BASEBALL PITCHING BIOMECHANICS AFTER SURGERY

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Baseball pitchers with and without histories of elbow or shoulder surgery were tested with a 240 Hz automated 3D motion capture system. No differences were found between pitchers with history of UCL reconstruction and matched controls. Pitchers tested shortly after returning from UCL repair demonstrated reduced elbow extension, elbow velocity, and shoulder velocity compared to a control group, but it is unknown whether these few kinematic differences resolve with time. Pitchers with a history of SLAP repair produced less shoulder horizontal abduction, shoulder external rotation, and forward trunk tilt than matched controls. The Thoracic Outlet Syndrome case report demonstrated significantly more shoulder abduction after surgery. Thus the ability to return to normal pitching biomechanics after injury depends upon the type of surgery.

KEYWORDS: elbow, ulnar collateral ligament, shoulder, SLAP, Thoracic Outlet Syndrome

INTRODUCTION: With continued advances in diagnosis and treatment, the number of pitchers able to return to baseball after surgery has continued to grow at all levels. The number of surgeries for the ulnar collateral ligament (UCL) of the elbow in Major League Baseball has approximately doubled from 2000 to 2017, from about 20 per year to about 40 per year (Camp, Conte, D'Angelo, & Fealy, 2018). Astonishingly, during that same time period the number of UCL surgeries in Minor League Baseball has grown from 10 per year to 140 per year (Camp et al., 2018). UCL injuries are also an epidemic in amateur baseball, as the vast majority of UCL surgeries are now performed on high school and college baseball players (Rothermich et al., 2018). The incidence of UCL surgeries in NCAA baseball is nearly one UCL surgery per team each year (0.86/team/year) (Rothermich et al., 2018). While UCL reconstruction has been a popular surgery among baseball players for decades, UCL repair has recently become another viable option. Although some UCL injuries are considered too severe for repair, the early outcomes of UCL repair show promising rates of return to play within considerably shortened time (Dugas et al., in press). Shoulder and clavicle injuries continue to be problematic as well, representing the single largest injury area (15%) of injuries in professional baseball. Shoulder surgeries such as repair of the superior labrum anterior-posterior (SLAP) are particularly troublesome, with poor rates of return and play performance (Gilliam et al., 2018).

There are several metrics to assess the success of surgery for baseball pitchers, including clinical outcomes (e.g., return to play, return to previous level, career length after surgery) and performance outcomes (e.g., pitch velocity, earned run average). Physical examination is routinely performed by physicians, physical therapists, and athletic trainers to measure passive range of motion and functional strength, but biomechanical evaluation of the surgically repair arm during pitching is equally important. The purpose of this study was to present the limited available biomechanical data for pitchers with histories of elbow or shoulder surgery.

METHODS: Three recent case-control studies compared the biomechanics of pitchers with histories of surgery (UCL reconstruction, UCL repair, and SLAP repair, respectively) to matched control groups of pitchers with no history of surgery. In addition, a case of a pitcher analysed before and after surgery for Thoracic Outlet Syndrome was presented. All four studies received IRB approval.

Eight Major League Baseball organizations agreed to participate in the UCL reconstruction study (Fleisig et al., 2015). Each organization identified all healthy, active minor league pitchers

during 2014 spring training who had UCL reconstruction within the past 48 months. For each pitcher who agreed to participate in the study, another pitcher was identified and invited from that same organization. The matched control pitcher was from the same minor league level (A, AA, or AAA) and had no history of elbow or shoulder surgery. In total, 40 pitchers with UCL reconstruction and 40 matched controls participated in this study.

For the UCL repair study (in review), patients of the authors (JRD, ELC, BAE) were recruited as soon as they felt they were back to "100%" after UCL repair. For each recruited pitcher who agreed to participate, a matched control pitcher was identified in a database of athletes previously tested at the biomechanics lab of the American Sports Medicine Institute (ASMI). Control pitchers were matched by level (high school or college), height, and weight. This study included 27 pitchers with UCL repair and 27 pitchers in the control group.

A retrospective review of ASMI's database identified 13 adult (collegiate and professional) pitchers who were healthy at the time of biomechanical testing with a history of SLAP repair at least one year before their testing (Laughlin et al., 2014). A control group of 52 healthy pitchers with no history of surgery was also created from the ASMI database. Control pitchers were selected to match the level, age, height, weight, and ball velocity during testing.

In 2018, a collegiate pitcher was tested in the ASMI biomechanics lab. Although this pitcher was healthy at the time of testing, he had his top rib and two scalene muscles on his throwing removed 17 months prior to treat Thoracic Outlet Syndrome. This athlete had also been evaluated at ASMI as a healthy pitcher in 2015. Thus, this pitcher served as his own control in a pre-post injury comparison.

At the time of testing, participants completed paperwork for informed consent, injury history, and playing history. Passive range of motion of both shoulders and both elbows were measured for the UCL reconstruction, UCL repair, and Thoracic Outlet Syndrome studies, but were not collected for the SLAP repair study.

The biomechanics of the pitchers in all four studies were collected with a motion capture system (Motion Analysis Corporation, Santa Rosa CA). Motion capture was performed at spring training facilities for the UCL reconstruction study and in the ASMI biomechanics lab for the other three studies. Each pitcher wore only tight shorts, socks, and shoes during testing. Retroreflective markers were attached to bony landmarks before the athlete performed his normal warmup routine. The pitcher then threw ten full-effort fastball pitches from a mound to a catcher or strike zone target behind a home plate positioned the standard distance (18.44 m) from the pitching rubber. Eight to 12 cameras tracked body marker motion at 240 Hz. Ball velocity was recorded with a radar gun.

Three-dimensional motions of the reflective markers were computed by the motion capture system. Marker motion data were filtered with a fourth-order Butterworth low-pass filter at 13.4 Hz. Full body pitching kinematics and upper extremity kinetics were then calculated using ASMI software (Fleisig et al., 2015; Laughlin et al., 2014). The kinematic parameters for the throwing shoulder and elbow are shown in Figure 1. Data for each pitcher's ten trials were averaged. Except for the Thoracic Outlet Syndrome case study, data were compared between the surgical treatment group and control group using student t-tests with alpha level set at 0.05.

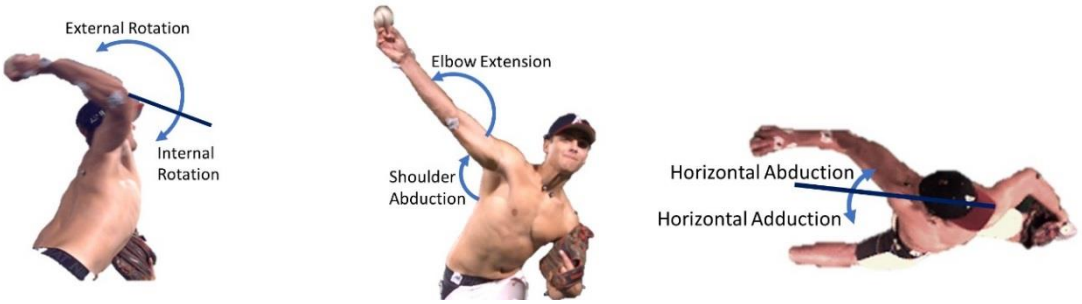

Figure 1: Shoulder and elbow kinematic parameters.

RESULTS: There were no significant differences between pitchers with a history of UCL reconstruction and their control group. Compared to their control group, pitchers tested shortly after UCL repair had decreased elbow extension (mean 153° vs. 157°), elbow extension velocity (2373°/s vs. 2630°/s), and shoulder internal rotation velocity (6079°/s vs. 6867°/s). Compared to their control group, pitchers with a history of SLAP repair had decreased shoulder horizontal abduction (10° vs. 21°), shoulder external rotation (168° vs. 178°), and trunk forward tilt (30° vs. 34°). Although no statistical tests were performed for the Thoracic Outlet Syndrome case, there were noticeable gains in passive shoulder external rotation (117° to 136°), ball velocity (81 to 85 mph), shoulder abduction at the instant of foot contact (86° vs. 105°), and shoulder abduction at ball release (93° vs. 98°). A summary of results is shown in Table 1.

Table 1: Pitchers with surgery history compared to matched controls.

	UCL reconstruction	UCL repair	SLAP repair	Thoracic Outlet decompression
Treatment group	40 minor league baseball pitchers	27 high school and collegiate pitchers	13 collegiate and professional pitchers	1 collegiate baseball pitcher
Time between surgery and evaluation, mean (range)	31 (11-47) months	10 (6-15) months	22 (13-47) months	17 months
Control group	40 minor league baseball pitchers	27 high school and collegiate pitchers	52 collegiate and professional pitchers	Same pitcher, 39 months before second evaluation
Passive range of motion	No differences	No differences	Not measured	Increased external rotation
Fastball velocity	No difference	No difference	No difference	Increased
Pitching kinematics	No differences	Significant decreases in elbow extension, elbow extension velocity, and shoulder internal rotation velocity	Significant decreases in shoulder horizontal abduction, shoulder external rotation, and trunk forward tilt	Increases in shoulder abduction at foot contact and ball release
Pitching kinetics	No differences	No differences	No differences	No differences

DISCUSSION: While baseball pitching biomechanics are well-documented, this paper represents the only known data for pitchers who have returned from surgery. For injuries to the medial elbow, pitchers undergo UCL reconstruction or UCL repair depending on the severity of the injury and the surgeon's recommendation. There were no differences between professional pitchers with a history of UCL reconstruction and their control group. This is consistent with the fact that professional pitchers who returned to MLB after UCL reconstruction performed as well as matched controls (Makhni et al., 2014). However these are the biomechanics and performance of pitchers who successfully returned from UCL reconstruction; one-third to one-fifth of pitchers don't return to their previous competition level after this surgery (Camp et al., 2018; Makhni et al., 2014). Pitchers evaluated shortly after UCL repair showed few differences (decreased elbow extension, elbow extension velocity, and internal rotation velocity) compared to their control group. Since there were no differences in joint kinetics, ball velocity, or passive range of motion, it's unknown whether the observed differences have clinical significance. Furthermore, it is unknown whether these kinematic deficits resolved with time.

The percentage of pitchers able to return to previous performance is much lower following shoulder surgery than elbow surgery due to the shoulder's complex anatomy, biomechanics, and demands during pitching. Even pitchers who successfully returned demonstrated compromised pitching biomechanics. The decreased shoulder external rotation and horizontal abduction during pitching after SLAP repair may be due to the surgical fixation of the biceps tendon (Laughlin et al., 2014). The pitcher tested after removal of his first rib and two scalene muscles for Thoracic Outlet Syndrome increased his shoulder abduction from typical values near 90° to values above normal ranges reported for elite pitchers. Removal of the rib and two scalene muscles relieved compression of the nerves and blood vessels, but appears to have also unconstrained shoulder abduction. As this is purely speculative based upon one athlete, future research is needed on pitching after Thoracic Outlet Syndrome.

CONCLUSION: There were no differences in biomechanics between pitchers who successfully returned from UCL reconstruction and uninjured healthy controls. Pitchers who successfully returned from UCL repair or SLAP repair demonstrated some kinematic deficits, particularly in the motion of the throwing elbow and shoulder. It is unknown whether the deficits shortly after UCL repair resolved with more time.

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