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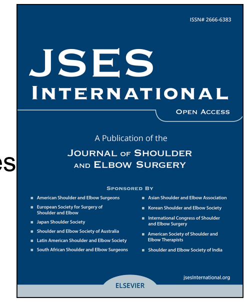

Criteria-based return-to-sport testing helps identify functional deficits in young athletes following posterior labral repair but may not reduce recurrence or increase return to play

Rajiv P. Reddy, BS, Ajinkya Rai, BS, Matthew Como, BS, Romano Sebastiani, BS, Christopher Como, MD, Nathan Hyre, BS, Alex Fails, DPT, Liane M. Miller, MD, Bryson Lesniak, MD, Adam Popchak, PhD, Albert Lin, MD

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Criteria-based return-to-sport testing helps identify functional deficits in young athletes following posterior labral repair but may not reduce recurrence or increase return to play

Running Title: Return to sport testing following posterior stabilization

Rajiv P. Reddy BS, Ajinkya Rai BS, Matthew Como BS, Romano Sebastiani BS, Christopher Como MD, Nathan Hyre BS, Alex Fails DPT, Liane M. Miller MD, Bryson Lesniak MD, Adam Popchak PhD, Albert Lin MD

Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, Pittsburgh, PA, USA

Corresponding Author: Albert Lin MD, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh, 3200 S. Water St, Pittsburgh, PA 15203, USA, Email: lina2@upmc.edu

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A waiver of consent was granted by the Institutional Review Board at the University of Pittsburgh for STUDY20030061. Retrospective chart review - waiver of consent was granted. No formal informed consent was obtained for patient inclusion in this study as no patient identifiers are included in the study.

ABSTRACT

Background: The purpose of this study was to compare recurrent instability and return to play (RTP) in young athletes who underwent clearance to full activity based on a validated return to sport (RTS) test to those who underwent time-based clearance following primary posterior labral repair.

Methods: This was a retrospective review of athletes with posterior shoulder instability who underwent primary arthroscopic posterior labral repair from 2012-2021 with minimum one-year follow-up. Patients who underwent RTS testing at a minimum of 5 months postoperatively were compared to a historic control cohort of patients who underwent time-based clearance.

Results: There were 30 patients in the RTS cohort and 67 patients in the control cohort (mean follow-up 32.1 and 38.6 months, respectively). Of the 30 patients who underwent RTS testing, 11 passed without failing any sections, 10 passed while failing one section, and 9 failed the RTS test by failing 2+ sections. No differences were found between the RTS and control cohort in the incidence of recurrent instability (6.7% vs 9.0%), overall RTP (94.7% vs 94.3%), RTP at the same level as prior to injury (84.2% vs 80.0%), recurrent pain/weakness (23.3% vs 25.4%), or revision surgery (0% vs 3.0%), respectively.

Discussion: While return to sports testing in young athletes after posterior labral repair did not reduce recurrence or improve return to play compared to time-based clearance, two-thirds of athletes who underwent testing failed at least one section, indicating some functional deficit. Thus, return to sport testing may help guide postoperative rehabilitation following posterior stabilization.

Level of Evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: return to sport; posterior instability; rehabilitation; testing; recurrent instability; athlete; posterior labral repair

Posterior shoulder instability is a relatively uncommon condition in the general population, accounting for 2-10% of all shoulder instability[2,8,22]. However, this incidence is as high as 22% in athletes, especially those participating in contact or overhead sports[8,19]. In overhead athletes, posterior labral injury is often insidious due to repetitive microtrauma and can present in a subtle manner including decline in performance[29]. Contact athletes, on the other hand, often experience acute instability episodes due to blunt force in a provocative arm position[8,19]. In both mechanisms, compromise of the posteroinferior capsule and the posterior labrum often co-occur[2,20]. Thus, when surgical management is indicated, arthroscopic posterior labral repair and capsulorrhaphy have been shown to have high rates of return to play (RTS), between 80-100% for collision athletes and 85.2-100% for overhead athletes[12,17].

Despite these relatively high rates of RTS after posterior stabilization, recurrent instability occurs at a rate of up to 11% in athletes and 17.7% in the general population[13,27]. Additionally, many athletes fail to return to sport at the same level as prior to injury[7,18]. After posterior shoulder stabilization, surgeons commonly clear patients for full activity on a time-from-surgery basis, often at around 6 months postoperatively. Recent literature using a validated, objective RTS testing protocol, however, has demonstrated that around 90% of competitive athletes still have residual and functional limitations at this timepoint following anterior shoulder stabilization surgeries[11,24,31]. Thus, clearance to full activity based on a validated RTS testing protocol, rather than time-based clearance, may be a promising avenue for increasing rates of return to sport and reducing recurrent posterior instability following arthroscopic posterior stabilization.

Clearance based on RTS testing has been extensively validated after ACL reconstruction, with an 84% reduction in re-injury risk compared to time-based clearance and is widely considered standard of care following these procedures[14]. Furthermore, a recent study by Drummond et al found that full clearance via criteria-based RTS testing after arthroscopic Bankart repair was associated with a four-fold reduction of recurrent anterior instability compared to athletes cleared via time-based clearance at a minimum of 1-year follow-up[11].

Thus, the purpose of this study was to investigate the effect of the same return to sport testing protocol on recurrence and return to play (RTP) rates following arthroscopic posterior shoulder stabilization surgery compared to time-based clearance. We hypothesized that patients who underwent RTS testing and were subsequently cleared would have a lower rate of recurrent instability and a higher rate of RTP compared to those who were cleared to return based on time from surgery.

METHODS

Study Design and Patient Selection

This was a retrospective cohort study that reviewed the electronic medical records of patients who underwent primary arthroscopic posterior labral repair (with or without SLAP repair) performed by two fellowship-trained orthopedic sports medicine surgeons at our institution from 2012-2021. A waiver of consent was granted by the Institutional Review Board at the University of Pittsburgh. All patients underwent arthroscopic posterior stabilization in the lateral decubitus position using standard arthroscopic techniques with labral repair and capsulorrhaphy. A concomitant SLAP repair was performed following diagnostic arthroscopic confirmation of

SLAP tear extension. SLAP repairs were performed using arthroscopic knotless suture anchor techniques through a low-profile percutaneous portal medial to the rotator cuff cable.

A minimum 1-year follow-up time from initial surgical stabilization was utilized for an individual to be included in the electronic medical record review. Exclusion criteria included open or revision procedures, patients above the age of 30 years at the time of surgery, patients with general joint hyperlaxity (score ≥ 4 according to the Beighton criteria[16], patients with glenoid bone loss, patients with concomitant rotator cuff injury, patients undergoing isolated anterior stabilization with or without concomitant SLAP tears, and patients with multidirectional instability.

Patients were separated into two groups based on whether they underwent criteria-based return to sport testing (RTS group) or time-based clearance (historic control group). The historic control group consisted of patients from 2012 to the end of 2016, whereas the RTS group consisted of patients from 2017 onwards, when the test was initiated and routinely implemented for all shoulder instability surgery. All patients in both groups initially underwent a standardized postoperative rehabilitation protocol for posterior labral repair surgery, which included three main phases, before either undergoing RTS testing or time-based clearance. Phase 1 (weeks 0-6) involved sling immobilization for 4 weeks with the initiation of pendulums at 2 weeks followed by formal physical therapy with passive range of motion (PROM) at 4 weeks, with limitations on internal rotation. Phase 2 (generally week 6 to week 12) involved initiation of active range of motion (AROM) with slow progressive strengthening via submaximal tissue loading, with a focus on dynamic stabilization and neuromuscular control. Phase 3 (generally week 12 to week 24) focused on the normalization of strength and neuromuscular control.

Between 5 and 6 months postoperatively, patients in the RTS group underwent criteria-based return to sport testing after approval from the surgeon during routine clinic visit. The RTS test was performed by a physical therapist using a previously validated protocol, similar to the one used by Drummond et al[11,24,31]. The battery of tests utilized in this study and their scoring were rigorously studied by Popchak et al and were concluded to have high validity and reliability for assessing shoulder function in young athletes[24]. The tests measured external and internal rotation strength with isokinetic and isometric methods as well as endurance with resisted external rotation. Isokinetic testing was measured on a Biodex System dynamometer (Shirley, NY, USA) using peak torque at 60 and 180 degrees per second (Figure 1). All Biodex testing was performed in a modified neutral position. Isometric external and internal rotation was measured at 0 and 90 degrees (Figure 2a and 2b). Patients were instructed to move through the range of IR and ER with maximum speed and power in both directions. The strength assessment at 60 degrees per second consisted of 5 repetitions, while the assessment at 180 degrees per second consisted of 10 repetitions, with a rest period of 1-2 min between tests. The peak torque generated for concentric movements of ER and IR at 60 and 180 degrees per second were taken as the measure of isokinetic strength. Participants were asked if they experienced any discomfort and if they could continue after each movement. The external rotation endurance test involved repetitions to failure with 5% of body weight at 0 and 90 degrees of abduction. For all strength assessments, patients were required to reach 90% of the values from the contralateral extremity in order to pass. Two additional tests of function were utilized, including the closed kinetic chain upper extremity stability (CKCUES) test and the unilateral seated shot-put (USS) test. The CKCUES consisted of touching the contralateral hand and returning to a base push-up position over 3 rounds of 15 active seconds with 45-second breaks (Figure 3). Touches per 15 seconds were averaged over three trials. Subjects passed with a minimum of 21 touches. The USS was a distance-based test of throwing a 2.72 kg medicine ball with a goal of achieving 90% of the contralateral side’s toss, while adjusting for hand dominance (Figure 4). The distance was averaged over three trials with 30-second rest periods between trials.

The results of the testing were conveyed to the surgeon for final approval for full clearance. Patients who passed all components of the RTS test were cleared to return to sports. Patients who failed only one component were given 4-6 weeks delayed clearance to return to sports after focusing on the specific deficit with the physical therapist during the intervening time period. Patients who failed multiple components of the test underwent additional formal rehabilitation to address deficits over a period of 4-6 weeks and repeated the test before final clearance. Once an athlete passed and was cleared to return to sport, final return to play was individualized based on the sport and injury pattern, including SLAP tear characteristics. For instance, a baseball player with a Type VIII SLAP repair of the throwing was cleared for a progressive throwing program after 5 months once they passed the RTS test, while a contact player was cleared to return to unrestricted activity with final return to play determined by the athletic training staff and coaches. This is especially important, as SLAP tears with posterior extension may represent different injury patterns than traumatic posterior inferior labral tears with SLAP tear extensions.

Patients in the historic control group did not undergo RTS testing and instead, were cleared for sports at a minimum of 6 months postoperatively at the discretion of the surgeon based on physical examination of symmetric ROM and strength to contralateral as well as lack of apprehension on instability testing. Clearance was delayed for patients who expressed apprehension or did not have adequate ROM and strength compared to contralateral side.

Data Collection and Outcomes

Baseline demographic variables of age, body mass index (BMI), hand dominance, and sex were recorded, along with activity status including sport played, position played, contact vs non-contact athlete, competitive athlete, and overhead athlete. Injury variables included side of injury, diagnosis, SLAP repair, number of anchors used, and whether or not RTS testing was employed.

The primary outcomes were recurrent instability (defined as having at least one documented recurrent subluxation/dislocation episode or physical exam demonstrating instability), RTP rate (both overall and at the same level as prior to injury), recurrent pain (defined as >3/10 pain on VAS) or weakness (self-reported and <5/5 on manual muscle testing), and revision surgery. Secondary outcomes were patient-reported outcomes (PROs) including pre and postoperative visual analog scale (VAS) and subjective shoulder value (SSV). VAS is a self-reported measure of pain from 0 to 10 taken at all clinic visits, with 0 being no pain and 10 being the worst pain. SSV is a self-reported measure from 0 to 100% taken at all clinic visits where the patient expresses their shoulder function as a percent of an entirely normal shoulder. All outcomes were collected at final follow-up during clinic visits.

Statistical Analysis

Outcomes and demographic variables for each group were compared using either independent samples T-test for parametric continuous data, and Chi-squared or Fisher's Exact Test for categorical data. A post-hoc power analysis was conducted for recurrence rates. With the effect size observed and a power of 0.8 to determine the true difference in recurrence at an alpha of 0.05, the study would need upwards of 4800 patients. All statistical analysis was performed using SPSS, version 26 (IBM Corp., Armonk, NY, USA) by an individual that did not participate in data collection. Two-tailed P values <0.05 were considered statistically significant.

RESULTS

Study Cohort

A total of 97 patients met the inclusion criteria and were included in the study. Of these 97 patients, 30 underwent RTS testing and 67 underwent time-based clearance. There were no differences between the RTS and control group with regards to age (19.9 ± 4.2 years vs 22.5 ± 4.7 years), BMI (27.2 ± 3.9 vs 26.2 ± 5.8), sex (80.0% vs 68.7% male), or proportion of overhead athletes (50.0% vs 44.8%) (Table 1). The RTS group, however, had a greater proportion of contact athletes (53.3% vs 28.4%; p=0.018) and competitive athletes (83.3% vs 44.8%; p<0.001) than the control group. Mean final follow-up was similar between the RTS and control cohort at 32.1 and 38.6 months after surgery, respectively (Table 1). Return to play outcomes were only available for 19 patients in the RTS testing cohort and for 35 patients in the control cohort.

With regards to operative characteristics, both groups had a similar proportion of concomitant SLAP repairs. In all cases, at least 2 suture anchors were used, with no difference in the mean number of anchors used between groups (Table 1).

Return to Sport Testing and Clearance Outcomes

Return to sport testing occurred at a mean time of 5.7 months postoperatively. For the isokinetic testing, isometric testing, endurance testing, and the USS test, a shoulder index score was calculated by dividing the value for the involved shoulder by the value for the uninvolved shoulder. Shoulder index scores ≥0.90 were considered "passing" scores for these assessments. Passing of the CKCUES test was determined by averaging ≥22 repetitions over 3 trials of the test.

Isometric strength testing was not completed in one patient and isokinetic testing was not completed in another patient. Of the 30 patients who tested, 11 passed the RTS test without failing any sections and 10 passed the RTS test while failing one section (Table 2). The 11 patients that passed all sections of the test were cleared to return to sports but the 10 that failed one section were asked to continue physical therapy to address their particular deficit for 4 weeks and then cleared (without needing to re-test). Nine patients failed RTS testing by failing two or more sections and thus, were not cleared to return to sport until re-test after a minimum of 4 weeks with further recommendations for full participation based on the repeat test. These nine patients all passed their repeat test. Isokinetic testing at 60 and 180 degrees per second proved most challenging for athletes, with only 51.7% passing both in ER and 55.2% passing both in IR, indicating that for those who failed, isokinetic strength in both ER and IR were not at least 90% that of the contralateral side. Mean time to clearance in this cohort was 6.5 months postoperatively.

Conversely, all patients in the control group were eventually cleared at a mean of 6.6 months postoperatively. Of the 67 patients, 12 (17.9%) were determined to have residual deficits at the 6-month postoperative clinic visit, requiring delayed clearance.

Clinical Outcomes

No differences were found between the RTS and control cohort in the incidence of recurrent instability (6.7% vs 9.0%; p=1.00), overall RTP (94.7% vs 94.3%; p=0.94), RTP at the same level as prior to injury (84.2% vs 80.0%; p=0.70), recurrent pain or weakness (23.3% vs 25.4%; p=0.83), or revision surgery (0% vs 3.0%; p=1.00), respectively (Table 3).

Of the 2 patients with recurrent instability in the RTS group, both were overhead athletes (1 football quarterback, 1 tennis player) and neither required revision surgery. The football quarterback failed two sections of the RTS test, while the tennis player failed one section of the RTS test. Of the 6 patients with recurrent instability in the control group, 4 were overhead athletes (1 baseball player, 1 softball player, 1 football quarterback, 1 weightlifter) and 2 were not (2 football players). In the control group, 2 revision surgeries were performed, one in the softball player and one in the non-overhead football player.

In the RTS cohort, there was one patient that was unable to return to play (1 baseball player) and two additional patients that were unable to return to play at the same level (1 softball player and 1 wrestler). Two of the three patients in this cohort that did not RTP at the same level were overhead athletes. Two of the three patients failed one section of the RTS test while one patient failed two sections. In the control cohort, there were two patients that were unable to return to play (1 softball player and 1 football player) and 5 additional patients that were unable to return to play at the same level (3 football players, 1 volleyball player, 1 wrestler). Two of the seven patients in this cohort that did not RTP at the same level were overhead athletes.

No differences were found between groups with regards to preoperative SSV or VAS. At final follow-up, SSV was greater in the RTS cohort compared to the control cohort (94±8% vs 88±14%; p=0.038) while VAS was similar between cohorts (0.9 ± 1.8 vs 0.9 ± 1.8; p=0.92) (Table 3).

DISCUSSION

The main finding of this study is that athletes who underwent RTS testing following arthroscopic posterior labral repair for posterior shoulder instability did not have significantly different rates of recurrent instability, RTP (overall and at same level as prior to injury), pain/weakness, or revision surgery compared to patients who underwent time-based clearance with overall similar, excellent outcomes in both cohorts. While RTS testing does not appear to have the same impact regarding recurrence rates following arthroscopic posterior stabilization compared to anterior stabilization, 2/3 of our athletes failed at least one component of the test, while 1/3 failed two or more components. Additionally, all the patients in the RTS testing cohort that had recurrence or failed to return to play at the same level failed at least one section of the RTS test. Finally, postoperative SSV was significantly higher in the RTS testing cohort, indicating that perhaps patients felt more secure in their shoulder function, having validated it through testing. These results suggests that RTS testing may still be helpful in guiding postoperative rehabilitation and may indicate which patients are at higher risk for negative outcomes following clearance.

To our knowledge, there is a paucity of available literature analyzing the impact of a criteria-based RTS test on outcomes after posterior shoulder stabilization surgery. Prior studies have investigated its use in anterior shoulder instability. Drummond et al found that patients who underwent RTS testing following arthroscopic Bankart repair had over a four-fold reduction in the rate of recurrent instability than those who did not undergo testing[11]. Their findings were similar to those in the ACL reconstruction population, where patients who did not meet clinical discharge criteria before returning to sport had a 4 times greater risk of ACL graft rupture[14,15]. There may be multiple reasons for the contrasting results in posterior instability. First, posterior instability is a less common occurrence than anterior instability, with much lower rates of subsequent recurrence[8]. Second, posterior subluxations/recurrent posterior instability often presents in a more subtle manner than recurrent anterior instability, potentially manifesting as gradual decline in performance rather than acute subluxation/dislocation, and is likely better tolerated[23,25]. Therefore, measurable differences with a modifiable factor, such as return to sport testing, for recurrent instability following arthroscopic posterior stabilization may be too subtle to detect. Lastly, our test group had a statistically higher proportion of contact and competitive athletes compared to our control group. It is also possible that RTS testing does have a significant impact on recurrence in a high-risk population following posterior stabilization and normalizes rates to a more general population versus no difference. Additionally, we believe this is one of the first studies addressing whether RTS testing affects rates of return to play overall and at the same level as prior injury. Future prospective studies with matched cohorts are necessary to further elucidate the effects of these tests in shoulder instability.

The overall incidence of recurrent instability in this study was 8.2% (2/30 in the RTS cohort and 6/67 in the control cohort), which is consistent with a systematic review by DeLong et al identifying an average recurrence rate of 8.1% after arthroscopic repair[9]. Six of the eight patients with recurrence in this study were overhead athletes, while only three of eight were contact athletes. These results are consistent with the literature, as the repetitive microtrauma from the compressive and distractive forces during overhead motions can cause weakening and contractures in the posterior capsulolabral complex and associated stabilizers[1,6,26,28].

The overall incidence of return to play in this study was 94.4% (18/19 in the RTS cohort and 33/35 in the control cohort) while incidence of return to play at the same level as prior to injury was 81.5% (16/19 in the RTS cohort and 28/35 in the control cohort). Of the 10 patients that failed to RTP at the same level as prior to injury, 4 were overhead athletes while 6 were contact athletes. This distinction between RTP and RTP at the same level as prior to injury may be useful in distinguishing insidious posterior labral re-injury, especially in overhead athletes, where repetitive trauma during the motion arc can cause a gradual decline in performance rather than acute subluxation/dislocation episodes. Rates of return to play have been characterized in the literature, ranging from 57.9% to 100%, with a systematic review by Matar et al reporting a pooled weight of 86.9%[17]. However, return to play at pre-injury level is lower, ranging from 47.4% to 100%, with a pooled weight of 74.9%[17].

Current literature on posterior shoulder instability is focused on how preoperative variables and surgical technique influence outcomes. Studies by Bradley et al have elucidated risk factors for recurrent posterior instability and revision repair including female sex, dominant shoulder injury, concomitant rotator cuff injury, and smaller glenoid bone width[4,5,30]. Furthermore, Owens et al and Dickens et al revealed that patients with baseline glenoid dysplasia and bone loss as well as glenoid retroversion>10% are associated with posterior instability and greater recurrence after initial surgery[3,10,21].

However, modifiable risk factors have been identified as well, including number of anchors used, type of sports participation, postoperative rehabilitation protocols, and clearance to return to sport[5,8,9]. The mean time to return to sport in the time-based clearance cohort was 6.6 months, consistent with the literature, reporting ranges between 4.3 and 7.7 months[17]. Although RTS testing in this study did not influence recurrence of posterior instability, as it does for anterior instability, it is important to note that across all studies, a majority of athletes did not meet the expected goals for their operative shoulder at time of testing. While 63.3% of athletes failed at least one component of the RTS test in this study, Drummond et al found that 83.3% of patients with anterior instability failed at least one component[11], and Wilson et al also found that 88.4% of patients with any type of instability failed at least one component[31]. In this study, isokinetic deficits were most apparent, with only 51.7% passing ER and 55.2% passing IR at both 60 and 180 degrees per second. Interestingly, however, over 90% of patients passed both functional tests, suggesting that athletes may be able to compensate functionally for focal strength deficits. These findings are also consistent with those of Drummond and Wilson et al, calling into question whether physical examination maneuvers during clinic visits are able to discern such deficits[11,31]. The merit of a formal criteria-based return to sport testing protocol is the ability to detect deficits through objective measures of strength and range of motion, that may otherwise be well compensated and go unnoticed. In this study, all of the patients in the RTS testing cohort that either had recurrence or failed to return to play at the same level failed at least one section of the RTS test. Therefore, the results of RTS testing may guide rehabilitation and demonstrate which patients are at risk of negative outcomes following clearance. Based on individual test results, providers may tailor their physical therapy and provide individualized clearance. These benefits must be weighed against the time and financial resources testing requires in order to determine whether RTS testing or time-based clearance should be employed.

While the RTS test in this study was able to identify residual deficits in nearly 2/3 of the athletes in the RTS cohort, future studies may focus on curating a test that is further tailored to athletes with posterior instability. Specifically, as over 90% of athletes passed both functional tests in this study, incorporating different functional tests that challenge patients more during posterior loading may further tease out patients not ready for full clearance. Other avenues of improvement include more reliable and valid endurance tests for the rotator cuff and scapular musculature. The authors of this study directly involved in testing noted that measuring ER endurance with repetitions to failure showed lower than acceptable reliability due to difficulty in uniform termination of testing across sessions[24].

This study is not without limitations. First, due to its retrospective observational design, the study is subject to confounding bias, attrition bias, and selection bias due to exclusion of those without sufficient follow-up. Second, due to the relatively novel utilization of return to sport testing as well as the low incidence of posterior shoulder instability, this study may be subject to Type II error. However, the very small observed effect size of 2.3% makes us fairly confident that there is no clinically important difference between the two cohorts with regards to recurrence rates, as a very large sample size (thousands of patients) would be needed to observe a statistical difference. Third, a minimum of 1 year follow-up was employed for this study and may not be sufficient to observe recurrence. However, the mean follow-up time was well above 30 months for each group with no differences found between groups. Fourth, the RTS cohort had more contact athletes and competitive athletes, which may influence rates of recurrence. Finally, this study did not report on rates of return to sport due to insufficient data. Overall, given low recurrence and reoperation rates, future multi-center prospective studies may be needed to detect further differences between RTS testing and time-based clearance after arthroscopic surgery for posterior shoulder instability.

CONCLUSION

While criteria-based on return to sports testing in young athletes after posterior labral repair did not appear to reduce recurrence or improve return to play compared to time-based clearance, nearly two-thirds of all athletes who underwent return to sport testing failed at least one section of the test, indicating some level of functional deficit. Thus, return to sport testing may still be a useful tool for guiding postoperative rehabilitation following arthroscopic posterior stabilization, although further work may be needed to refine testing procedures to improve its reliability and validity.

REFERENCES

1. Altchek DW, Dines DM. Shoulder Injuries in the Throwing Athlete. *J Am Acad Orthop Surg*. 1995;3(3):159-165.
2. Antosh IJ, Tokish JM, Owens BD. Posterior Shoulder Instability. *Sports Health*. 2016;8(6):520-526. doi:10.1177/1941738116672446
3. Bedrin MD, Owens BD, Slaven SE, LeClere LE, Donohue MA, Tennent DJ, et al.

Prospective Evaluation of Posterior Glenoid Bone Loss After First-time and Recurrent Posterior Glenohumeral Instability Events. *Am J Sports Med*. 2022;50(11). doi:10.1177/03635465221115828

4. Bradley JP, Arner JW, Jayakumar S, Vyas D. Revision Arthroscopic Posterior Shoulder Capsulolabral Repair in Contact Athletes: Risk Factors and Outcomes. *Arthroscopy*. 2020;36(3):660-665. doi:10.1016/J.ARTHRO.2019.09.029
5. Bradley JP, Arner JW, Jayakumar S, Vyas D. Risk Factors and Outcomes of Revision Arthroscopic Posterior Shoulder Capsulolabral Repair. *Am J Sports Med*. 2018;46(10):2457-2465. doi:10.1177/0363546518785893
6. Bradley JP, Forsythe B, Mascarenhas R. Arthroscopic management of posterior shoulder instability: diagnosis, indications, and technique. *Clin Sports Med*. 2008;27(4):649-670. doi:10.1016/J.CSM.2008.06.001
7. Bradley JP, McClincy MP, Arner JW, Tejwani SG. Arthroscopic capsulolabral reconstruction for posterior instability of the shoulder: a prospective study of 200 shoulders. *Am J Sports Med*. 2013;41(9):2005-2014. doi:10.1177/0363546513493599
8. Brelin A, Dickens JF. Posterior Shoulder Instability. *Sports Med Arthrosc*. 2017;25(3):136-145. doi:10.1097/JSA.0000000000000160
9. DeLong JM, Bradley JP. Posterior shoulder instability in the athletic population: Variations in assessment, clinical outcomes, and return to sport. *World J Orthop*. 2015;6(11):927. doi:10.5312/WJO.V6.I11.927
10. Dickens JF, Slaven SE, Cameron KL, Pickett AM, Posner M, Campbell SE, et al. Prospective Evaluation of Glenoid Bone Loss After First-time and Recurrent Anterior Glenohumeral Instability Events. *Am J Sports Med*. 2019;47(5):1082-1089.

doi:10.1177/0363546519831286

11. Drummond Junior M, Popchak A, Wilson K, Kane G, Lin A. Criteria-based return-to-sport testing is associated with lower recurrence rates following arthroscopic Bankart repair. *J Shoulder Elbow Surg*. 2021;30(7S):S14-S20. doi:10.1016/J.JSE.2021.03.141

12. Fried JW, Hurley ET, Duenes ML, Manjunath AK, Virk M, Gonzalez-Lomas G, et al. Return to Play After Arthroscopic Stabilization for Posterior Shoulder Instability-A Systematic Review. *Arthrosc Sport Med Rehabil*. 2020;3(1):e249-e256. doi:10.1016/J.ASMR.2020.08.007

13. Gouveia K, Kay J, Memon M, Simunovic N, Bedi A, Ayeni OR. Return to Sport After Surgical Management of Posterior Shoulder Instability: A Systematic Review and Meta-analysis. *Am J Sports Med*. 2022;50(3):845-857. doi:10.1177/03635465211011161/ASSET/IMAGES/LARGE/10.1177_03635465211011161-FIG2.JPEG

14. Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L, Risberg MA. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med*. 2016;50(13):804-808. doi:10.1136/BJSPORTS-2016-096031

15. Kyritsis P, Bahr R, Landreau P, Miladi R, Witvrouw E. Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *Br J Sports Med*. 2016;50(15):946-951. doi:10.1136/BJSPORTS-2015-095908

16. Malek S, Reinhold EJ, Pearce GS. The Beighton Score as a measure of generalised joint hypermobility. *Rheumatol Int*. 2021;41(10):1707-1716. doi:10.1007/S00296-021-04832-4

17. Matar RN, Shah NS, Gardner TJ, Grawe BM. Return to sport after surgical treatment for posterior shoulder instability: a systematic review. *JSES Int*. 2020;4(4):797. doi:10.1016/J.JSEINT.2020.08.002

18. McClincy MP, Arner JW, Bradley JP. Posterior Shoulder Instability in Throwing Athletes: A Case-Matched Comparison of Throwers and Non-Throwers. *Arthroscopy*. 2015;31(6):1041-1051. doi:10.1016/J.ARTHRO.2015.01.016

19. Naimark M, Bryant J, Zhang A, Ma B, Feeley B, Wolf B, et al. Posterior Shoulder Instability in Athletes: An Analysis of the MOON Shoulder Stabilization Cohort. *Arthroscopy*. 2017;33(6):e28-e29. doi:10.1016/J.ARTHRO.2017.04.088

20. O'Brien SJ, Schwartz RS, Warren RF, Torzilli PA. Capsular restraints to anterior-posterior motion of the abducted shoulder: a biomechanical study. *J Shoulder Elbow Surg*. 1995;4(4):298-308.

21. Owens BD, Campbell SE, Cameron KL. Risk factors for posterior shoulder instability in young athletes. *Am J Sports Med*. 2013;41(11):2645-2649. doi:10.1177/0363546513501508

22. Owens BD, Duffey ML, Nelson BJ, DeBerardino TM, Taylor DC, Mountcastle SB. The Incidence and Characteristics of Shoulder Instability at the United States Military Academy. *https://doi.org/101177/0363546506295179*. 2017;35(7):1168-1173. doi:10.1177/0363546506295179

23. Perron AD, Jones RL. Posterior shoulder dislocation: avoiding a missed diagnosis. *Am J Emerg Med*. 2000;18(2):189-191.

24. Popchak A, Poploski K, Patterson-Lynch B, Nigolian J, Lin A. Reliability and validity of a return to sports testing battery for the shoulder. *Phys Ther Sport*. 2021;48:1-11.

doi:10.1016/J.PTSP.2020.12.003

25. Provencher MT, Leclere LE, King S, McDonald LS, Frank RM, Mologne TS, et al. Posterior instability of the shoulder: diagnosis and management. *Am J Sports Med*. 2011;39(4):874-886. doi:10.1177/0363546510384232

26. Radkowski CA, Chhabra A, Baker CL, Tejwani SG, Bradley JP. Arthroscopic capsulolabral repair for posterior shoulder instability in throwing athletes compared with nonthrowing athletes. *Am J Sports Med*. 2008;36(4):693-699. doi:10.1177/0363546508314426

27. Robinson CM, Seah M, Akhtar MA. The epidemiology, risk of recurrence, and functional outcome after an acute traumatic posterior dislocation of the shoulder. *J Bone Joint Surg Am*. 2011;93(17):1605-1613. doi:10.2106/JBJS.J.00973

28. Seroyer ST, Nho SJ, Bach BR, Bush-Joseph CA, Nicholson GP, Romeo AA. Shoulder pain in the overhead throwing athlete. *Sports Health*. 2009;1(2):108-120. doi:10.1177/1941738108331199

29. Sheean AJ, Kibler WB, Conway J, Bradley JP. Posterior Labral Injury and Glenohumeral Instability in Overhead Athletes: Current Concepts for Diagnosis and Management. *J Am Acad Orthop Surg*. 2020;28(15):628-637. doi:10.5435/JAAOS-D-19-00535

30. Vaswani R, Arner J, Freiman H, Bradley JP. Risk Factors for Revision Posterior Shoulder Stabilization in Throwing Athletes. *Orthop J Sport Med*. 2020;8(12). doi:10.1177/2325967120967652

31. Wilson KW, Popchak A, Li RT, Kane G, Lin A. Return to sport testing at 6 months after arthroscopic shoulder stabilization reveals residual strength and functional deficits. *J Shoulder Elbow Surg*. 2020;29(7S):S107-S114. doi:10.1016/J.JSE.2020.04.035

Table and Figure Legends

Figure 1. Isokinetic internal and external rotation test using Biodex dynamometer

Figure 2a. Isometric external and internal rotation test at 0 degrees abduction

Figure 2b. Isometric external and internal rotation test at 90 degrees abduction

Figure 3. Closed kinetic chain upper extremity stability test

Figure 4. Unilateral seated shot-put test

Table 1. Demographic characteristics of study cohorts

Abbreviations: RTS=return to sport testing; SLAP= Superior Labrum Anterior and Posterior; n=number of patients, BMI = body mass index. Significance set at p value < 0.05 (bold)

Table 2. Criteria-based return to sport testing results

Abbreviations: ER=external rotation; IR=internal rotation; ERET=external rotation endurance test; CKCUE=closed kinetic chain upper extremity; n=number of patients

Table 3. Comparison of outcomes between cohorts

Abbreviations: RTS=return to sport testing; n=number of patients; SSV=subjective shoulder value; VAS = visual analog scale for pain. Significance set at p value < 0.05 (bold)

Characteristic	RTS (n=30)	Control (n=67)	p-value
Age (years)	19.9 ± 4.2	22.5 ± 4.7	0.07
BMI (kg/m^2)	27.2 ± 3.9	26.2 ± 5.8	0.32
Sex (n, % Male)	24 (80.0%)	46 (68.7%)	0.25
Contact Athlete (n, %)	16 (53.3%)	19 (28.4%)	**0.018**
Competitive Athlete (n, %)	25 (83.3%)	30 (44.8%)	**<0.001**
Overhead Athlete (n, %)	15 (50.0%)	30 (44.8%)	0.34
SLAP Repair (%)	14 (46.7%)	23 (34.3%)	0.25
Suture Anchors (n)	4.8 ± 1.8	4.2 ± 1.5	0.10
Final Follow Up Time (months)	32.1 ± 17.2	38.6 ± 24.7	0.14

Result	n (%)
Pass (0 sections failed)	11 of 30 (36.7%)
Pass (1 section failed)	10 of 30 (33.3%)
Fail (2+ sections failed)	9 of 30 (30.0%)
Component	**Pass, n (%)**
Isokinetic	
ER at 60°/s	16 of 29 (55.2%)
ER at 180°/s	19 of 29 (65.5%)
ER at 60°/s + 180°/s	15 of 29 (51.7%)
IR at 60°/s	17 of 29 (58.6%)
IR at 180°/s	20 of 29 (69.0%)
IR at 60°/s + 180°/s	16 of 29 (55.2%)
Isometric	
ER at 0°	26 of 29 (89.7%)
ER at 90°	19 of 29 (65.5%)
IR at 0°	26 of 29 (89.7%)
IR at 90°	21 of 29 (72.4%)
ER/IR at 0°	26 of 19 (89.7%)
ER/IR at 90°	18 of 29 (62.1%)
ERET at 0°	18 of 23 (78.3%)
ERET while prone	17 of 23 (73.4%)
CKCUE	27 of 30 (90%)
Shot-put	28 of 30 (93.3%)

Outcome	RTS (n=30)	Control (n=67)	p-value
Preop SSV (%)	59 ± 18	64 ± 18	0.07
Postop SSV (%)	94 ± 8	88 ± 14	**0.038**
Preop VAS (0-10)	4.9 ± 1.8	5.0 ± 2.4	0.94
Postop VAS (0-10)	0.9 ± 1.8	0.9 ± 1.8	0.92
Recurrent Instability (n, %) **Football (n)** **Baseball/Softball (n)** **Weightlifting (n)** **Tennis (n)**	2 (6.7%) 1 0 0 1	6 (9.0%) 3 2 1 0	1.00
Recurrent Pain/Weakness (n, %)	7 (23.3%)	17 (25.4%)	0.83
Revision Surgery (n, %) **Football (n)** **Baseball/Softball (n)**	0 (0.0%) 0 0	2 (3.0%) 1 1	1.00
Return to Sport	18 (94.7%) (n=19)	33 (94.3%) (n=35)	0.94
Return to Sport at Same Level	16 (84.2%) (n=19)	28 (80.0%) (n=35)	0.70