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The influence of posterior acromial morphology on outcomes and return to pushups in young patients undergoing arthroscopic posterior capsulolabral repair

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Background: Prior evidence has identified specific posterior acromial morphology as significantly associated with unidirectional posterior shoulder instability. The purpose of this study is to determine the influence of posterior acromial morphology on the outcomes of arthroscopic posterior capsulolabral repair (APCLR) for unidirectional posterior shoulder instability. Additionally, we sought to determine the influence of posterior acromial morphology on the rate and time to return to pushups following APCLR.
Methods: We performed a retrospective review of prospectively collected data. The study included consecutive patients undergoing APCLR. Data collected included demographics, radiographic measurements including posterior acromial height (PAH) and posterior acromial tilt on preoperative scapular-Y radiographs, and patient-reported outcome measures at the preoperative and postoperative visits. In addition, starting at 6 months postoperative, patients were asked if they could perform pushups defined as at least 10 repetitions. At the final follow-up, we collected the number of pushups patients were able to perform.
Results: Thirty-two consecutive patients underwent APCLR with a mean follow-up of 26 months (range, 12-41). Significant improvement from preoperative to 2 years postoperative was demonstrated in Subjective Shoulder Value (50-85), VAS (6-2.5), American Shoulder and Elbow Surgeons (48 to 83), and Western Ontario Shoulder Instability (WOSI) (1437-777), $P = .001$. The recurrent instability rate was 3/32 (9%). Patients with PAH > 23 (N = 17) had a recurrent instability rate of 18% (3/17) versus PAH ≤ 23 (N = 15) 0% (0/15), worse WOSI scores ($P = .41$), and a lower number of pushups ($P = .48$). The percentage of patients reporting the ability to perform pushups was (6 months/1 year/2 years) (50%/78%/95%). The mean number of pushups reported at the final follow-up was 33 (range, 1-60).
Discussion: Following APCLR, approximately 50% of patients resume pushups at 6 months postoperatively, and 80% return at 1 year. Patients reported performing a mean of 33 pushups following APCLR at the final follow-up. Patients with a PAH greater than 23 on preoperative scapular-Y radiographs had a higher rate of recurrent posterior instability, worse WOSI scores, and lower return to pushups; however, the results did not meet statistical significance. Therefore, future larger studies are needed to determine if posterior acromial morphology is independently associated with worse outcomes and increased recurrent instability rates following APCLR.

Posterior shoulder instability is becoming increasingly recognized in young instability populations.[22,23,26] Arthroscopic posterior capsulolabral repair (APCLR) with suture anchors is a well-established surgical solution for patients with posterior labral tears and symptomatic unidirectional posterior shoulder instability with reliable improvement in stability, pain, and function.[2-4,6,10,12,15,19-21]

Prior studies have identified radiographic variables significantly associated with posterior shoulder instability and outcomes of APCLR including glenoid retroversion, chondrolabral version, glenoid dysplasia, glenoid width, posterior capsular area, and posterior acromial morphology.[3,7,15-17] Meyer et al performed a retrospective study of patients with unidirectional posterior

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instability who were age- and sex-matched to a cohort of patients with unidirectional anterior instability.[16] They found that posterior acromial height (PAH) was significantly greater in the posterior instability group compared with the anterior instability group (30.9 versus 19.5 mm; $P < .001$). With a cutoff value of PAH of 23 mm, the odds ratio (OR) for posterior instability was 39. The authors hypothesized that this acromial position which is situated higher and more horizontal in the sagittal plane may provide less osseous restraint to posterior humeral translation. However, the influence of variations in posterior acromial morphology on the clinical outcomes of arthroscopic posterior labral repair is less clear.

Studies have also shown a high rate of return to sport (RTS) and preinjury activity level following APCLR.[18-21] However, the rate and time to RTS are limited by the heterogeneity of cohorts with various sports and activity levels. In young athletes, RTS is contingent on the ability to perform sport-specific tasks, pushing and pulling activities, and achieve strength and functional rehabilitation goals. Few studies have examined the rate and time to return to pushing and pulling activities following posterior shoulder stabilization.[25] Pushups are a common functional exercise for athletes and especially military personnel. In the military population, return to duty (RTD) is contingent on a successful return to high-level activity including the ability to perform pushups. However, there are no studies investigating the rate and time to return to pushups following posterior shoulder stabilization. This information would be valuable to athletes, trainers, coaches, and military commanders.

The purpose of this study is to determine the influence of posterior acromial morphology on the outcomes of APCLR for unidirectional posterior shoulder instability. Additionally, we sought to determine the influence of posterior acromial morphology on the rate and time to return to pushups following APCLR. We hypothesized that patients with increased PAH would have worse outcomes, lower number of pushups, and higher rates of recurrent posterior instability.

Methods

After institutional review board approval, we performed a retrospective review of prospectively collected data from a single institution. The study included all active duty military patients, aged 18 to 45 years old, undergoing APCLR for symptomatic unidirectional posterior shoulder instability. Thirty-seven patients were identified. Patients were excluded if they had less than 1-year clinical follow-up. Therefore, 32 of 37 (86%) patients were available with preoperative radiographs including a scapular-Y view, clinical outcome scores, return to pushup data, and at least 1-year clinical follow-up. A post hoc power analysis was performed. We utilized prior literature to determine the mean and standard deviation for the American Shoulder and Elbow Surgeons (ASES) score following APCLR[4,6] and determined that 32 patients achieved an 80% power, with an alpha error set at 0.05.

Indications

Patients were indicated for APCLR if they had a history, physical examination, and magnetic resonance imaging (MRI) or magnetic resonance arthrogram consistent with a posterior labral tear and symptomatic unidirectional posterior shoulder instability and had failed a trial of at least 6 weeks of nonoperative treatment with physical therapy and activity modification. All patients reported a history of shoulder pain and/or an instability event or apprehension in the flexed, adducted, and internally rotated position. Additionally, patients demonstrated physical examination findings consistent with posterior shoulder instability, including a positive jerk test and 2+ posterior load and shift.[8,11] Furthermore, examination under anesthesia demonstrated 2+ posterior load and shift according to the Antoniou classification.[1] We excluded those patients with a history of prior surgery, collagen disorders, functional shoulder instability, and those with a diagnosis of multidirectional instability. Lastly, we excluded patients with bone loss requiring an arthroscopic posterior bone augmentation procedure.

Operative technique

All arthroscopic posterior shoulder stabilization procedures were performed in the lateral decubitus position. Surgeries were performed by five orthopedic surgeons at a single institution which is a high-volume center with approximately 350 arthroscopic shoulder surgeries performed per year, with 200 of them being shoulder stabilizations. Surgical cases were equally distributed among all surgeons with no variation in techniques. After an examination under anesthesia, a standard diagnostic arthroscopy was performed. While viewing anteriorly, a curved arthroscopic liberator was used to free the torn labrum from the glenoid and scapular neck through the anterior mid-glenoid portal. A combination of rasps and an arthroscopic shaver was utilized for the biologic preparation of the posterior glenoid rim. Repairs were accomplished with two types of knotless suture anchors, Knotless Fibertak (Arthrex, Naples, FL, USA) and Mitek Proknot anchors (Mitek, Raynham, MA, USA) and was based on staff surgeon preference. A mean of 3.9 knotless suture anchors were used for APCLR. Patients underwent concomitant biceps tenodesis based on age, preoperative physical examination findings, surgeon preference, and arthroscopic findings of the superior labral biceps complex and rotator interval sling.

Rehabilitation

Postoperative rehabilitation consisted of shoulder immobilizer wear for 6 weeks with no active use of the arm and early initiation of passive range of motion. The therapy protocol emphasized protecting the posterior capsule with restrictions in internal rotation until 3 months postoperatively and avoidance of the flexion, adduction, and internal rotation position. All APCLRs were allowed to return to pushups and unrestricted activities at 6 months postoperatively, per the standard institutional rehabilitation protocol.

Data collection

Demographic data were collected for all patients, including sex, the laterality of surgery, patient hand dominance, military rank status (enlisted versus officer) and (junior versus senior enlisted), and the presence of anxiety or depression (Table I). Patient-reported outcomes collected included the Subjective Shoulder Value (SSV), ASES score, Visual Analog Scale (VAS) for pain, and the Western Ontario Shoulder Instability (WOSI) index at the preoperative visit, and short-term postoperative visits (3 months, 6 months, 1 year, and 2 years). At the 6-month, 1-year, and 2-year clinic visits, patients were asked if they could perform at least 10 continuous repetitions of pushups. Lastly, at the final follow-up, patients were asked the total number of continuous repetitions of pushups they could perform.

Radiographic measurements collected included glenoid version using Friedman angle[5] and was measured on a standard institutional MRI/magnetic resonance arthrogram. Additionally, we collected PAH (mm) and posterior acromial tilt (PAT) (degrees) on a standardized preoperative scapular-Y radiograph as described by Meyer et al[16] (Fig. 1 *A* and *B*). PAH was measured according to previously

Table I
Demographics.

Variables	Arthroscopic posterior labral repairs (N = 32)
Mean age, y, SD (range)	28 ± 6 (20-39)
Sex (male: female)	30:2
Laterality of surgery (R:L)	13:19
Hand dominance (R:L)	28:4
Enlisted: officer	30:2
Junior enlisted: senior enlisted	20:12
Depression/Anxiety (yes: no)	11:21
Glenoid version (degrees), SD (range)	−10 ± 8 (−3, −47)
Posterior acromial height (mm), SD (range)	24 ± 8 (5, 39)
Posterior acromial tilt (degrees), SD (range)	68 ± 8 (53, 88)
Preoperative Zone 2 biceps tenderness (yes: no) (%)	24:8 (75)
Concomitant biceps tenodesis (yes: no)	3:29
Mean follow-up (mo), SD (range)	26 ± 8 (12-41)

SD, standard deviation; *R*, right; *L*, left; *mm*, millimeters.

described methods[16] by a perpendicular line drawn from the reference line (connecting the inferior angle of the scapula with the center of the intersection of the small arms of the scapular "Y") to the most posterior point of the inferior aspect of the acromion. The PAH (blue bracket) is then measured as the distance from the center of the intersection of the small arms of the scapular "Y" to the perpendicular line. PAT is determined by measuring the angle formed by the reference line (connecting the inferior angle of the scapula with the center of the intersection of the small arms of the scapular "Y") and a line connecting the most posterior point of the inferior aspect of the acromion to the most anterior point of the inferior aspect.

We performed a comparative analysis between those patients with PAH greater than 23 mm (N = 17) and PAH ≤ 23 (N = 15). We selected a PAH of 23 mm as the cutoff value based on the study by Meyer et al which identified the OR for developing posterior instability with a PAH of >23 mm was 39 (95% confidence interval = 10 to 155; $P < .001$).[16]

Statistical analysis

Descriptive statistics were determined for the study cohort's variables. Univariate analysis was performed for all variables. The Mann-Whitney nonparametric test for unpaired samples was used for continuous variables, and the 2-tailed Fisher exact test was used for categorical data. A multivariate linear regression was performed to identify variables significantly associated with the number of pushups postoperatively. Data were checked for multicollinearity with the Belsley-Kuh-Welsch technique. Heteroskedasticity and normality of residuals were assessed, respectively, by the Breusch-Pagan test and the Shapiro-Wilk test. A P value < .05 was considered statistically significant. Statistical analysis was performed with the online application EasyMedStat (version 3.20.4 www.easymedstat.com; EasyMedStat, Levallois-Perret, France).

Results

Thirty-two consecutive patients were identified following APCLR for unidirectional posterior shoulder instability with a mean age of 28 years (range, 20-39) and a mean follow-up of 26 months (range, 12-41). The mean glenoid version was −10 degrees (range, −3 to −47), mean PAH 24 mm (range, 5-39), and mean PAT 68 degrees (range, 53-88) (Table I). Seventy-five percent of patients had preoperative Zone 2 biceps groove tenderness. Zone 2 is defined as the region from the distal margin of the subscapularis tendon to the proximal margin of the pectoralis major tendon.[24] Three of 32 (9%) underwent concomitant biceps tenodesis. Significant improvement in SSV, VAS, ASES, and WOSI was shown at both 1 and 2 years postoperative, SSV 80, VAS 2, ASES 80, WOSI 464, $P = .001$, and SSV 85, VAS 2.5, ASES 83, WOSI 777, $P = .001$. The percentage of patients reporting the ability to perform pushups was: (6 months/1 year/2 years) (50%/78%/95%) (Fig. 2). The mean number of pushups patients reported they could perform at the final follow-up was 33 (range, 1-60).

In multivariate analysis, preoperative VAS (β = −3.5, [−6.4; −0.6], $P = .02$) was associated with lower values of the number of pushups postoperatively. No other demographic or radiographic variables were significantly associated with the reported number of pushups postoperatively.

Influence of posterior acromial height on outcomes

We performed a comparative analysis between those patients with PAH greater than 23 mm (N = 17) and PAH ≤ 23 (N = 15). We selected a PAH of 23 mm as the cutoff value based on the study by Meyer et al which identified the OR for developing posterior instability with a PAH of >23 mm was 39 (95% confidence interval = 10 to 155; $P < .001$).[16] The mean PAH was 29.5 mm for the PAH>23, and 16.7 mm for the PAH ≤ 23. There was no significant difference ($P = .41$) in the rate and time to returning to pushups or postoperative WOSI scores; however, there was a trend toward worse 2-year postoperative WOSI scores in the group of patients with a larger PAH (PAH>23: WOSI 763 (interquartile range 602); PAH ≤ 23: WOSI 567 (interquartile range 731). Additionally, the PAH >23 group had 3 patients (18%) recurrence rate whereas the PAH ≤ 23 group had no patients with recurrent instability (Table II).

Additionally, we examined the PAT. The mean PAT was 68 degrees ± 8 (range, 53-88). On multivariate linear regression, PAT was not independently significantly associated with the mean number of pushups ($P = .77$) or WOSI scores ($P = .66$) at the final follow-up. Furthermore, there was no significant difference in the PAT between the two groups of PAH greater than 23 mm (N = 17) and PAH ≤ 23 (N = 15).

Three of 32 patients underwent a concomitant biceps tenodesis at the time of arthroscopic posterior labral repair. The mean age of the patients was 35 (range, 32-39). These patients underwent arthroscopic posterior labral repair with biceps tenodesis as the preoperative anterior shoulder pain and Zone 2 biceps tenderness[24] was a significant component of their shoulder pain. Additionally, these patients all had 100% improvement with a preoperative ultrasound-guided biceps groove injection. At the final follow-up, the median outcome scores were: SSV 85, ASES 85, VAS 3, and WOSI 821. No patients had recurrent shoulder instability or reoperation. The mean number of pushups was 30 (range, 25-35), which is slightly lower than the remainder of the cohort.

Complications, recurrence, and reoperations

There were no intraoperative or postoperative complications. Three of 32 (9%) patients reported recurrent posterior shoulder instability with feelings of subluxation events. These patients had the following PAH measurements: 28 mm, 30 mm, and 24 mm. The first patient, PAH = 28, had a traumatic recurrent posterior instability event 15 months after surgery, and repeat imaging demonstrated a retear of the posterior labrum. The patient elected to not undergo further surgery and underwent medical separation from the military. The second patient, PAH = 30 mm, denied any traumatic event but reported developing gradual recurrent posterior shoulder subluxations at his 2-year follow-up. He also declined further surgery. Lastly, the third patient, with a PAH of 24 mm, had a recurrent instability episode at 12 months postoperatively once he had returned to active duty. He elected to undergo a medical separation from the military.

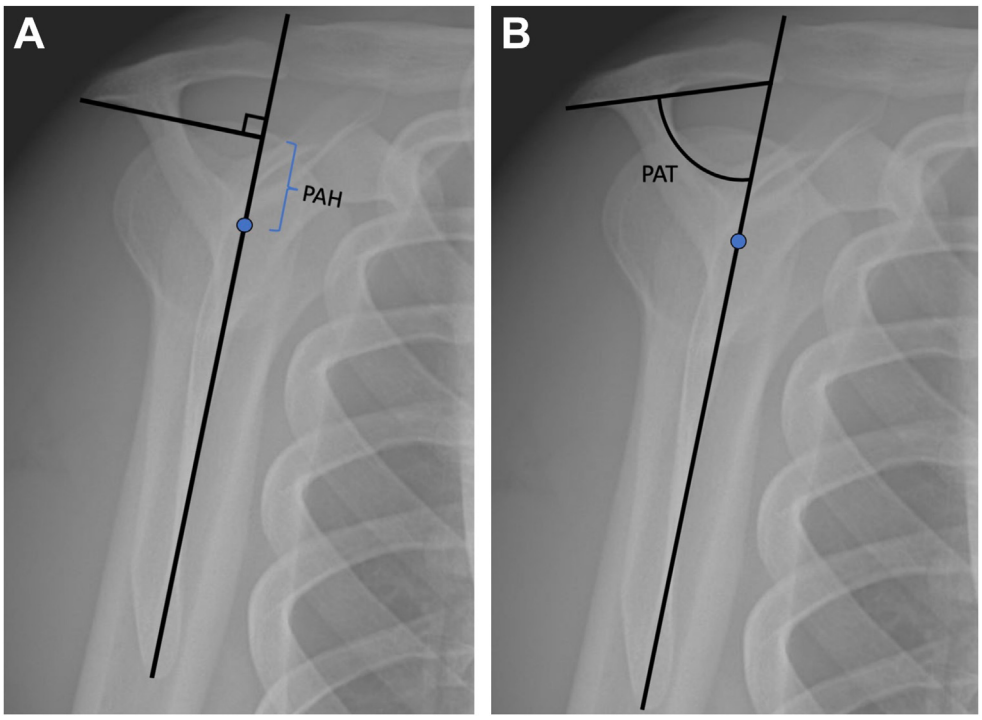

Figure 1 **A**, **B**: Scapular Y radiograph demonstrating the posterior acromial height (PAH) and posterior acromial tilt (PAT) measurements.

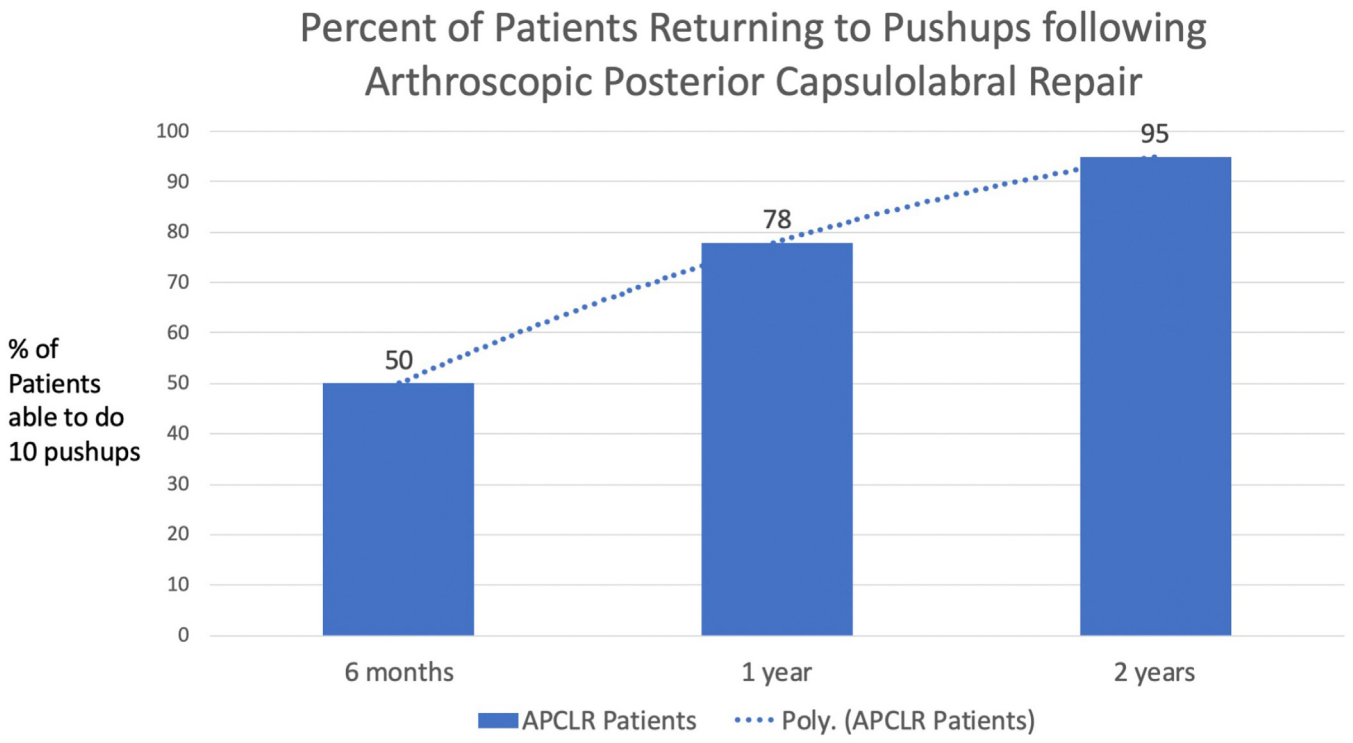

Figure 2 Graph depicting the speed of recovery and rate and time to return to pushups following arthroscopic posterior capsulolabral repair. *APCLR*, arthroscopic posterior capsulolabral repair.

One of 32 (3.1%) patients underwent a reoperation. This patient had no recurrent instability but had continued Zone 2 biceps groove tenderness and had significant improvement in pain after an ultrasound biceps groove injection. The patient underwent an uncomplicated reoperation for diagnostic shoulder arthroscopy and open subpectoral biceps tenodesis.

Six of 32 patients (19%) underwent medical separation from the military for their shoulder condition; therefore, the rate of RTD following APCLR was 81%. At the time of medical separation from the military at 1 year postoperatively, 4 of the 6 patients were unable to perform 10 continuous repetitions of pushups.

Table II
Comparison of posterior instability outcomes based on posterior acromial height (PAH).

Variables	PAH > 23 (N = 17) Mean: 29.5 mm	PAH ≤ 23 (N = 15) Mean: 16.7 mm	*P* value
Mean age, y, SD	28 ± 7	28 ± 4	.45
Sex (male: female)	17:0	13:2	.21
Laterality (right: left)	7:10	6:9	.99
Number of suture anchors	4.1	3.9	.47
Posterior acromial tilt (degrees)	70	66	.15
Glenoid version (degrees)	−9 (−5, −15)	−11 (−5, −47)	.61
Preop WOSI (IQR), n = 32	1399 (124)	1505 (277)	.24
6 mo WOSI (IQR), n = 32	770 (979)	790 (604)	.93
1 y WOSI (IQR), n = 32	643 (673)	614 (557)	.68
2 y WOSI (IQR), n = 21	763 (602)	567 (731)	.41
6 mo–able to pushups (%)	57%	42%	.70
1 y–able to pushups (%)	87%	67%	.36
2 y–able to pushups (%)	92%	100%	.99
Mean number of pushups, range	31 (1-60)	35 (5-60)	.48
Recurrent instability, n (%)	3 (18%)	0 (0%)	.23

PAH, posterior acromial height; *SD*, standard deviation; *IQR*, interquartile range; *R*, right; *L*, left; *mm*, millimeters; *WOSI*, Western Ontario Shoulder Instability Index; *n*, number of patients available for follow-up at each postoperative time point.

Discussion

The primary findings of this study are that young military male patients undergoing APCLR patients undergoing APCLR have a high rate of return to pushups. Approximately 50% of patients resume pushups at 6 months postoperatively, and 80% return at 1 year. At 2 years, 95% of patients reported the ability to perform at least 10 continuous pushup repetitions, which indicates that it may take select patients up to 2 years to return to performing the pushup exercise. Patients reported performing a mean of 33 pushups at the final follow-up. A higher preoperative VAS pain score is significantly associated with return to a lower number of postoperative pushups. Additionally, we examined the influence of posterior acromial morphology on outcomes, recurrent instability, and return to pushups. We found that patients with PAH > 23 had a higher rate of recurrent posterior instability (19% versus 0%) ($P = .23$), lower WOSI scores ($P = .41$), and a lower mean number of pushups ($P = .48$). Therefore, it should be noted that although there was a difference in recurrence rate and patient-reported outcome scores, the results were not statistically significant, and future larger studies are needed to determine the impact of PAH and morphology on outcomes of APCLR.

The outcomes following APCLR are well established and multiple studies have demonstrated good outcomes with high rates of RTS and RTD.[2-4,6,10,12,15,19-21] The time to RTS following APCLR is less clear. Recently, Wilson et al evaluated the ability of 43 patients following arthroscopic shoulder stabilization surgery to meet expected rehabilitation goals by using standardized objective evaluations of strength and physical function. In this cohort, there were 15 patients who underwent arthroscopic posterior shoulder stabilization. At 6 months postoperatively, they found that a substantial number of athletes did not meet the expected goals for their operative shoulder in achieving appropriate function and strength.[25] One of the functional exercises tested in this assessment is the Closed Kinetic Chain Upper Extremity Stability (CKCUES) test which is performed in a pushup position and measured by alternating touches. This functional exercise is very similar to the pushup. In their series of young athletes, only 1 patient failed this test, and the mean number of touches for the CKCUES test was 23.4. Only 23% did not meet the goal of 21 touches. However, they did not find that repair type (anterior versus posterior) affected the results. Although this test is similar to the pushup exercise, it does not involve a "down repetition" which places considerable loads on the glenohumeral and scapulothoracic musculature.[9,14] To our knowledge, there are no studies which have evaluated the rate or time to return to pushups following APCLR.

Interestingly, when we separated the patients into two groups based on their PAH, those with PAH greater than 23 had a lower median WOSI score (763) versus PAH ≤ 23 (567), although this did not reach statistical significance ($P = .41$). Additionally, the recurrent instability rate was higher with all 3 failures (3/17) 18% occurring in the group with PAH > 23. Meyer et al performed a retrospective study of patients with unidirectional posterior instability who were age- and sex-matched to a cohort of patients with unidirectional anterior instability.[16] They found that PAH was significantly greater in the posterior instability group compared with the anterior instability group (30.9 versus 19.5 mm; $P < .001$). With a cutoff value of PAH of 23 mm, the OR for posterior instability was 39. They hypothesized that the posterior acromion which is situated higher and more horizontal in the sagittal plane may provide less osseous restraint to posterior humeral translation. Furthermore, a more recent study by Livesey et al evaluated whether acromial morphology influences the extent or pattern of posterior glenoid bone loss in a cohort of patients with posterior glenohumeral instability. In this retrospective multicenter MRI study, the authors found that an acromion with a flatter sagittal tilt and less posterior coverage is associated with glenoid bone loss in the setting of posterior glenohumeral instability.[13] In our cohort, the mean PAH was 23.5 (range, 5-39). In addition, in patients with a PAH > 23, they had not only worse postoperative WOSI scores, but a lower rate of return to pushups and a lower overall mean number of pushups at 2-year follow-up. We acknowledge that although there was a difference in recurrence rate and outcomes scores, this difference was not statistically significant. However, this is the first study to evaluate the influence of posterior acromial morphology on outcomes following treatment of posterior shoulder instability. Future investigation is needed in larger cohorts to determine if posterior acromial morphology is an independent variable significantly associated with outcomes following posterior shoulder instability.

We also collected the ability of patients to perform pushups at 3 months postoperatively. Seven of 32 patients (22%) reported the ability to perform at least 10 continuous repetitions of pushups. Of these patients, their median WOSI at 3 months was 726, and at 2-year follow-up the median WOSI was 559. The mean number of pushups reported at the final follow-up was 45 (range, 30-60), which is greater than the mean of 33 pushups for the entire cohort. No patients reported recurrent posterior shoulder instability at 2-year follow-up. Although surgeons and physical therapists would not allow patients to return to pushups this soon after APCLR, these data are interesting and provides insight into the speed of recovery in select individuals. These data suggest that patients self-reporting

of ability to do pushups at 3 months following APCLR are a good prognostic indicator of functional recovery. Although these data are limited by patient reporting bias, further investigation is needed.

Strengths of the study include the detailed collection of preoperative and postoperative patient-reported outcomes scores at granular time points and the novelty of tracking return to pushups at multiple clinical follow-up appointments after APCLR.

Limitations

Limitations of the study include its retrospective nature and the inherent limitations of patient self-reporting of return to pushups.[27] Additionally, this cohort of young military males may not be generalizable to a similar young male civilian cohort. Also, we acknowledge that the pushup is a common functional exercise performed by both military and civilian patients. However, military athletes are tested annually on the number of pushups they can continuously perform; therefore, the reported number of pushups in this cohort may be different than a similar age-matched civilian cohort. Furthermore, we did not collect the number of pushups patients were able to perform preoperatively; therefore, we do not have a preoperative comparison. Lastly, this is a small cohort and these findings need to be confirmed in a larger study with a longer follow-up.

Conclusion

Following APCLR, approximately 50% of patients resume pushups at 6 months postoperatively, and 80% return at 1 year. Patients reported performing a mean of 33 pushups following APCLR at the final follow-up. Patients with a PAH greater than 23 on preoperative scapular-Y radiographs had a higher rate of recurrent posterior instability, worse WOSI scores, and lower return to pushups; however, the results did not meet statistical significance. Therefore, future larger studies are needed to determine if posterior acromial morphology is independently associated with worse outcomes and increased recurrent instability rates following APCLR.

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