Preoperative Rotator Muscle Strength Ratio Predicts Shoulder Function in Patients After Rotator Cuff Repair

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Background: Shoulder function after rotator cuff repair is associated with patient satisfaction after surgery. Several studies have demonstrated that the muscle strength ratio (external rotators/internal rotators) is an important factor to evaluate shoulder function, but little is known about the relationship between the preoperative muscle strength ratio and postoperative shoulder function.

Purpose: To evaluate the effect of the preoperative muscle strength ratio of the shoulder rotators on function after rotator cuff repair.

Study Design: Cohort study; Level of evidence, 3.

Methods: The study participants were patients with small- to medium-sized rotator cuff tears diagnosed by magnetic resonance imaging; 77 patients were included in the analysis. Preoperative muscle strength was assessed through use of isokinetic equipment. Patients were classified into 2 groups (normal and abnormal) according to a normal strength ratio range of 55% to 75%, with "abnormal" meaning a deviation of more than 15% from the normal range. The American Shoulder and Elbow Surgeons (ASES) score and the Constant score were used to evaluate shoulder function preoperatively and postoperatively at 6 months, 1 year, and 2 years.

Results: There were 30 patients in the normal group and 47 in the abnormal group, with a preoperative muscle strength ratio of 63.5% $\pm$ 5.5% and 42.6% $\pm$ 6.1%, respectively. The ASES score was 88.6 $\pm$ 9.1 in the normal group and 77.5 $\pm$ 13.6 in the abnormal group at 2 years postoperatively, and the Constant score was 82.7 $\pm$ 8.4 in the normal group and 69.5 $\pm$ 13.4 in the abnormal group at 2 years postoperatively. A significant difference was found in postoperative shoulder function between the normal and abnormal groups.

Conclusion: This study demonstrated that the preoperative muscle strength ratio was associated with postoperative shoulder function. The preoperative muscle strength ratio should be considered an important predictor of shoulder function after rotator cuff repair.

Keywords: rotator cuff injury; muscle strength; strength ratio; preoperative

Rotator cuff tear is the most common shoulder injury.[3,35] Major causes of rotator cuff tears include overuse, injury due to shoulder malalignment, and trauma.[5] Successful rotator cuff repair is determined by the recovery of rotator cuff function and the time required to return to a normal lifestyle.[18,22]

A previous study showed that 10% to 20% of patients who underwent rotator cuff repair could not return to their preoperative physical activity levels.[19] Risk factors for delayed functional recovery include smoking, diabetes, thyroid disease, initial tear size, fatty degeneration, and cholesterol levels.[2,9,28,38] Previous studies have focused on the size of preoperative rotator cuff tear and the suture technique of surgery for postoperative recovery.[8,20,39]

Researchers have reported the effect of preoperative muscle strength on postoperative functional status and muscle strength after knee surgery.[30,36] Previous studies on rotator cuff tears have analyzed the impact of tear size of the rotator cuff or retear on clinical outcomes,[28] but studies on the effect of muscle strength ratio are lacking.

Here, we examined the preoperative strength ratio of the shoulder external and internal rotators and its effect on the recovery of shoulder function after rotator cuff repair.

METHODS

Participants

This study was approved by an institutional review board. Participants were 232 patients who were diagnosed with small- and medium-sized rotator cuff tears by magnetic

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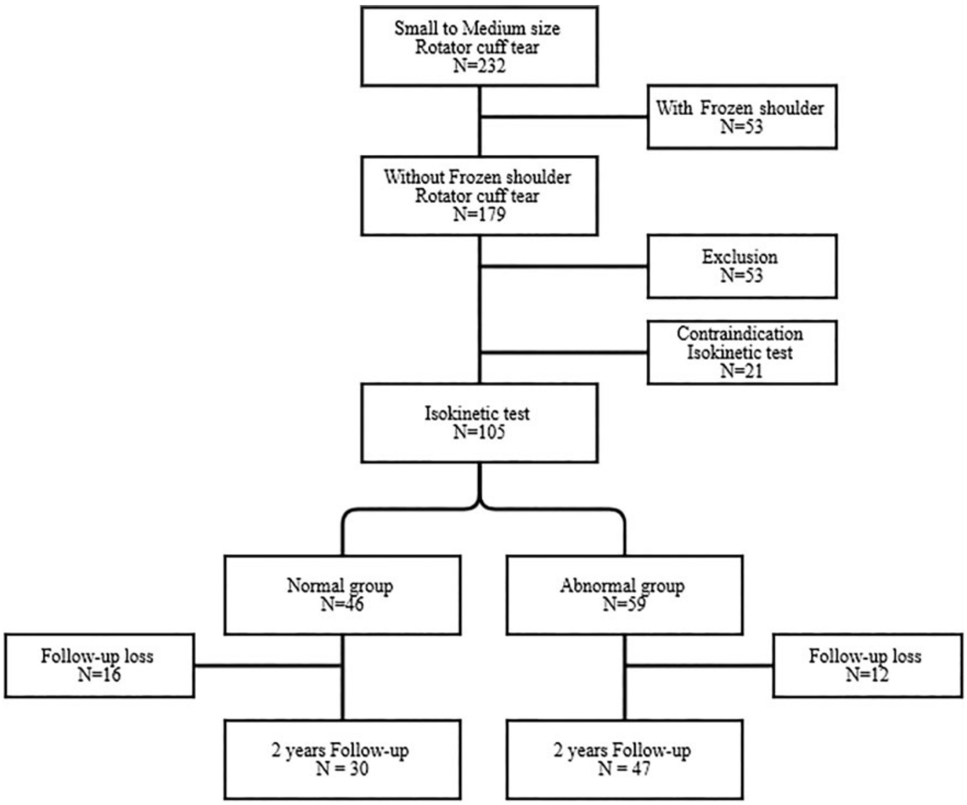

Figure 1. Flowchart of patient selection.

resonance imaging between March 2013 and July 2016; subsequently, 53 patients were excluded due to frozen shoulders. Of 179 patients without frozen shoulders, 53 patients with a history of shoulder surgery, trauma, fracture, dislocation, infection, inflammatory arthropathy, or shoulder osteoarthritis were excluded. The remaining 126 patients were scheduled to undergo an isokinetic muscle strength test; however, 21 patients were excluded due to increased pain or because they refused to take the test. Ultimately, 105 patients underwent preoperative isokinetic muscle strength testing (Figure 1).

All of the patients underwent rotator cuff repair by the same orthopaedic surgeon (J.C.Y.) using the arthroscopic double-row with suture bridge technique (Figure 2).

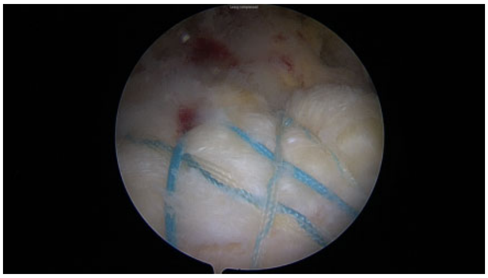

Figure 2. Arthroscopic double-row with suture bridge technique.

Rehabilitation Exercise Program

All of the patients used abduction braces for 6 weeks after rotator cuff repair and participated in a rehabilitation program after 6 weeks. Passive range of motion (ROM) exercise was performed at 6 weeks postoperatively, and muscle strengthening exercise was started at 12 weeks postoperatively. Exercise training consisted of shoulder extension, internal rotation (IR), external rotation (ER),

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and scaption exercise using a resistance band. All patients were instructed to perform each exercise daily for 3 sets of 15 repetitions and received re-education for the exercise program at 6 months postoperatively.

Muscle Strength Evaluation

Shoulder muscle strength was evaluated through use of an isokinetic dynamometer (CSMi Medical Solutions). The patients were instructed to perform the test according to a standardized protocol. During testing, each patient was seated on a chair with his or her trunk strapped to the dynamometer and was instructed to hold a handle on the contralateral side of the dynamometer.[42] The patients were asked to abduct their shoulder at 45° in the scapular plane while flexing the elbow at 90°. The dynamometer axis was aligned with the rotational axis of the shoulder joint. With the forearm positioned horizontally at 0° with an automatic computer-controlled safety margin, the ROM was 25° for IR and 65° for ER.

To assess the shoulder muscle strength, the peak torque (measured in pounds) at a testing speed of 60° per second was recorded. The tests for all of the patients were conducted by the same clinical exercise specialist (S.M.L).

The muscle strength ratio of the shoulder external and internal rotators was calculated by dividing the external peak torque by the internal peak torque and multiplying the result by 100. Based on previous studies, the normal ratio was defined as a range of 55% to 75%, and a deviation of more than 15% from the normal range was considered abnormal.[27,34] According to the muscle strength ratio, the participants were divided into 2 groups: normal and abnormal.

Functional Evaluation

Shoulder function was assessed preoperatively and at 6 months, 1 year, and 2 years postoperatively. The severity of shoulder pain was assessed by measuring the physical and functional visual analog scale scores. Shoulder function was measured with Constant score and the American Shoulder and Elbow Surgeons (ASES) score. The ASES score consists of a pain score and a questionnaire on 10 self-assessed activities of daily living.[14] The questionnaire has been validated in previous studies and is usually used for the evaluation of shoulder function.[1] The Constant score is a commonly used outcome measure for the treatment of shoulder disorders. This score is a comprehensive measure of shoulder pain and activities of daily living, ROM, and strength.[11] Other parameters such as ROM were assessed by a physician assistant who had 10 years of experience in physical rehabilitation (S.M.L.).

Statistical Analysis

All of the quantitative variables are presented as mean ± SD. We used repeated-measures analysis of variance to compare the differences in postoperative functional scores between the normal and abnormal groups. Statistical significance was set at $P < .05$.

TABLE 1
Characteristics of the Patients[a]

	Normal Group	Abnormal Group	*P*
Age	59.0 ± 8.6	61.0 ± 9.4	.354
Sex, male/female	12/18	15/32	
Height, cm	162.2 ± 9.5	158.9 ± 8.7	.118
Weight, kg	68.6 ± 12.7	62.43 ± 9.8	.027
Body mass index	26.0 ± 3.8	24.6 ± 2.5	.090
Dominant arm, right/left	28/2	44/3	
Side of involvement, right/left	22/8	34/13	
Tear size, small/medium	8/22	14/33	
Muscle strength			
Internal rotators, ft-lb	13.2 ± 6.6	15.1 ± 6.5	.220
External rotators, ft-lb	8.3 ± 4.2	6.5 ± 3.0	.026
Ratio, %	63.5 ± 5.5	42.6 ± 6.1	<.001[b]

[a]Values are presented as mean ± SD or absolute values.
[b]Statistically significant difference between groups.

RESULTS

Of the 105 initial study patients, 77 were available for 2-year follow-up (30 in the normal group, 47 in the abnormal group). The characteristics of the patients are shown in Table 1.

The preoperative ASES scores were 57.7 ± 21.9 in the normal group and 54.9 ± 16.5 in the abnormal group ($P = .516$). At 2-year follow-up, the ASES scores were 88.6 ± 9.1 in the normal group and 77.5 ± 13.6 in the abnormal group. The postoperative ASES scores were significantly different between the groups ($P < .05$).

The preoperative Constant scores were 60.3 ± 22.6 in the normal group and 62.1 ± 12.6 in the abnormal group ($P = .705$). At 2 years postoperatively, the Constant scores were 82.7 ± 8.4 in the normal group and 69.5 ± 13.4 in the abnormal group. The postoperative Constant scores were also significantly different between the groups ($P < .05$) (Table 2).

In this study, the preoperative strength ratio of the shoulder muscles had a significant impact on the functional scores of the shoulder (Figure 3).

DISCUSSION

The purpose of this study was to examine the effect of preoperative shoulder muscle strength ratio on shoulder function after rotator cuff repair. This study demonstrated that a normal preoperative muscle strength ratio had more beneficial effects on the recovery of shoulder function than an abnormal preoperative muscle strength ratio.

Recovery of shoulder function after surgery is related to patient satisfaction after surgery, and the patient's ability to return to the preoperative physical activity level also improves patient satisfaction. Factors such as smoking, diabetes, thyroid problems, and tear size are associated with worse postoperative clinical outcomes.[5,28,38] A large rotator cuff tear can lead to delayed functional recovery,

TABLE 2
Shoulder Function Scores Throughout the Study[a]

	Normal Group				Abnormal Group					
	Preop	6 mo	1 y	2 y	Preop	6 mo	1 y	2 y	*F* Value	*P* Value
ASES	57.7 ± 21.9	72.4 ± 15.4	87.9 ± 8.4	88.6 ± 9.1	54.9 ± 16.5	58.0 ± 12.2	71.0 ± 14.6	77.5 ± 13.6	24.853	<.001[b]
Constant	60.3 ± 22.6	69.2 ± 10.1	80.8 ± 7.7	82.7 ± 8.4	62.1 ± 12.6	52.9 ± 12.6	64.1 ± 12.8	69.5 ± 13.4	27.779	<.001[b]

[a]Values are presented as mean ± SD. ASES, American Shoulder and Elbow Surgeons score; Preop, preoperative.
[b]Statistically significant difference between groups.

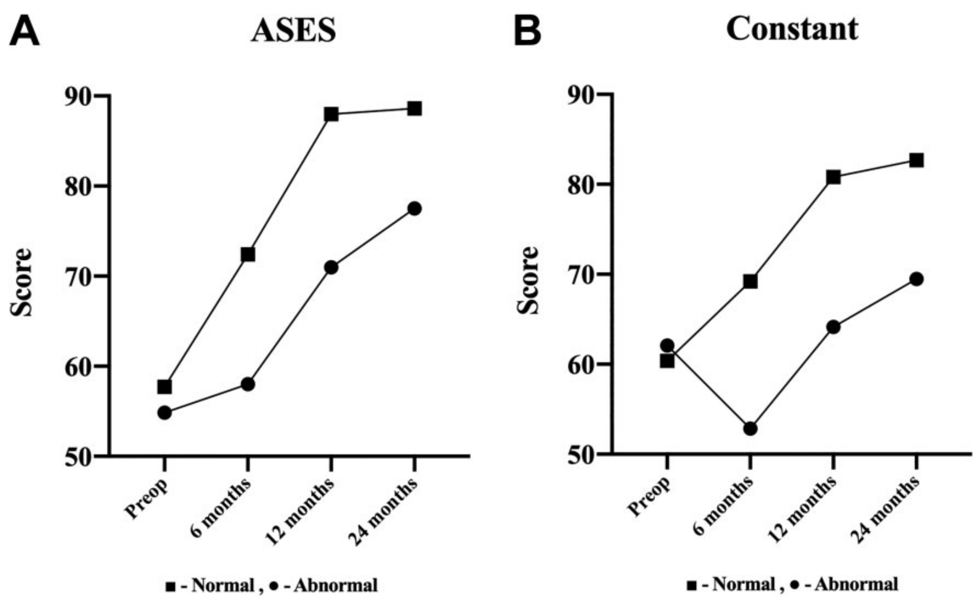

Figure 3. Plots showing pre- and postoperative shoulder function scores measured in the normal and abnormal groups. (A) American Shoulder and Elbow Surgeons (ASES) score. (B) Constant score.

late return to normal function, and limited ROM.[4] Obesity also negatively affects the postoperative recovery of shoulder function.[41]

In a study similar to the current one, improvements in preoperative quadriceps muscle strength enhanced postoperative knee function and recovery after anterior cruciate ligament reconstruction.[30] Moreover, preoperative knee function was shown to be predictive for successful recovery after surgery.[36,40] Unlike the knee and ankle joints however, the shoulder is not a weightbearing joint. Therefore, muscle strength ratio is an important factor to consider. Previous studies have analyzed differences in muscle strength of the left and right shoulders and the effect of these differences on postoperative functional recovery,[27,37] however these studies did not study the strength ratio within the shoulder.

All muscles in the body require proper strength ratios to ensure stability and maintenance of joint function, and joint stability is needed to reduce injury rates and enhance dynamic function.[25] Imbalance of muscle strength in the shoulder joint leads to scapular dysfunction, characterized by a decrease in shoulder function and increase in shoulder pain.[10,12,16,20] It is important to understand the kinematic interaction of the rotator cuff during shoulder movement.[31] The external rotators provide muscular strength to externally rotate the humeral head and move it up and down, while the internal rotators internally rotate the humeral head and move it down. The internal rotators provide anterior stability of the shoulder, and weakness of these muscles can result in excessive forward gliding of the humeral head,[31-33] which is related to shoulder impingement syndrome.[17,23] Therefore, the function of the internal and external rotator muscles is an important factor in shoulder injury. Maintaining the muscle strength ratio while increasing stability and preventing injury of the shoulder joint is challenging.[21,27,37] Interestingly, we found that the preoperative Constant scores were not significantly different between the abnormal and normal groups ($P = .705$). Given that strength is a component of the Constant score, this finding suggests that muscle strength may not be accurately assessed on clinical examination. Therefore, based on these results, preoperative muscle strength should be assessed through use of isokinetic equipment, and a clinical specialist should strive to maintain the normal muscle strength ratio in order to improve postoperative shoulder function.

Abnormal shoulder posture can also be considered a risk factor for rotator cuff injuries.[6,26] Abnormal shoulder posture has been reported as a cause of shoulder dysfunction and impingement syndrome and can also result in weakness and tightness of the serratus anterior and rotator cuff, leading to a reduction in coordinated kinematic shoulder movements.[13,15,24] Conversely, most patients with rotator cuff tears have abnormal shoulder posture due to shoulder pain, and that posture can cause tightness and shortness of the pectoralis minor muscle.[7] In other words, an abnormal shoulder muscle strength ratio may be associated with scapular dysfunction.[26] Therefore, patients with normal preoperative internal and external rotator muscle strength ratios have fewer abnormal motion patterns, indicating high functional scores after rotator cuff repair.[29]

This study has some limitations. First, it is a retrospective study with a small sample size; therefore, it is difficult to generalize the results. Further studies are needed, such as a prospective study with more participants. Second, shoulder function was assessed by a questionnaire in this study. A patient's daily life activities can affect questionnaire scores, limiting its use in evaluating shoulder function. Further, we did not examine the effect of preoperative exercise on differences in strength ratios. Therefore, other methods of shoulder function assessment are needed for more precise results in future studies. Third, the follow-up period in this study was only 2 years; a longer follow-up period is needed to assess a patient's condition after surgery and to evaluate outcomes. Fourth, this study did not report postoperative magnetic resonance imaging findings. It is unknown whether the rotator cuff repairs healed or whether preoperative muscular fatty atrophy resolved. Fifth, we did not measure the strength ratio at final follow-up; it might have been interesting to see whether some of the patients who had an abnormal postoperative strength ratio had experienced any change in this ratio at final follow-up.

CONCLUSION

A normal muscle strength ratio of 55% to 75% in the preoperative period was related to a positive outcome in shoulder function after rotator cuff surgery. Therefore, the normal ratio should be considered an important parameter before and after surgery. Surgeons can use preoperative IR and ER strength ratio to counsel patients on the expected outcome after rotator cuff repair for small- to medium-sized tears.

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