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Shoulder Strength After Open Versus Arthroscopic Stabilization

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Background: With current techniques, the main difference between arthroscopic and open shoulder stabilization is the violation of the subscapularis tendon. No studies have looked at strength differences of internal and external rotation between these groups.

Hypothesis: Internal rotation strength deficits will exist in patients having undergone an open shoulder stabilization procedure compared with an arthroscopic one.

Study Design: Piggy-back randomized controlled trial; Level of evidence, 1.

Methods: Forty-eight patients (38 men, 10 women), average age, 30.6 years (range, 18-59 years), were randomized to either open (n = 24) or arthroscopic (n = 24) shoulder stabilization. Rehabilitation protocols were standardized. At a mean follow-up of 19.4 months (range, 12-36 months) from surgery, patients underwent isokinetic strength testing (concentric and eccentric peak moments at 60 deg/s and 180 deg/s). Measurements were body-mass normalized. Primary outcome was internal rotation strength at 60 deg/s.

Results: There were no significant differences between groups with respect to age, gender, or operative limb. There were no statistical differences between operative groups for the primary outcome of internal concentric strength at 60 deg/s (mean difference, 0.011 N·m/kg; 95% confidence interval, -0.043 to 0.066; $P = .677$) or secondary strength measures. When compared with the contralateral limb, strength deficits existed for both surgical groups for both internal and external rotation. Regression analysis demonstrated that arm dominance is a factor in strength deficits.

Conclusion: The results of this trial suggest there are no side-to-side isokinetic strength deficits between patients having an open stabilization using a subscapularis splitting approach versus arthroscopic stabilization for anterior traumatic shoulder instability at 1 year after surgery. Strength deficits exist in both groups when compared with the contralateral limb.

Keywords: shoulder instability; isokinetic strength; strength deficit; arthroscopy; stabilization

Surgical stabilization is considered the standard treatment for patients with recurrent traumatic anterior shoulder instability and can be performed with either an open incision or an arthroscopic approach. Meta-analyses and systematic reviews of the literature have suggested that the open technique is superior to the arthroscopic with regard to preventing redislocations^{8,15,18,21,26} and return to activity.^{18,21,26} These reviews, however, also report a greater loss of external rotation (ER) with the open procedure than arthroscopically.^{8,26}

These results must be seen in the light of improved techniques of arthroscopic repairs, including the introduction of suture anchors, improved suture strength, and the addition of capsular plication sutures.⁶ Recent studies have shown that newer arthroscopic techniques have redislocation rates approaching those reported for the open procedure.^{3,6,17} Theoretical and real advantages of the arthroscopic repair include improved cosmesis, reduced pain, improved range of motion (ROM), decreased operative time, and preservation of the subscapularis tendon.^{1,10} It is the violation of the subscapularis tendon during the open approach that has become the key difference between the 2 techniques. Dysfunction of the subscapularis muscle and rerupture after open stabilization have been reported in the literature.^{11,24} Disruption of the subscapularis could also lead to weakness of internal rotation (IR) of the shoulder and overall rotator cuff strength.²⁵ The identification of strength deficits between these techniques is necessary to assist in surgical decision making and to improve postoperative rehabilitation protocols.

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To the authors' knowledge, there are no studies in the published literature that directly compare strength outcomes in patients receiving an open versus an arthroscopic anterior stabilization procedure for traumatic recurrent anterior instability of the shoulder. There are, however, noncomparative studies that examine postoperative isokinetic strength. Four studies were identified that evaluated isokinetic strength outcomes after arthroscopic stabilization.^{9,12,13,22} Three of these studies demonstrated IR and ER strength deficits in the operated limb when compared with the contralateral limb,^{12,13,22} and 1 study showed no strength deficits.⁹ Two noncomparative studies of isokinetic strength after open stabilization were found,^{20,23} both of which demonstrated no strength deficit compared with the contralateral limb. Comparison of these studies is difficult because of the small sample size, the variations in surgical techniques, and the variations in the strength testing protocols.

The purpose of the current trial was to determine whether differences exist in IR and ER isokinetic shoulder strength between patients having an open versus an arthroscopic stabilization procedure for recurrent traumatic anterior shoulder instability.

METHODS

This study was a piggyback randomized clinical trial. Patients were drawn from an existing randomized trial assessing disease-specific quality of life in patients who had been randomized to receive either an open or arthroscopic stabilization procedure for recurrent anterior shoulder instability (Clinical Trials Registration Number NCT00251264). Patients meeting the current study's inclusion criteria were contacted by one or a combination of mail, telephone, or e-mail in a consecutive fashion and invited to participate in the current trial. Recruitment for the current trial was terminated when strength tests were completed on the calculated sample size of 48 patients (24 patients having an arthroscopic procedure and 24 having an open procedure). A Consolidated Standards of Reporting Trials (CONSORT) diagram (Figure 1) outlines the flow of patients throughout the course of the study. Ethical approval was obtained (separate from the original study) from the University of Calgary Conjoint Health Research Ethics Board.

Inclusion criteria for this trial included patients who underwent randomization in the larger trial and were a minimum 1-year postoperative, 18 years of age or older, had no reported postoperative dislocation or subluxation of the surgical shoulder, a normal contralateral shoulder, no contraindications to isokinetic shoulder testing, no third-party claims, and an ROM in their operative shoulder sufficient to complete strength testing. Patients having a painful surgical shoulder (pain greater than 3 out of 10 on a pain scale) or symptoms of instability in their operative shoulder were not eligible.

All surgeons involved in the study were fellowship trained; 2 surgeons performed the open repairs, and 2 performed the arthroscopic repairs. The open procedure was performed using a 5-cm standard deltopectoral incision. The conjoined tendon was identified and then retracted

medially. The underlying subscapularis tendon was then identified and incised horizontally. The shoulder capsule was entered by performing a T-shaped arthrotomy, and retractors were placed to allow for full exposure of the glenoid. With the approach complete, the shoulder injury was addressed with suture anchor repair of any capsulolabral detachment, that is, Bankart lesion, and a capsular plication for repair of any existing capsular redundancy. A standard deep and superficial soft-tissue closure was performed, a sterile dressing was placed over the wound, and the operated shoulder was placed in a shoulder immobilizer.

The arthroscopic procedure was performed through a standard posterior arthroscopy viewing portal. A diagnostic arthroscopy was performed, and the intra-articular lesions were identified and documented. Any labral detachment, that is, Bankart lesion, was repaired using suture anchor fixation and arthroscopic tying techniques. Capsular redundancy was addressed with suture plication of the redundant capsule. A sterile dressing was applied over the wound and the operated shoulder placed in a shoulder immobilizer.

Follow-up visits and rehabilitation protocols were identical for both surgical groups. Patients were allowed to see the physiotherapist of their choice. The rehabilitation protocol was a guideline, and the patients/therapists were permitted to modify the program based on the patient's progress. In the operating room, patients' shoulders were placed in a shoulder immobilizer that was worn for 2 to 4 weeks. At 2 weeks, passive- and active-assisted ROM exercises were allowed for elevation and ER to neutral. At 6 weeks, active shoulder exercises in all planes of motion were allowed with progression to strengthening exercises when tolerated. Each patient was encouraged to individualize modifications to his or her program depending on the extent of the original injury, type of surgery performed, level of pain, degree of stiffness, and strength. Return to sport was allowed on completion of the program and at least 4 months after surgery. Return to sport was dependent on their progress but was generally allowed by 4 months. Compliance to the rehabilitation protocol and patient attendance (at physiotherapy) were not recorded.

Testing Instrument

A standardized testing protocol using the Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY) was employed by a research coordinator who was blinded to treatment allocation (open vs arthroscopic). Patients were seated with their feet on a footrest, their trunk firmly against a backrest, and were stabilized with 3 straps (2 across the chest and 1 across the pelvis). The shoulder was positioned in 90° of abduction and the elbow at 90° of flexion. The level on the dynamometer was used to ensure the forearm was parallel to the floor, establishing a measurable and reproducible arm position. The elbow and forearm were supported in a cuff attachment and secured with a Velcro® strap for further stabilization. There was a handle at the end of the attachment that the patient grasped during the testing. The axis of rotation of

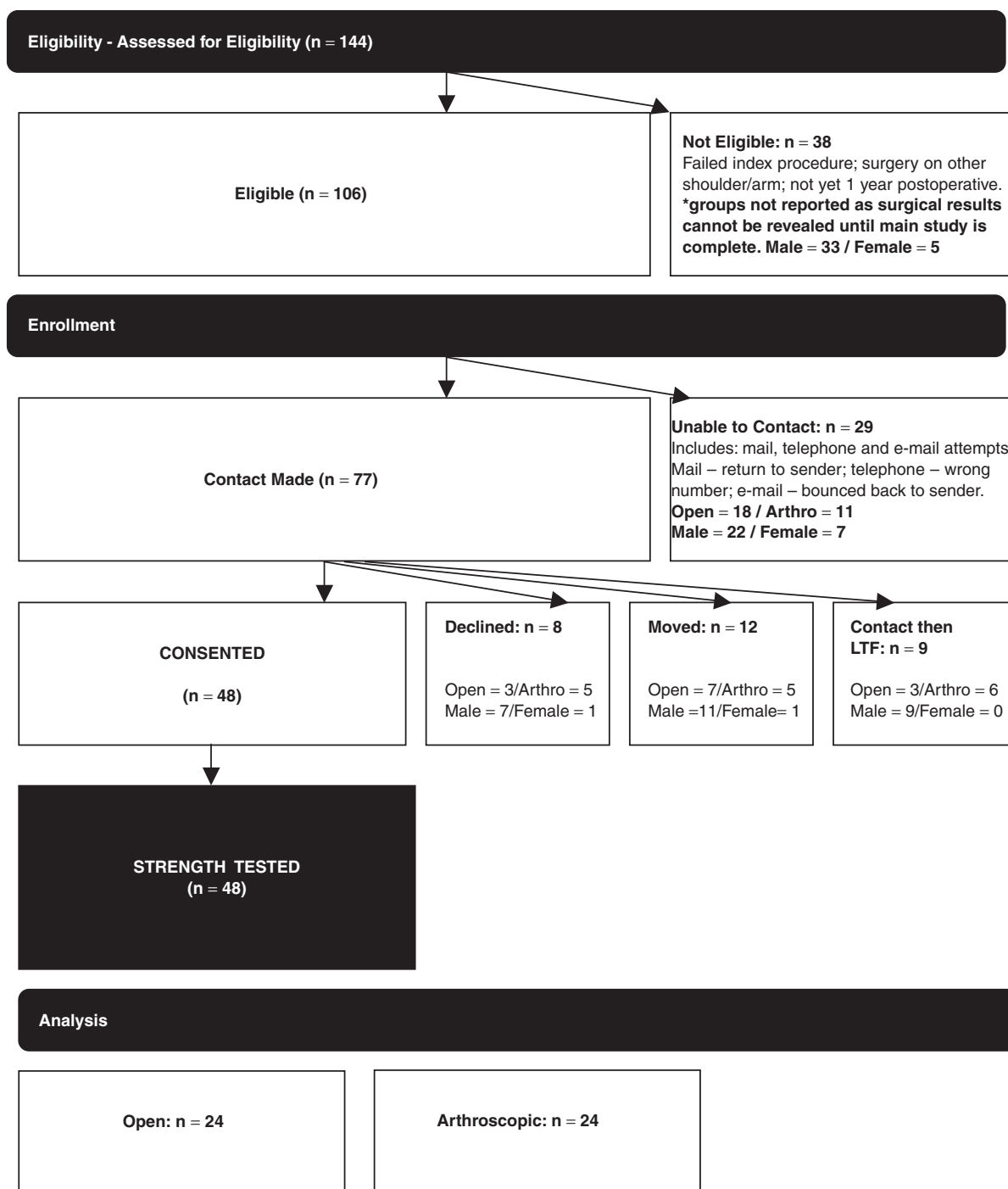


Figure 1. Flow diagram of patients. LTF, Lost to follow-up.

the dynamometer was aligned with the shoulder joint along the longitudinal axis of the humerus through the olecranon. The seat and subject were rotated 30° toward the testing arm so that measurements were performed in the scapular plane. From this position, external and internal testing ranges were set so that the shoulder would move through a 90° ROM: -40° of IR to 50° of ER.

Testing included a brief information session followed by a 5-minute warm-up on an upper body ergometer and light stretching. The nonoperative limb and slower angular velocity were tested first in all patients. Participants performed 2 submaximal repetitions on the dynamometer to become familiar with the testing procedure. A 1-minute rest was employed before full testing.

Strength Testing

Isokinetic concentric and eccentric peak strength tests were performed at angular velocities of 60 deg/s and 180 deg/s for both IR and ER of the shoulder. Three maximum repetitions were performed at each angular velocity with a 1-minute rest between velocities. The average peak moment was calculated as the average of the 3 repetitions.

Outcome Measures

Strength outcomes were calculated for angular velocities of 60 deg/s and 180 deg/s, for concentric and eccentric contractions, and for internal and external shoulder rotations. For each subject, the average peak moment from the 3 trials at each angular velocity was calculated. Strength deficits were calculated as the average peak moment for nonoperative contralateral limb minus operative limb. Percentage strength deficits were calculated as the difference between limbs (contralateral nonoperative minus operative) divided by the contralateral limb. All measurements were body-mass normalized and reported in Newton meters per kilogram (N·m/kg).^{4,7,14,16,27,28}

The primary outcome was isokinetic internal concentric contraction shoulder rotation strength at 60 deg/s. The major difference between the arthroscopic and open procedure is the disruption of the subscapularis tendon with an open repair. The subscapularis muscle functions as an internal rotator of the shoulder; therefore, IR was selected as the primary motion of interest. An angular velocity of 60 deg/s was selected as the primary angular velocity because velocities greater than 180 deg/s have been reported as having only fair reproducibility,⁵ and slower speeds are considered to be more representative of functional tasks.¹⁹ A 1-sided sample size calculation was performed using strength deficit estimates obtained from pilot testing, with an α of .05 and a β of .8 resulting in the need for 24 patients per group.

Secondary outcome measures included the American Shoulder and Elbow Surgeon (ASES) score and ROM data, which were recorded at baseline and at 1 year.

Statistical Considerations

Data were entered into Microsoft Excel (Microsoft Corp, Redmond, Wash) and imported into SPSS Version 14.0 (SPSS Inc, Chicago, Ill). An unpaired *t* test was performed for the primary outcome with significance set at $P < .05$. Confidence intervals (CIs) were calculated for all secondary measures. Regressions were performed in Stata Version 9.0 (Stata, College Station, Tex) on an exploratory basis for age, gender, and arm dominance.

RESULTS

Demographics and Baseline Characteristics

Forty-eight patients (38 men, 10 women) with an average age of 30.6 years (range, 18-59 years) consented to participate in the study. Demographic data are presented in Table 1. The

TABLE 1
Demographic Characteristics for the Open and Arthroscopic Surgical Groups

Characteristic	Open Group	Arthroscopic Group
Gender		
Men, n	18	20
Women, n	6	4
Mean age, y (SD)	30.8 (10.2)	30.4 (10.7)
Median body mass, kg	79.0 ^b	80.9 ^c
Mean surgery to test date, mo (SD)	20.5 (7.8)	18.2 (8.9)
Dominant arm as operative arm, n (%)	14 (58.3)	6 (25)
Baseline ASES ^a score (SD)	78.1 (15.6)	71.0 (19.3)
External rotation at side, deg (SD)		
Operative	60.7 (16.7)	56.1 (19.1)
Nonoperative	63.8 (18.5)	62.6 (17.1)
External rotation in abduction, deg (SD)		
Operative	84.3 (15.3)	85 (11.2)
Nonoperative	96.0 (14.6)	94.0 (9.6)

^aASES, American Shoulder and Elbow Surgeon score; SD, standard deviation.

^b25th percentile, 71.2; 75th percentile, 92.5.

^c25th percentile, 74.0; 75th percentile, 90.2.

2 groups were similar in age, mass, gender, and time from surgery to strength testing. With respect to which arm was operated on (dominant vs nondominant), 58.3% of patients in the open group had surgery on their dominant arm compared with only 25% in the arthroscopic group. Baseline ASES scores were similar between the 2 groups (Table 1).

Primary Outcome (Concentric Internal Rotation at Strength 60 deg/s)

No statistical differences were detected between operative groups for concentric IR strength at 60 deg/s ($P = .677$; difference = 0.011 N·m/kg; 95% CI, -0.043 to 0.066) (Table 2). Two outliers were identified in the open group; both patients were men who had surgery on their nondominant arm with body masses of 72 kg and 101 kg. One patient indicated he was having trouble contracting the muscles in his operative arm during both concentric and eccentric testing at 60 deg/s but did not report any episodes of instability. When data for the outliers were removed from the dataset, the *P* value remained relatively unchanged ($P = .691$; 95% CI, -0.058 to 0.039).

Secondary Outcomes

Group means, the differences between groups, and CIs for all secondary strength outcomes are presented in Table 2. Internal rotation strengths for both groups are similar with the exception of 180 deg/s concentric contraction. At 180 deg/s,

TABLE 2
Mean Strength Deficit (Nonoperative Minus Operative Limb) and Confidence Intervals for Peak Moment Strength Deficits^a

Internal Shoulder Rotation	Open Procedure, ^b Mean Deficit (SD)	Arthroscopic Procedure, ^b Mean Deficit (SD)	Between Group Difference ^c (95% CI)
60 deg/s concentric ^d	0.065 (0.09)	0.054 (0.09)	0.011 (−0.043 to 0.066)
180 deg/s concentric	0.024 (0.11)	−0.030 (0.09)	0.054 (−0.003 to 0.112)
60 deg/s eccentric	0.083 (0.12)	0.063 (0.17)	0.020 (−0.067 to 0.106)
180 deg/s eccentric	0.064 (0.13)	0.066 (0.16)	−0.002 (−0.085 to 0.081)
External Shoulder Rotation	Open Procedure, ^b Mean Deficit (SD)	Arthroscopic Procedure, ^b Mean Deficit (SD)	Between Group Difference ^c (95% CI)
60 deg/s concentric	0.068 (0.11)	0.088 (0.06)	−0.020 (−0.075 to 0.034)
180 deg/s concentric	0.040 (0.08)	0.039 (0.06)	0.001 (−0.040 to 0.043)
60 deg/s eccentric	0.064 (0.09)	0.049 (0.09)	0.015 (−0.038 to 0.067)
180 deg/s eccentric	0.022 (0.10)	0.069 (0.06)	−0.047 (−0.098 to 0.003)

^aValues are reported as N·m/kg. CI, confidence interval; SD, standard deviation.

^bA negative value in either the open or arthroscopic column implies the operative arm was stronger than the nonoperative arm.

^cThe mean difference was calculated as open minus arthroscopic.

^dPrimary outcome measure.

TABLE 3
Internal and External Rotation Strength Deficits Expressed as a Percentage^a

Internal Shoulder Rotation	Open Group, % Strength Deficit Mean (SD)	Arthroscopic Group, % Strength Deficit Mean (SD)
60 deg/s concentric	10.1% (14.5)	7.4% (12.0)
180 deg/s concentric	2.9% (17.9)	−6.9% ^b (15.7)
60 deg/s eccentric	10.4% (13.9)	6.1% (23.4)
180 deg/s eccentric	7.3% (15.1)	8.0% (19.5)
External Shoulder Rotation	Open Group, % Strength Deficit Mean (SD)	Arthroscopic Group, % Strength Deficit Mean (SD)
60 deg/s concentric	17.0% (27.6)	20.6% (16.4)
180 deg/s concentric	12.3% (24.7)	9.4% (19.4)
60 deg/s eccentric	12.5% (17.9)	10.3% (18.2)
180 deg/s eccentric	3.1% (21.6)	11.9% (11.8)

^aDifference between limbs (uninjured minus operative) divided by the uninjured limb × 100. SD, standard deviation.

^bA negative percentage deficit demonstrates a relative strength gain; the operative limb is stronger than the nonoperative control limb.

the arthroscopic group mean was negative, indicating the operative arm was stronger than the nonoperative arm, resulting in a comparatively large difference of 0.05 N·m/kg.

Mean ER strength values suggest that strength deficits exist in the operative arm when compared with the contralateral nonoperative limb. The nonoperative arm was stronger than the operative arm across almost all measures. This is true even for the open stabilization group in whom 60% of the subjects had their surgery on their dominant limb. Eccentric ER strength at 180 deg/s produced the largest difference between groups (0.047 N·m/kg) (Table 2).

Strength deficits expressed as a percentage of the non-surgical limb are presented in Table 3. For IR, both groups demonstrated strength deficits ranging from −6.9% to 10.4%. Although large standard deviations exist in these groups, the overall trend is showing consistent strength deficits across angular velocities and contraction types. External rotation testing shows consistent strength

deficits in the operative limb in both surgical groups, ranging from 3.1% to 20.6%.

There was no evidence to suggest a difference between groups in mean ASES scores at 1 year after surgery: open = 93.3 (SD, 9.67); arthroscopic = 92.1 (SD, 11.6); difference = 1.2; 95% CI, −5.14 to 7.40. Range of motion at 1 year after surgery showed similar results for both the open (IR = 66.1 [SD, 18.1]; ER at side = 43.5 [SD, 14.6]; ER in abduction = 91.5 [SD, 8.9]) and arthroscopic groups (IR = 71.5 [SD, 19.6]; ER at side = 46.3 [SD, 14.1]; and ER in abduction = 88.2 [SD, 17.6]).

Exploratory

Linear regression analyses revealed that surgery on a patient's nondominant arm is predictive of strength deficit (Table 4). The strength deficits were greater if the nondominant arm was the operative arm, regardless of surgery type (open or arthroscopic).

TABLE 4
Linear Regression Analysis of Strength Deficit

Predictor	Coefficient, N·m/kg	Standard Error	Statistic, <i>t</i>	<i>P</i> Value
Dominant arm is operative arm	-0.09096	0.03760	-2.42	.020
Constant	0.12573	0.02427	5.18	<.001

DISCUSSION

The current standard of care for recurrent anterior shoulder dislocation is surgical stabilization using either an arthroscopic or open technique. Comparison of these techniques has generally used redislocation rates as the primary outcome measure without a detailed examination of strength.

The results of this clinical trial demonstrated no significant isokinetic strength deficits when directly comparing the operative arms of patients undergoing an arthroscopic versus open surgical stabilization. Our study demonstrated both IR and ER strength deficits after open (IR = 2.9% to 10.4%; ER = 3.1% to 17%) and arthroscopic procedures (IR = -6.9% to 8.0%; ER = 9.4% to 20.6%). Interestingly, the ER deficits were larger than the IR deficits (in both groups). This suggests that, in this patient population using the described open surgical technique, violation of the subscapularis does not conclusively result in an IR strength deficit. Instead, patients in both groups exhibit both IR and ER deficits, which are consistent with either the inability of the shoulder joint to achieve strength in the operative limb equal to the contralateral limb after these procedures or under-rehabilitation of the shoulder.

If directed rehabilitation protocols are unable to correct this deficit, an ER strength deficit could theoretically function as a protective mechanism against future dislocations. Under-rehabilitation could include any or all of the following: incomplete rehabilitation, program deficient in exercises for the internal and external rotators, lack of inclusion of scapular stabilization exercises in rehabilitation, or lack of continued conditioning after initial postoperative rehabilitation since surgery. Although the rehabilitation component of our study was generalizable (closely represents what happens in real practice), it does not permit us to make conclusions regarding its effects on the results. However, similar ASES scores suggest the groups had equal rehabilitation as they regained equal function. The relationship between strength and function is not fully understood; this is an important area of future research in this population. In order to further elucidate the cause of the strength deficits, we must determine if the identified strength deficits can be eliminated with a focused and aggressive rehabilitation protocol.

Although no difference in IR strength was found between the 2 groups, several issues must be taken into account when examining the data. The open Bankart repair group was repaired using a subscapularis split surgical approach as opposed to the historical standard of detaching the subscapularis tendon.² This has been the

evolution of this surgical technique at our institution and highlights the fact that both the arthroscopic and open techniques are continuing to evolve. This may account for the lack of strength deficit demonstrated in the open group, and thus the possibility of strength deficits in an open group with detachment of the subscapularis tendon is still in question. Future investigations, including an open repair group with detachment of the subscapularis tendon, would further delineate this issue.

Patients in this study were drawn from a population participating in a larger randomized trial. To reduce the potential for selection bias, eligible patients were contacted in a consecutive fashion by 1 individual using a standardized protocol. The distribution of characteristics such as surgical (treatment) group and gender for patients who declined, moved, or were lost to follow-up is similar to those patients who responded and participated in the study. Therefore, the authors suggest that the magnitude of distortion introduced by any potential bias would be negligible.

The issue of arm dominance could also play a role in our results. The exploratory regression analysis demonstrated that the strength deficits were less if the dominant arm was the surgical limb than if the nondominant arm was the surgical limb. The current study results could be skewed because the open surgical group had more patients who had surgery on their dominant arm (and thus less strength deficits) than the arthroscopic group. Unfortunately, there are no baseline data to explain the relationship between arm dominance and strength before surgery. This study provides evidence that arm dominance is a variable to consider in future clinical trials.

The strengths of this study include the randomized design with a well-recognized, objective outcome measure of isokinetic strength. The isokinetic strength testing followed a standardized, pilot-tested protocol performed by 1 individual blinded to treatment allocation. It is the first study to directly compare strength outcomes between the open and arthroscopic surgery types. We attempted to perform comprehensive strength testing, including both concentric and eccentric contractions, with 2 angular velocities. Testing was performed in a functional position: the scapular plane and at 30° of flexion.

In conclusion, there is no evidence of a difference in 1-year postoperative shoulder strength between patients having an arthroscopic versus an open subscapularis split shoulder stabilization procedure. Further study is required to determine if detachment of the subscapularis tendon yields increased IR strength deficits and, secondly, to evaluate the effect of different rehabilitation programs on postoperative strength.

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REFERENCES

1. Armstrong A, Boyer D, Ditsios K, Yamaguchi K. Arthroscopic versus open treatment of anterior shoulder instability. *Instr Course Lect.* 2004;53:559-563.
2. Bankart ASB. Recurrent or habitual dislocation of the shoulder-joint. *Br Med J.* 1923;2:1132-1133.
3. Bottoni CR, Smith EL, Berkowitz MJ, Towle RB, Moore JH. Arthroscopic versus open shoulder stabilization for recurrent anterior instability: a prospective randomized clinical trial. *Am J Sports Med.* 2006;34(11):1730-1737.
4. Castro MJ, McCann DJ, Shaffrath JD, Adams WC. Peak torque per unit cross-sectional area differs between strength-trained and untrained young adults. *Med Sci Sports Exerc.* 1995;27(3):397-403.
5. Durall CJ, Davies GJ, Kernozek TW, Gibson MH, Fater DCW, Straker JS. The reproducibility of assessing arm elevation in the scapular plane on the Cybex 340. *Isokinet Exerc Sci.* 2000;8:7-11.
6. Fabbriani C, Milano G, Demontis A, Fadda S, Ziranu F, Mulas PD. Arthroscopic versus open treatment of Bankart lesion of the shoulder: a prospective randomized study. *Arthroscopy.* 2004;20(5):456-462.
7. Falkel JE, Sawka MN, Levine L, Pandolf KB. Upper to lower body muscular strength and endurance ratios for women and men. *Ergonomics.* 1985;28(12):1661-1670.
8. Freedman KB, Smith AP, Romeo AA, Cole BJ, Bach BR Jr. Open Bankart repair versus arthroscopic repair with transglenoid sutures or bioabsorbable tacks for recurrent anterior instability of the shoulder: a meta-analysis. *Am J Sports Med.* 2004;32(6):1520-1527.
9. Goertzen M, Hille E, Schmitz S, Spahnke B. The value of arthroscopic labrum stapling in anterior shoulder dislocation [in German]. *Sportverletz Sportschaden.* 1990;4(3):130-134.
10. Green MR, Christensen KP. Arthroscopic versus open Bankart procedures: a comparison of early morbidity and complications. *Arthroscopy.* 1993;9(4):371-374.
11. Greis PE, Dean M, Hawkins RJ. Subscapularis tendon disruption after Bankart reconstruction for anterior instability. *J Shoulder Elbow Surg.* 1996;5(3):219-222.
12. Hartsell HD, Forwell L. Postoperative eccentric and concentric isokinetic strength for the shoulder rotators in the scapular and neutral planes. *J Orthop Sports Phys Ther.* 1997;25(1):19-25.
13. Hehl G, Lang E, Hoellen I, Kiefer H, Becker U. Arthroscopic capsule-labrum refixation in anterior shoulder dislocation. Primary or secondary management? [in German]. *Unfallchirurg.* 1996;99(11):831-835.
14. Hiemstra LA, Webber S, MacDonald PB, Kriellaars DJ. Knee strength deficits after hamstring tendon and patellar tendon anterior cruciate ligament reconstruction. *Med Sci Sports Exerc.* 2000;32(8):1472-1479.
15. Hobby J, Griffin D, Dunbar M, Boileau P. Is arthroscopic surgery for stabilization of chronic shoulder instability as effective as open surgery? A systematic review and meta-analysis of 62 studies including 3044 arthroscopic operations. *J Bone Joint Surg Br.* 2007;89(9):1188-1196.
16. Hoffman T, Stauffer RW, Jackson AS. Sex difference in strength. *Am J Sports Med.* 1979;7(4):265-267.
17. Kim SH, Ha KI, Kim SH. Bankart repair in traumatic anterior shoulder instability: open versus arthroscopic technique. *Arthroscopy.* 2002;18(7):755-763.
18. Lenters TR, Franta AK, Wolf FM, Leopold SS, Matsen FA III. Arthroscopic compared with open repairs for recurrent anterior shoulder instability. A systematic review and meta-analysis of the literature. *J Bone Joint Surg Am.* 2007;89(2):244-254.
19. Meeteren J, Roebroeck ME, Stam HJ. Test-retest reliability in isokinetic muscle strength measurements of the shoulder. *J Rehabil Med.* 2002;34(2):91-95.
20. Meller R, Krettek C, Gosling T, Wahling K, Jagodzinski M, Zeichen J. Recurrent shoulder instability among athletes: changes in quality of life, sports activity, and muscle function following open repair. *Knee Surg Sports Traumatol Arthrosc.* 2007;15(3):295-304.
21. Mohtadi NG, Bitar IJ, Sasyniuk TM, Hollinshead RM, Harper WP. Arthroscopic versus open repair for traumatic anterior shoulder instability: a meta-analysis. *Arthroscopy.* 2005;21(6):652-658.
22. O'Neill DB. Arthroscopic Bankart repair of anterior detachments of the glenoid labrum. A prospective study. *J Bone Joint Surg Am.* 1999;81(10):1357-1366.
23. Pavlik A, Csepai D, Hidas P, Banoczy A. Sports ability after Bankart procedure in professional athletes. *Knee Surg Sports Traumatol Arthrosc.* 1996;4(2):116-120.
24. Sachs RA, Williams B, Stone ML, Paxton L, Kuney M. Open Bankart repair: correlation of results with postoperative subscapularis function. *Am J Sports Med.* 2005;33(10):1458-1462.
25. Snyder SJ. Glenohumeral instability. In: Snyder SJ, ed. *Shoulder Arthroscopy.* Philadelphia, Pa: Lippincott Williams & Wilkins; 2002: 97-106.
26. Tingart M, Bathis H, Bouillon B, Neugebauer E, Tiling T. Surgical therapy of traumatic shoulder dislocation. Are there evidence-based indications for arthroscopic Bankart operation? [in German]. *Unfallchirurg.* 2001;104(9):894-901.
27. Wilmore JH. Alterations in strength, body composition, and anthropometric measurements consequent to a 10-week weight-training program. *Med Sci Sports.* 1974;6(2):133-138.
28. Wojtyls EM, Huston LJ. Neuromuscular performance in normal and anterior cruciate ligament-deficient lower extremities. *Am J Sports Med.* 1994;22(1):89-104.