjective outcome measurement tools. The *P* value was set at .05.
Results: Fair direct correlations were found between grip strength and the Veterans RAND 12-Item Health Survey (VR-12) mental health scores, ER strength and Simple Shoulder Test (SST), abduction strength, and both the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) function score and SST score. Abduction and ER strengths were also found to possess a fair direct correlation. Fair negative correlations were found between the ASES function score and each of the following: percentage loss of abduction strength, percentage loss of ER strength, and tear size in centimeters. Another fair negative correlation was found between the Single Assessment Numerical Evaluation (SANE) score and tear size in centimeters.
Discussion: Our findings suggest that as shoulder strength decreases, ipsilateral shoulder RC dysfunction increases. Grip strength was not related to shoulder RC dysfunction.
Conclusion: Grip strength was not found to correlate with RC tears. Those with decreased abduction and ER strengths and low ASES scores should be considered more likely to have an RC tear.
Level of Evidence: Level III; Diagnostic Study
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Keywords: Grip strength; shoulder strength; rotator cuff dysfunction

University of Kansas Medical Center Institutional Review Board approved this study.

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The incidence of rotator cuff (RC) dysfunction and subsequent arthroscopic repair have steadily increased over the past 20 years.[7] The preoperative costs of these repairs are significant, with 65% coming from diagnostic imaging, specifically magnetic resonance imaging (MRI).[49] A quick and easy surrogate to complement an MRI would be of great value. The aim of this study was to determine if a relationship exists between grip and shoulder strength and RC dysfunction. In this study, RC dysfunction refers to the tearing of 1 or more of the 4 RC tendons (supraspinatus, infraspinatus, teres minor, and/or subscapularis) with subjective complaints, physical examination findings of weakness, confirmation with MRI of a tear, and with documented challenges expressed through the results of 6 subjective outcome measures. Tendon tears are described as absolute size in centimeters as determined by the operative surgeon at the time of surgery.

Grip strength is the maximum amount of force generated with one's hand in a single all-out effort. Grip strength is commonly tested and used as an indicator of strength and function. Previous research has shown a positive relationship between RC function and grip strength in healthy individuals.[12,23] Currently, no literature is available regarding the relationship between grip strength and RC dysfunction in those with RC tears, highlighting the need for the present study. Finding a statistically significant relationship between grip strength and RC dysfunction may be instrumental in helping to reduce preoperative costs in RC repairs and assist in preoperative planning. If grip strength correlates highly with RC dysfunction, other more costly diagnostic imaging tests may not be needed as often, resulting in an overall cost savings for all.

Loss of shoulder strength is common in patients with RC dysfunction. This decreased strength mainly affects shoulder elevation, abduction, and external rotation (ER). Significant abduction weakness, when compared to the unaffected extremity, is indicative of a larger RC tear.[29] Decreased abduction and ER strength, compared with the unaffected extremity, is also associated with supraspinatus tears.[28]

There are several purposes for this study: the first purpose was to prospectively examine the relationships between absolute grip and shoulder strengths, and RC dysfunction in those with proven RC tears; and second, to prospectively examine the relationship between percentage loss (affected compared to unaffected) of grip and shoulder strength, and RC dysfunction in those with proven RC tears.

It was hypothesized that there will be a significant correlation between the following: (1) RC dysfunction and strengths of grip, abduction, and ER and (2) RC dysfunction and the percentage loss of grip, abduction, and ER.

Materials and methods

Patient population

The prospective study enrolled a cross-sectional cohort of 47 patients, 25 males and 22 females. Grip and shoulder strength testing were completed on all 47 patients. Subjective outcomes questionnaires were sent to the patient's e-mail address and filled out online as part of the Surgical Outcomes System. At the time of this manuscript's submission, 4 patients had not completed the Surgical Outcomes System. Forty-three patients completed the Simple Shoulder Test (SST), Single Assessment Numerical Evaluation (SANE), American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) function score, visual analog score (VAS), and Veterans RAND 12-Item Health Survey (VR-12) mental health score. The VR-12 physical health score was not included in the patient-reported outcome measures during the initial data collection of the first 27 patients. Therefore, only 20 patients completed the VR-12 physical health score.

All data obtained from this population were included as a single assignment for comparison of parameters in a prospective manner. Inclusion criteria included the following: patients aged 25-75 years, presenting with shoulder pain, weakness, and MRI-confirmed RC tears. All patients were diagnosed and deemed surgical candidates by surgeon (D.J.P.). Patients with any history of the following criteria were excluded from the study: known cervical spine pathology, previous upper extremity surgery, significant upper extremity trauma, or acute upper extremity fracture. Before taking any measurements, each patient read and signed a participation consent form and filled out a medical history questionnaire, which were both approved by the University of Kansas Medical Center Institutional Review Board.

Physical examination and outcome assessment

Patients underwent a standardized physical examination including strength testing with handheld dynamometers.[13] A Dynatronics dynamometer (Dynatronics Corporations, Salt Lake City, UT, USA) was used to measure grip strength in pounds and converted to kilograms. This tool provides an objective measurement for users and is considered the gold standard for measurement of grip strength.[10] Abduction and ER strengths were measured in pounds using a digital handheld dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) which has good reliability,[19] and converted to kilograms. Strength loss was reported as a percentage, with the difference between the average strengths of the affected and unaffected extremities being divided by the average of the unaffected extremity. Percentage loss was used because there was no control group. Tear size was confirmed via arthroscopic surgery and provided in a postoperative report. Tear size was reported per DeOrio and Cofield as: small (<1 cm), medium (1-3 cm), large (3-5 cm), or massive (>5 cm).[8]

A certified athletic trainer (ATC) obtained all data for each subject at the preoperative appointment. Standardization of objective data collection was achieved using an hour-long training session with specific instruction on uniform positioning and application of testing procedures using hydraulic and digital handheld dynamometers to obtain grip as well as shoulder abduction and ER strength, respectively. The ATC demonstrated proficiency in strength measurements independently prior to data collection. The use of dynamometry was deemed preferential to manual muscle testing as it provides improved intra- and inter-rater reliability.[2] In addition, handheld dynamometry has been shown to detect weakness in shoulder RC muscles deemed normal by manual muscle testing.[45]

Procedures for grip strength testing

Grip strength has been previously shown to have acceptable test-retest reliability in a variety of studies.[24,25,36,38] Grip strength was measured with a standard, adjustable-handle Jamar dynamometer, while the patient was seated upright in a chair with the arm hanging straight down; the extremity in a neutral position (0° of both flexion and ER), with elbow fully extended, and palm facing midline.[20,23,41,43] The second or third position (of the 5 available) was used, depending on the comfort of the subject.[43] The patient held the dynamometer in the hand of the limb to be tested using a cylindrical grasp. The contraction was held for up to 5 seconds. Three measurements were taken at each side with intertrail rest periods of 1 minute between repetitions.[32] Consistent verbal encouragement was given for each repetition. Peak force generated (in pounds, which were converted to kilograms) during testing was recorded for use in analysis.

Procedure for shoulder strength testing

Abduction and ER strength testing with handheld dynamometry has been shown to be a reliable method to test shoulder and RC strength.[1,6,9,11,19,27,44] Abduction strength was measured while the subject was seated with the shoulder in 90° of abduction, or within available range of motion, and 90° of elbow flexion.[16] The digital dynamometer was placed at the lateral aspect of the distal humerus just proximal to the elbow. The patient was given instruction to apply force in a superior direction. ER strength was measured while the patient was seated with the shoulder in a neutral position and the elbow in 90° of flexion and 0° of pronation/supination. The digital dynamometer was placed on the distal portion of the dorsal forearm just proximal to the wrist. The patient was instructed to apply force in a lateral direction with the elbow remaining at the patient's side. All tests used a ''make'' test. Three trials were performed bilaterally for each strength measurement described above. A 30-second rest period was allocated between trials. All strength testing was performed initially with the noninjured extremity, followed by the injured extremity. Instructions were provided to patients to avoid compensatory movements during testing. Excessive shoulder elevation, trunk side-bending, and/or pelvic weight shifting were considered compensatory motions, which required elimination of data and repeat measurement. Adherence to the 30-second rest period was continued in these instances. The average measurement for each set of trials was used for data analysis. Consistent verbal encouragement was given during trials.

Before surgery, the following subjective outcome measurement tools were used to quantify shoulder function and pain levels in participating patients: SST,[22] Quick-DASH,[31] ASES,[18,33,39,46] VAS,[4] VR-12,[15,37,40] and SANE.[42,47] Patient-reported outcome measurements were collected using the Surgical Outcomes System online.

The following assumptions were made regarding this study: (1) each subject provided accurate medical history to the best of his or her knowledge in accordance with the inclusion and exclusion criteria, (2) subjective data collected were correct based on instructions given to patients to respond as truthfully as possible to all standardized questions, and (3) the data collector was accurate and consistent in following specific methods for obtaining the requested information and data.

Analysis

Data was compiled at approximately 3-week intervals for continuous analysis. Descriptive statistics, difference analyses, and Pearson product-moment correlation coefficients were used to analyze the data. Grip, abduction and ER strengths, percentage loss of grip, abduction and ER strength (percentage loss affected vs. unaffected), and tear size were analyzed in relation to all of the scores on the selected subjective outcome measurement tools. Relationships were reported as either direct or negative. Statistical Package for Social Sciences (SPSS, version 23; IBM, Armonk, NY, USA) was used for all data analysis. The alpha level was set at ≤ 0.05.

Results

The average age of all patients was 59.8 years, ranging from 34-74. The average body mass index of patients was 31, ranging from 22-41. Height averaged 171 cm, and weight averaged 88 kg. Grip, abduction and ER strengths were each averaged over 3 trials. Table I represents the means, standard deviations, and statistical significance of the differences between affected vs. unaffected extremity grip strength. In all cases, strength was decreased in the affected side compared to the unaffected side.

The right shoulder was found to be more involved: 34/47 patients were right-handed and had a right-side RC tear. Eleven left-hand dominant patients had right side tears. Among the 2 left-hand–dominant patient, 1 right side tear and 1 left side tear was noted.

Tear size varied from medium to massive, and the number of patients who fall into each tear size category is listed in Table II. The average tear size was 3.5 ± 2.5 cm. Results of correlation analyses are in Tables III and IV. Significant and direct correlations were found between the following: (1) grip strength and VR-12 mental health score, (2) grip strength and individual strengths of abduction and ER, (3) ER strength and SST score, (4) abduction strength and individual outcome scores for ASES function score and SST score, and (5) percentage loss of abduction strength loss and tendon tear size in centimeters. In addition, significant and negative correlations were found between the following: (1) percentage loss of abduction strength, (2) percentage loss of ER strength and ASES function score, and (3) tear size and both SANE and ASES function score.

Table I Mean and standard deviation of strength measurements before surgery (N = 47).

	Mean	Standard deviation	*P* value*
Grip strength (A), kg	27.8	11.0	<.001
Grip strength (U), kg	30.2	10.4	
Abduction strength (A), kg	5.2	2.9	<.001
Abduction strength (U), kg	6.8	2.7	
ER strength (A), kg	6.9	3.4	<.001
ER strength (U), kg	8.7	3.5	

A, affected; *U*, unaffected; *ER*, external rotation.
* Based on independent samples *t* test.

Table II Number of patients in tear size category

	Tear size category			
	Small: <1 cm	Medium: 1-3 cm	Large: >3-5 cm	Massive: >5
Number of subjects	0	19	10	12

Data for 6 subjects were unavailable at the time of submission.

Nonsignificant correlations were present between percentage grip strength loss and percentage shoulder strength loss.

Discussion

This study evaluated the relationship between absolute grip and shoulder strength, and RC dysfunction as well as percentage grip and shoulder strength loss and RC dysfunction. Correlations were found between grip strength and VR-12 mental health score, ER strength and the SST score, and abduction strength and ASES function score, and abduction strength and the SST score (Table III). A fair[30] correlation was also found between percentage abduction strength loss and tendon tear size in centimeters. The relationship between percentage loss in grip strength and RC dysfunction outcome scores was found to be insignificant (Table IV). However, a negative relationship appears to exist between percentage loss in abduction strength and ASES function score, and between percentage loss in ER strength and ASES function score. These findings suggest that as the ASES function score decreases, the percentage loss of abduction and ER strength increases.

Several studies have shown a statistically significant direct or positive relationship between grip strength and RC function.[12,23,41] However, these studies used healthy subjects rather than patients with proven RC tears. Horsely and colleagues examined grip strength and shoulder ER strength and found correlations (r) between 0.91 and 0.72 across various positions that included shoulder ER strength tested in neutral, 90° abduction, and 90° abduction with 90° of ER.[12] Mandalidis and O'Brien examined the relationship between hand grip isometric strength and isokinetic moment of the shoulder. They measured hand grip in 3 different positions of shoulder flexion and found relationships to concentric isokinetic moments of the shoulder rotators, abductors, and elbow flexors.[23] Correlations revealed positive relationships between hand grip strength and isokinetic moments of shoulder ER (0.40-0.54), abduction (0.42-0.71), and elbow flexors (0.45-0.66).[23] Sporrong and colleagues reported that there was a direct association between static handgrip and shoulder muscle activity that they measured using electromyography.[41] The results of the present study indicated that a statistically significant relationship only exists between grip strength and VR-12 mental health score, but not grip strength and any of the other patient-reported measures of RC dysfunction. The VR-12 scores are related more to health quality of life, which may be more closely associated to RC dysfunction than the other patient-reported outcome measures that were assessed in this population. It was determined that a relationship did exist between the SST score and absolute abduction and ER strength. It is possible that the SST and ASES scores correlated with grip and shoulder strength measurements in those with RC tears because they measure a composite, both function and pain, while other subjective outcomes such as Quick-DASH, VAS, and SANE outcome measures individually measure function or pain separately. RC tears may have a direct intertwined relationship with function and pain. However, further studies are needed to validate this finding.

The present study found significant differences in abduction and ER strength loss in those with proven RC tears compared with the unaffected extremity. Previous studies have reported that loss of strength in abduction[17,26,48] and ER[26] are associated with larger RC tear sizes in symptomatic patients.

Health information, including history of tobacco use (8 of 47) and/or presence of diabetes (9 of 47) were recorded, but because of a limited number of patients reporting either of these factors, they were not considered in the data analysis. Tobacco use and/or the presence of diabetes can implicate poor tissue healing. Thus, any patients with either of these circumstances could potentially demonstrate a greater loss of strength and function in their affected extremity.[3,5,21,35] Such information could be helpful information for future studies.

A main limitation of this study was small sample size, high responder burden, lack of intrarater reliability, and using the unaffected extremity as the control. The small sample size was due to a constrained time for data collection, and a single location from which to access participating patients. A larger subject population could

Table III Pearson correlation coefficients (*r*) and *P* values of percentage loss in strength measurements of the affected arm, tear size, and scores of shoulder dysfunction surveys

	% Grip strength loss		% Abduction strength loss		% ER strength loss		Tear size, cm	
	Pearson correlation	*P* value	Pearson correlation	*P* value	Pearson correlation	*P* value	Pearson correlation	*P* value
% Abduction strength loss	0.270	.066						
% ER strength loss	0.193	.195	0.292*	.047*				
Tear size, cm	0.019	.899	0.289*	.048*	0.228	.124		
SANE score	−0.025	.876	−0.136	.385	−0.120	.443	−0.312*	.042*
ASES function score	−0.152	.329	−0.441*	.003*	−0.317*	.038*	−0.479*	.001*
ASES index score	−0.026	.870	−0.211	.175	−0.299	.051	−0.251	.104
VAS score	−0.123	.433	0.012	.938	0.179	.251	−0.020	.900
VR-12 physical health score	−0.106	.658	0.897	.201	−0.201	.396	−0.156	.511
VR-12 mental health score	−0.154	.325	−0.150	.336	−0.222	.152	0.122	.436
Simple Shoulder Test	−0.195	.188	−0.100	.503	−0.114	.444	−0.041	.784
Quick-DASH	0.173	.244	0.144	.334	0.173	.244	−0.021	.887

ER, external rotation; *SANE*, Single Assessment Numerical Evaluation; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *VAS*, visual analog scale; *VR-12*, Veterans RAND 12-Item Health Survey; *DASH*, Disabilities of the Arm, Shoulder, and Hand.
* Statistical significance.

Table IV Pearson correlation coefficients (*r*) and *P* values of strength measurements of the affected arm and scores of shoulder dysfunction

	Grip strength		Abduction strength		ER strength	
	Pearson correlation	*P* value	Pearson correlation	*P* value	Pearson correlation	*P* value
Abduction strength	0.378*	.009*				
ER strength	0.421*	.003*	0.693*	.000*		
SANE score	−0.191	.220	0.126	.422	0.150	.337
ASES function score	−0.044	.779	0.360*	.018*	0.285	.064
ASES index score	0.035	.824	0.145	.355	0.226	.145
VAS score	−0.067	.671	0.026	.870	−0.105	.501
VR-12 physical health score	−0.008	.974	−0.291	.213	0.060	.802
VR-12 mental health score	0.374*	.013*	−0.060	.701	−0.087	.581
Simple Shoulder Test	0.225	.129	0.320*	.028*	0.398*	.006*
Quick-DASH	−0.190	.202	−0.076	.613	−0.223	.131

ER, external rotation; *SANE*, Single Assessment Numerical Evaluation; *ASES*, American Shoulder and Elbow Surgeons Standardized Assessment Form; *VAS*, visual analog score; *VR-12*, Veterans RAND 12-Item Health Survey; *DASH*, Disabilities of the Arm, Shoulder, and Hand.
* Statistical significance.

potentially show a higher correlation coefficient between factors. Because patients were recruited from a single physician's office, it is difficult to generalize data to other population demographics. Obtaining patients from more than a single office and geographical region could possibly lead to different results, and additional complexities due to multiple examiners and inconsistency of data collection.

High responder burden can lead to incomplete or inaccurate responses.[14,34] Having to complete 6 online assessments may have influenced answers. Another problem is the mixture of domains (eg, pain, patient function, and emotional well-being) either in separate tests or in tests in which multiple domains were measured. Because a single ATC collected the data, inter-rater reliability was not determined.

When considering grip strength, it should be recognized that there is a 5%-10% range of difference in grip strength when comparing dominant and nondominant upper extremities, except in individuals who are left-hand dominant.[31] Therefore, a true loss of grip strength may not have been observed in the present study because of patients having both dominant and nondominant side injuries, despite our attempt to use the unaffected extremity as a control. Additionally, the dominant and nondominant extremities were not compared to each other, as we used affected and unaffected for our results. Because of the limitations defined above, subsequent research expanding on the findings of this study would be warranted to better substantiate the strengths of correlations made. Future research should include analyzing a larger sample size with an expanded geographic region from which to collect patients, and including additional data points such as tobacco use, presence of diabetes, prior level of function, activity levels, and chronicity of injury.

Conclusion

This study was unable to obtain a consistent statistically significant relationship between grip strength and RC dysfunction. However, statistically significant direct relationships were found between grip strength and VR-12 mental health score, ER strength and SST score, abduction strength and the ASES function score, abduction strength and the SST score, and percentage loss of abduction strength and tendon tear size noted in centimeters. Negative correlations were found between percentage loss abduction strength and SST score and percentage loss ER strength and ASES function score. Our findings suggest that as shoulder strength decreases, ipsilateral shoulder RC dysfunction increases. Grip strength was not related to shoulder RC dysfunction. Based on the present findings, grip strength should not be used alone to diagnose RC tears.

Disclaimer

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