DEFICIENCIES IN PITCHING BIOMECHANICS IN BASEBALL PITCHERS WITH A HISTORY OF SLAP REPAIR

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Baseball pitchers who undergo SLAP (superior labrum, anterior to posterior) repair often have trouble returning to their previous level of performance. While the reason is often assumed to be diminished shoulder range of motion or other mechanical changes, differences in pitching biomechanics following surgery have not been previously studied. Pitching biomechanics were compared retrospectively between collegiate and professional pitchers with a history of a SLAP repair (n=10) and a control group (n=40) with no history of surgery. Full body biomechanics were compared between the two groups. For each comparison, a Student's t-test was used at an α level of 0.05. Pitchers with history of SLAP repair produce less shoulder external rotation, shoulder horizontal abduction, and trunk forward tilt during pitching than pitchers with no history of injury.

KEY WORDS: Shoulder, labral tear, external rotation, horizontal abduction

INTRODUCTION: SLAP (superior labrum, anterior to posterior) tears, first reported by Andrews et al (1985), are serious, career-threatening injuries for overhead throwing athletes. These tears affect the origin of the long head of the biceps tendon on the shoulder labrum, and may occur as the abducted shoulder externally rotates during the arm cocking phase in throwing (Burkhart & Morgan, 1998) or as the biceps contracts to resist glenohumeral distraction and elbow extension (Jee et al., 2001). Shepard et al (2004) measured *in vitro* strength of the biceps-labral complex during both the distal force and peel-back mechanisms, and concluded that SLAP lesions most likely occur from repetition of both peel-back and distal forces. Even in the appropriate setting with proper patient selection, arthroscopic SLAP repair does not lead to uniform return to play, and the most common complication is postoperative shoulder stiffness (Brockmeier et al., 2009).

Postoperative shoulder stiffness could compromise shoulder function and performance of overhead throwing athletes. Furthermore, anecdotal evidence suggests that pitchers with a history of shoulder surgery modify their elbow or body biomechanics to compensate and protect their surgically repaired shoulder. However no previous study has examined throwing biomechanics after surgical repair and rehabilitation of SLAP tears. Thus the purpose of this study was to determine if there are differences in pitching biomechanics between pitchers with a history of SLAP repair and a matched uninjured control group.

The primary hypothesis was that compared to the control group, the SLAP group would exhibit compromised shoulder range of motion (horizontal abduction and external rotation) and internal rotation torque during pitching. There were two secondary hypotheses, the first being that pitchers with a history of SLAP repair would have compensations affecting elbow function (flexion, extension velocity, and flexion torque). Another secondary hypothesis was that pitchers with a history of SLAP repair would exhibit mechanical symptoms associated with "holding back" from injury - namely a shorter stride length, increased maximum horizontal adduction, decreased trunk forward tilt at the instant of ball release, and decreased trunk forward tilt at the instant of maximum shoulder internal rotation.

METHODS: This study was determined to be exempt from review by the Institutional Review Board of St. Vincent's Health System (Birmingham, AL). A review of the biomechanics database at the American Sports Medicine Institute identified 512 collegiate and professional male baseball pitchers tested between 2000 and 2013. Pitchers were included in the SLAP group if they were healthy at the time of testing and had undergone SLAP repair at least six months prior to their biomechanical testing. A six month period between SLAP repair and biomechanical testing was selected as this is consistent with the timeline that athletes return to competition (Wilk et al., 2005). Of the 512 pitchers in the database, 10 met the inclusion criteria for the SLAP group. These pitchers were evaluated in the ASMI biomechanics lab an average of 19 months after SLAP repair. A control group (n = 41) was identified from the database, and had no history of surgical repair to the throwing elbow or shoulder and matched the SLAP group in age, height, mass, pitch velocity, and level of play.

After completing the informed consent and history forms, each subject changed into Spandex shorts, socks, and athletic shoes. Anthropometric measures were taken and reflective markers were then attached to the subject. Twenty-three reflective markers were attached, four to a hat worn on the head and bilaterally on the acromion process, lateral elbow epicondyle, ulnar styloid, greater trochanter, lateral femoral epicondyle, lateral malleolus, and second metatarsal. Additional markers were placed on the medial elbow epicondyle, forearm, radial styloid and third metacarpal of the throwing arm as well as the heel of the lead foot. After markers were applied, the subject was instructed to conduct his normal warm-up routine of stretching and non-throwing drills. Each subject concluded his warm-up by throwing a non-specified number of pitches in the indoor testing facility. Once the subject indicated he was ready to begin, data for ten fastball pitches were collected for analysis. Pitches were thrown from a portable pitching mound (Athletic Training Equipment Company, Sparks, Nevada) toward a strike zone ribbon located over a home plate 18.5 m (60.5 ft.) from a pitching rubber. Ball speed was recorded with a radar gun (Stalker Sports Radar, Plano, TX). An automated digitizing motion analysis system (Eagle System, Motion Analysis Corporation, Santa Rosa, CA) used eight synchronized cameras to measure the location of the reflective markers attached to the participant at a rate of 240-Hz. Three-dimensional motion was calculated using the direct linear transformation method as described by Wood and Marshall (1986). Kinematic variables and kinetic values at the shoulder and elbow joints were calculated as previously described (Fleisig, Bolt, Fortenbaugh, Wilk, & Andrews, 2011).

All statistical tests were performed using JMP 10 (SAS Institute, Inc., Cary, North Carolina). Level of play was compared between the SLAP group and control group using a Fisher's exact test, while group age, height, mass, and ball velocity were compared using independent Student's t-tests. For the three hypotheses, mean values for kinematic and kinetic variables were computed for each participant and then compared between the SLAP group and control group using independent Student's t-tests. Prior to analysis, the alpha level (α) was set as 0.05 for every test.

RESULTS: There were no differences in subject anthropometrics, ball velocity, and level of play between the SLAP and the control groups. Shoulder biomechanics during pitching are presented in Table 1. The SLAP group had less horizontal abduction at foot contact and less maximum external rotation. However there was no difference in internal rotation torque between groups.

Table 1
Shoulder Biomechanics

	SLAP	Control	p
Shoulder Horizontal Abduction at Foot Contact (°)	5.7 ± 12.3	19.2 ± 12.4	<0.01*
Maximum Shoulder External Rotation Angle (°)	164.5 ± 8.5	175.1 ± 10.6	<0.01*
Maximum Shoulder Internal Rotation Torque (Nm)	83.1 ± 7.5	83.7 ± 21.3	0.88

* significant difference ($p < 0.05$) between groups

Biomechanics of the elbow are presented in Table 2. There were no significant differences in elbow biomechanics between the SLAP and control groups.

Variables that, in our experience, are associated with "holding back" from injury were compared between groups and are presented in Table 3. The SLAP group pitched more upright, exhibiting less trunk forward tilt at ball release. The SLAP group appeared to still be more upright in follow-through, but difference in trunk forward tilt at maximum internal rotation was not quite statistically significant. There were no significant differences in stride length or in maximum horizontal adduction angle.

Table 2
Elbow Biomechanics

	SLAP	Control	p
Maximum Elbow Extension Angular Velocity (°/sec)	2335 ± 284	2283 ± 340	0.63
Maximum Elbow Flexion Torque (Nm)	44.8 ± 10.6	51.5 ± 22.3	0.18
Maximum Elbow Flexion Angle (°)	109.6 ± 15.4	100.5 ± 14.3	0.12

* significant difference ($p < 0.05$) between groups

Table 3
Hold Back Mechanics

	SLAP	Control	p
Stride Length (% Height)	80.3 ± 5.6	81.2 ± 4.6	0.63
Maximum Shoulder Horizontal Adduction Angle (°)	17.8 ± 7.2	17.4 ± 6.7	0.88
Forward Trunk Tilt Angle at Ball Release (°)	27.4 ± 6.8	34.7 ± 7.3	<0.01*
Forward Trunk Tilt Angle at Maximum Shoulder Internal Rotation (°)	41.1 ± 11	49 ± 9.4	0.06

* significant difference ($p < 0.05$) between groups

DISCUSSION: As hypothesized, shoulder biomechanics were compromised in pitchers with a history of SLAP repair. Pitchers exhibited less maximum external rotation and horizontal abduction at foot contact. The decreased external rotation is consistent with previous cadaveric research that demonstrated anchors placed anterior to the long head of the biceps tendon during SLAP repair can limit shoulder external rotation (McCulloch et al., 2013). The most common complication after symptomatic Type II SLAP repair has been reported as refractory postoperative stiffness in forward flexion and external rotation, reported at 8.5% (Franceschi et al., 2008). Furthermore, there has been a reported increased risk of postoperative stiffness after SLAP repair with concomitant rotator cuff repair, which likely occurs with poor patient selection (Forsythe, Guss, Anthony, & Martin, 2010) as SLAP repair is typically indicated in overhead throwing athletes and patients with shoulder instability.

SLAP repair may affect elbow function as well since the surgery involves fixation of the detached origin of the long head of the biceps tendon in the shoulder. The biceps is a two-joint muscle and is the principal torque generator of elbow flexion (Fortenbaugh, Fleisig, & Andrews, 2009). Thus, SLAP repair may compromise the ability to generate elbow flexion torque to decelerate elbow extension during pitching. Elbow biomechanics might also be compromised as compensation. However, the hypothesis that elbow biomechanics would be different for pitchers with SLAP repair was not confirmed. There were no differences in maximum elbow flexion torque, maximum elbow flexion angle, or maximum elbow extension velocity.

While some pitchers successfully return after injury, others have difficulty returning to their previous ball velocity and performance. This is frustrating for the athlete and his team. Biomechanists and pitching coaches often observe a pitcher after returning from injury looks like he is “holding back” in his mechanics. Based upon our clinical experience in the biomechanics lab, pitchers in this situation demonstrate a shorter stride, less forward trunk tilt, and/or “pushing the ball.” Pushing the ball is a colloquial expression for throwing with increased shoulder horizontal adduction and increased elbow flexion. As hypothesized, the SLAP group exhibited less forward trunk tilt than the control group. However there were no differences between the two groups in stride length or in horizontal adduction.

The main limitation of this study was the assumption that differences between the SLAP group and the control group were due to the SLAP repair and rehabilitation. It is conceivable that before their SLAP tears, the SLAP group possessed different pitching biomechanics from the control group. Ideally, a better-designed study would have been to quantify pitching biomechanics of the SLAP group before their injury as well as after recovery, but biomechanical data before SLAP injury were not available. While all biomechanics testing was performed at the American Sports Medicine Institute, athletes had SLAP repair at various institutions. Therefore, these athletes did not have a single surgeon performing the repair or a uniform rehabilitation protocol. There may be differences in SLAP repair technique and rehabilitation, as well as variations in concomitant shoulder pathology and treatment.

CONCLUSION: Understanding common deficiency in pitching mechanics after SLAP repair can hopefully lead to improve surgical techniques, rehabilitation, and pitching instruction for more successful outcomes. The value of this study was the confirmation of theoretical deficiencies in pitching mechanics for pitchers with history of SLAP repair. The decreased shoulder external rotation and horizontal abduction should be of particular concern for sports medicine surgeons and physical therapists as these motions are essential for pitchers and can be compromised by excessive tensioning of the glenohumeral ligaments associated with non-anatomic SLAP repair. Physical therapy should encourage early return of range of motion, particularly passive and active external rotation with 90 degrees of abduction.

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