Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 10), Art 319, pp. 2794 - 2803, October 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Integrating glenohumeral range of motion with dynamic postural control for early detection of elbow injury risk in collegiate baseball pitchers: A preliminary prospective case series

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Published online: October 31, 2023
(Accepted for publication : October 15, 2023)
DOI:10.7752/jpes.2023.10319

Abstract:
Introduction: Medial elbow ulnar collateral ligament (UCL) injuries are common in baseball with increased surgical incidence in pitchers. There is no consensus on which modifiable injury risk metrics or performance screening tools to use to identify at risk collegiate baseball pitchers. Current literature on UCL injury risk has focused on local passive glenohumeral rotational motion with limited forays into more global movement patterns. The aim of this study was to assess possible relationships involving UCL injuries and modifiable local and global motor control performance risk factors. **Material and Methods:** An observational single cohort case series involving 15 collegiate baseball pitchers aimed to elucidate disparitites in glenohumeral active and passive range of motion alongside an assessment of general movement competency and dynamic motor control performance to identify injury risk for the UCL. Preseaon baseline metrics, including the Functional Movement Screen, Upper and Lower Quarter Y Balance Test, and glenohumaral internal and external rotation active, passive, and total arc range of motion were examined. **Results:** The two pitchers with UCL injury demonstrated less ability to actively move into their available passive rotational range with decreased lower extremity dynamic postural control, but no difference with general movement competency. The pitcher requiring UCL surgical intervention demonstrated even greater excessive passive range compared to the other injured pitcher and a decreased ability to control base of support during the dynamic single-leg balance performance test. **Discussion:** Participants with UCL injuries exibited noticable deficiencies in baseline active and passive mobility, suggestive of a potential motor control deficit and a compromised ability to fully access available range of motion. Furthermore, diminished performance on the Lower Quarter Y Balance Test identified potential motor control limitations involving a decreased ability to dynamically maintain a base of support. **Conclusions:** This is the first study designed to identify motor control issues in the both the local shoulder region and global body movement to identify modifiable risk factors for UCL injuries in baseball pitchers. This study may begin to address the gap in the literature by combining modifiable local shoulder range of motion and global balance metrics to identify pitchers at risk for UCL injuries. It underscores the significance of comparing active and passive range of motion in tandem with dynamic postural control assessments to better evaluate the risk of injuries in baseball pitchers. This case series lays the groundwork for future randomized clinical trials to evaluate the utiliity of combining this information.
Keywords: Collateral ligaments; Lower extremity; Shoulder joint; Range of motion, articular; Postural balance

Introduction

In collegiate baseball pitchers, ulnar collateral ligament (UCL) injuries are highly prevalent. From 2014 to 2019, elbow injuries were among the most common injuries, occurring in 16% of baseball players in the National Collegiate Athletic Association (NCAA) (Boltz et al., 2021). The annual surgical rate for UCL injuries for NCAA Division I collegiate baseball players in 2017 was 2.5%, with surgical rates 5.9 times greater in pitchers than nonpitchers (Rothermich et al., 2018). Current literature on potential risk factors for elbow injuries among baseball athletes suggests higher risk among individuals working with higher ball velocities, namely pitchers and catchers, and those with limited shoulder range of motion (ROM) (Mine et al., 2021). However, there is no consensus on injury risk metrics or on performance screening tools with the validated reliability and validity to identify collegiate baseball pitchers at risk for UCL injury.

Reliable balance and perteration response metrics are commonly used to assess normal performance (Harper et al., 2022; Daniel Miner et al., 2022; Miner et al., 2020), to identify deficiancies after sports participation (Harper et al., 2022; Harper et al., 2023), or to identify relevant risk-related variations from baseline metrics (Harper et al., 2021). Several modfiable and non-modifiable risk factors for elbow injuries have been

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identified (Mine et al., 2021). One primary modifiable domain of interest involves physical function and characteristics assessed by shoulder rotational ROM, both internal and external, and single-leg balance (Mine et al., 2021). Mine et al.'s (2021) scoping review identified consistent findings in the literature supporting decreased shoulder ROM as a risk factor for elbow injuries in baseball pitchers; however, they found no increased risk with differences in shoulder ROM between throwing and non-throwing sides. In contrast, a systematic review by Labott et al. (2023) did not find shoulder ROM limitations, specifically limited glenohumeral internal rotation deficit (GIRD) or posterior shoulder tightness, to be an indicator of elbow injury when comparing healthy individuals to those with a UCL injury. According to Labott et al. (2023), predictors for increased risk of UCL injury included a difference in total rotational motion (TRM) between throwing and non-throwing arms. Moreover, decreased performance on the Y-Balance Test, a single-leg dynamic task of postural control functional metric, may further increase UCL injury risk (Labott et al., 2023). Garrison et al. (2013) was the first to notice the relationship between UCL tears and the modifiable factor of decreased balance.

Conflicting opinions in research persists regarding the value of shoulder mobility as a modifiable factor. The value of GIRD as a risk variable may be not fully validated, however, treating the IR ROM limitations and improving TRM seems to be a mitigating activity for future injuries (Cools et al., 2015; Johnson et al., 2018). Smith et al. (2019) demonstrated that GIRD in pitchers did not result in increased elbow torque and is not an inherent risk factor for elbow injuries. Increased shoulder external rotation results in greater torque to the medial elbow, and decreased shoulder TRM has been associated with lower torque to the medial elbow (Khalil et al., 2021). When Whitt et al. (2019) retrospectively looked at shoulder abduction mobility, a component of shoulder external rotation, they found that those who experienced a UCL injury had increased shoulder ROM on their throwing arm compared to healthy controls and greater ROM differences between their throwing and non-throwing sides. At present, consensus revoles solely around throwing mechanics, overuse, and high velocity throwing (Erickson et al., 2023), all of which are dramatcially impacted by excessive or limited ROM at the shoulder, decreased ability to move in the available range, and dynamic balance. Due to the conflicting results of different studies and literature reviews, consensus is lacking regarding the utility of physical findings of shoulder ROM and dynamic single-leg balance performance.

Not only are passive glenohumaral rotational mobility symmetry discrepancies common in pitchers, these rotational deficits are more likely to lead to injury when compared with healthy controls (Wilk et al., 2014, 2015). A primary study on baseball pitchers was completed by Wilk et al. (2011) in which they measured multiple glenohumeral metric motions on professional baseball pitchers over three competitive seasons. In this study, they prospectively measured glenohumeral mobility of internal and external rotation, computed the difference between the TRM, calculated loss of GIRD, while they observed the athletes over the course of those seasons in order to correlate these metrics with injury risks. These authors concluded that pitchers with TRM of 5^0 were more 2.5 times more likely to get injured (p = .03), with 75% of those having more than 176^0 TRM in their dominant throwing arm. Pitchers with GIRD were 1.9 times more likely to become injured but this was not significant (p = .17). Furthermore, minor league professional pitchers were 2.5 times more likely to get injured than their major league counterparts.

The current study replicated the general methodology of Wilk et al. (2011) by prospectively measuring shoulder metrics and dynamic postural control in order to correlate these metrics with UCL injury risk. UCL injury is prevalent in collegiate baseball pitchers. Presently, there is no consensus on injury risk performance metrics. Furthermore, the studies to date measuring shoulder internal and external ROM have only been passive measurements and have not included active range, demonstrating the motion the athlete can control or actively manage and move into volitionally. Moreover, no studies have been performed comparing motor control during shoulder ROM movements with dynamic postural control performance using upper and lower body movements. The purpose of this study was to address the current gap in literature regarding the correlation between active and passive shoulder ROM and the ability to move into available range, general whole body movement comptency using the FMS, and neuromuscular motor control performance for the upper and lower extremities. The aim of this study was to take baseline metrics of glenohumeral ROM, the performance of dynamic motor control tasks, and imbalances in mobility and strength between right and left sides among collegiate baseball pitchers and to follow them through the competitive season to see if any suffered a UCL injury. The second intent was to analyze the baseline metrics to determine if an at-risk profile could be identified for those who sustained a UCL injury.

Materials and Methods

Participants

This was an observational cohort study. The Institutional Review Board approved this study. All participants were 18 years of age or older, had their rights and possible risks regarding participation in this study explained to them, and had any questions answered prior to obtaining informed consent. To meet inclusion criteria, participants had to be on the baseball team with no injuries within the last three months, not treated by a medical professional at the time of baseline metric assessments, and they had to complete the self-screen Physical Activity Readiness Questionnaire (PAR-Q), an indication of readiness to exercise which is generally used when a physician consult is not warranted and commonly used as a safety screen for participation in research (Aron et al., 2022; Harper & Aron, 2023; Harper et al., 2023; Harper & Glass, 2021; D. Miner et al., 2022). Exclusion criteria included not meeting inclusion criteria, participant answering "yes" to any of the seven questions on the PAR-Q, and any surgical procedures within the last six months.

Procedure

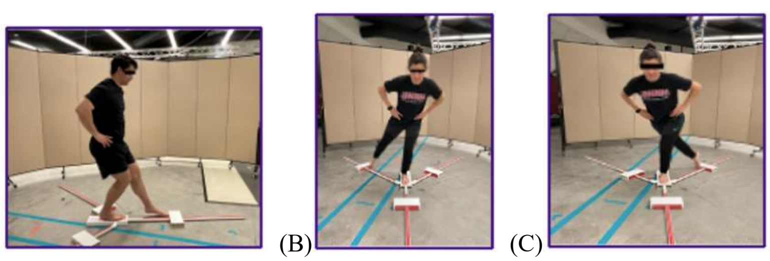
Fifteen NCAA Division I collegiate baseball pitchers agreed to participate in preseason functional movement and motor control assessments. A certified athletic trainer collected baseline preseason metrics from the cohort. Assessments included the Functional Movement Screen (FMS); Upper and Lower Quarter Y Balance Test (UQ-YBT and LQ-YBT); and active (AROM), passive (PROM), and total arc glenohumeral internal (IR) and external rotation (ER) range of motion. The athletes were followed throughout the season to monitor for injuries by the athletic trainer assigned to the sport. Injury was defined as any elbow injury preventing an athlete from participating in practice or competition.

Data Collection

Researchers conducted data collection for the FMS, UQ-YBT, and LQ-YBT within an open gym space. The athletes completed each subtest of the FMS at separate testing stations. The FMS scores range from zero to three, with three as the best score. Five of the seven subtests received scores for right and left sides, including the hurdle step, incline lunge, shoulder mobility, active straight leg raise, and rotary stability (Boudreau et al., 2022). Asymmetries between sides were assessed by comparing right and left raw scores (Cook et al., 2014a, 2014b). The FMS has excellent inter-rater reliability for total scoring (ICC = 0.37-0.98), fair to good reliability for individual subtest scoring (ICC = 0.30-0.89), and good intra-rater reliability (ICC = 0.81) (Bonazza et al., 2017). Furthermore, FMS has been shown to be relaible for novice raters (Harper & Glass, 2021).

The protocol for the UQ-YBT and LQ-YBT (Fig. 1 and Fig. 2) followed the one proposed by Westrick et al (2012) and Plisky et al (2009), respectively (Plisky et al., 2009; Westrick et al., 2012). Each pitcher performed three consecutive practice trials on the right and left UE for all three reach directions, then completed three test trials on the right and left UE for all three directions on the UQ-YBT followed by the LQ-YBT. The UQ-YBT (Boudreau et al., 2022) assesses upper quadrant closed chain movement limitations and asymmetries to identify motor control deficits. The UQ-YBT has good test-retest reliability (ICC=0.80-0.99) and interrater reliability (ICC=1.00) (Gorman et al., 2012). However, the utility of UQ-YBT for overhead athletes has yet to be elucidated (Bauer et al., 2020; Borms et al., 2016).

Figure 2. *Lower Quarter Y-Balance: Superolateral Reach shown. Not shown is Inferolateral and Medial reaches.*

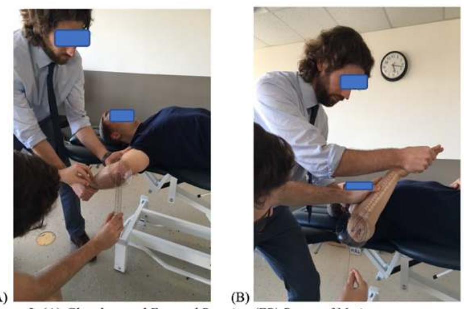


(A) (B) (C)

Figure 2. *Lower Quarter Y-Balance:* (A) *Anterior Reach;* (B) *Posteromedial Reach;* (C) *Posterolateral Reach*

The LQ-YBT protocol varied from the method used by Plisky et al. (2009). The pitchers performed three practice trials in each direction rather than six, which has been utilized successfully in other studies utilizing the LQ-YBT (Jagger et al., 2020; Tsvetkova-Gaberska & Pencheva, 2022). The examiner recorded the distance for all three trials in each direction and calculated composite scores using the maximum reach distance of the three trials to evaluate for asymmetries between right and left reach distances, which standardizes the composite score based on participant leg length. The LQ-YBT is a reliable test of lower quadrant dynamic motor control. The LQ-YBT has intra-rater reliability of 0.85-0.91 in adult populations, inter-rater reliability of 0.81-1.00, and test-retest reliability of 0.63-0.93 (Plisky et al., 2009). The composite reach score intra-rater reliability was 0.91, and interrater reliability was 0.99 on the LQ-YBT for collegiate soccer players (Plisky et al., 2009). Furthermore, a recent systematic review and meta-analysis was performed on the LQ-YBT which supported the reliability of this instrument in assessing single-leg balance as an indirect metric of neuromuscular postural control at the limits of stabilty; however, there are differences between athletes of different sports, indicating cross-sport reliability has yet to be established (Plisky et al., 2021).

Data collection for glenohumeral IR and ER ROM was based on the methods published by Wilk et al. (2011) (Fig. 3). Measurements of AROM and PROM for both ER and IR of the throwing and non-throwing arms were taken before any warm-ups, exercises, or throwing activities. The examiner assessed AROM first, followed by PROM for each athlete. The certified athletic trainer assigned to the team assessed shoulder ROM for all participants. The participant's UE was placed in 90 degrees of shoulder abduction in the scapular plane with the scapula manually stabilized by a second examiner. The scapula was manually stabilized at the coracoid process rather than at the humeral head to avoid altering the normal glenohumeral arthrokinematics. The athletic trainer decided when the athlete's end IR PROM was reached when the coracoid process rose into the athletic trainer's thumb and they observed compensatory movements. The previously described protocol yielded ICC of 0.87 and 0.81 for GH ER and IR ROM (Wilk et al., 2011). Mihata et al. (2016) utilized the same supine passive glenohumeral IR and ER test positions resulting in an inter-rater ICC of 0.78 and a intra-rater ICC of 0.89.


(A) (B)
Figure 3. (A) *Glenohumeral External Rotation (ER) Range of Motion.*
(B) *Glenohumeral Internal Rotation (IR) Range of Motion.*

Data Analysis

During the course of the seasons, two of the 15 pitchers sustained UCL injuries to their throwing arm. The injured pitchers were compared to those in the cohort with the same dominant throwing arm. The cohort of 13 non-injured pitchers was separated into two groups based on dominant throwing arm: right-handed pitchers (RHP) (*n* = 7) and left-handed pitchers (LHP) (*n* = 6). Participant 1 was a 22-year-old right-handed pitcher who suffered from UCL inflammation resulting in 29 missed games over four weeks and was compared to the RHP group. Participant 2 wasa 20-year-old left-handed pitcherw who suffered from a UCL tear requiring surgical repair and which resulted in 55 missed games over the entire season and was compared to the LHP group.

3. Results

Demographic information for the 15 pitchers is presented in Table 1.

Table 1: Characteristics of participants

Variable	Participants	Age (year)	BMI (kg/cm^2)	Throwing UE	Type of Injury	Games Missed
	n	*M (SD)*	*M (SD)*			*n*
RHP	7	19.6 (0.8)	27. (2.3)	R	Non-injured	0
Athlete 1	1	22 (0.0)	27 (0.0)	R	UCL inflammation	29
LHP	6	18.7 (0.5)	26.2 (1.8)	L	Non-injured	0
Athlete 2	1	20 (0.0)	27 (0.0)	L	UCL tear	55

n, numbers; BMI, body mass index; UE, upper extremity; *M*, mean; *SD*, standard deviation; UCL, ulnar collateral ligament; RHP, right-handed pitchers; LHP, left-handed pitchers; R, right; L, left.

Glenohumeral ROM results are listed in Table 2. Participant 1 demonstrated greater ER PROM than ER AROM and greater Total Arc PROM, indicating that this baseball pitcher may have a motor control issue. In addition, participant 1 presented with greater Total Arc AROM and PROM compared to the mean of the RHP cohort. However, participant 1 did not present with GIRD compared to the RHP group. Participant 2 presented with differences in IR PROM and AROM, ER PROM and AROM, and Total Arc PROM compared to AROM, indicating a potential motor control deficit compared to the normative values of the non-injured cohort. In addition, participant 2 presented with larger ER PROM and Total Arc PROM compared to the mean of the LHP group.

Table 2 Glenohumeral range of motion among participants

Variable	Throwing UE	Non-throwing UE	Throwing UE	Non-throwing UE
	M (SD)	*M (SD)*		
	RHP (*n* = 7)		**Athlete 1 (*n* = 1)**	
IR ROM				
AROM (deg)	49.6 (12.2)	62.4 (13.8)	61	65
PROM (deg)	60.4 (10.6)	78.4 (10.0)	68	75
Difference in ROM (deg)	10.8	16	7	10
ER ROM				
AROM (deg)	104.7 (9.6)	98.4 (4.4)	109	92
PROM (deg)	128.0 (11.2)	113.6 (6.0)	125	126
Difference in ROM (deg)	23.3	15.2	16	34
Total Arc ROM				
AROM (deg)	154.3 (5.9)	160.9 (12.9)	170	157
PROM (deg)	188.4 (11.6)	192.0 (10.6)	193	201
Difference in ROM (deg)	34.1	31.1	23	44
Presence of GIRD	Yes (*n* = 3)		No (*n* = 1)	
	LHP (*n* = 6)		**Athlete 2 (*n* = 1)**	
IR ROM				
AROM (deg)	41.8 (16.4)	48.5 (7.34)	39	59
PROM (deg)	63.8 (8.9)	67.5 (9.4)	69	75
Difference in ROM[a] (deg)	22.0	19.0	30	16
ER ROM				
AROM (deg)	108.0 (10.9)	108.8 (6.7)	109	105
PROM (deg)	127.5 (5.3)	127.7 (12.5)	140	122
Difference in ROM[b] (deg)	19.5	18.9	31	17
Total Arc ROM[c]				
AROM (deg)	149.8 (24.6)	157.3 (13.0)	148	164
PROM (deg)	191.3 (12.0)	195.2 (12.1)	209	197
Difference in ROM[d] (deg)	41.5	37.9	61	33
Presence of GIRD[e]	Yes (n = 1)		No (n = 1)	

n, numbers; UE, upper extremity; M, mean; SD, standard deviation; RHP, right-handed pitchers; LHP, left-handed pitchers; ROM, range of motion; AROM, active range of motion; PROM, passive range of motion IR, internal rotation; ER, external rotation; Deg, degrees; GIRD, glenohumeral internal rotation deficit.
[a] IR Difference in ROM = IR PROM – IR AROM.
[b] ER Difference in ROM = ER PROM – ER AROM.
[c] Total Arc ROM = ER ROM + IR ROM
[d] Total Arc Difference in ROM = Total Arc PROM – Total Arc AROM.
[e] GIRD was defined as ≥20° difference in internal rotation ROM of the throwing shoulder compared to the non-throwing shoulder.

Functional movement results are listed in Table 3. Both participants 1 and 2 scored below the mean composite scores compared to the non-injured cohort on the FMS and LQ-YBT. Participant 2 demonstrated asymmetries between right and left UE on the shoulder reach subtest. Participant 1 scored below the mean of the non-injured cohort for the throwing limb on the UQ-YBT, whereas participant 2 scored below the mean bilaterally. Both cases demonstrated imbalances between the right and left sides on the UQ-YBT, but only participant 2 demonstrated asymmetries on the LQ-YBT. Compared to the non-injured cohort, participant 2 demonstrated larger differences in performance between the right and left sides on the UQ-YBT and LQ-YBT compared to the cohort mean.

Table 3 Dynamic motor control performance outcomes from the Functional Movement Screen, Upper Quarter Y Balance Test, and Lower Quarter Y Balance Test.

Variable	Non-injured Pitchers (*n* = 13)	RHP (*n* = 7)	LHP (*n* = 6)	Athlete 1 RHP (*n* = 1)	Athlete 2 LHP (*n* = 1)
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
FMS					

Composite Score[a]	15.2 (0.5)	15.0 (0.4)	15.5 (1.0)	15	15
SR Asymmetry[b]				No	Yes
ASLR Asymmetry[b]				No	No
UQ-YBT					
R Composite Score[c]	106.7 (10.3)	100.4 (10.8)	114.0 (19.1)	104.1	79.6
L Composite Score[c]	107.4 (10.2)	101.6 (11.1)	114.2 (18.7)	111.7	80.4
UQ Asymmetry[d]				Yes (IL, SL)	Yes (SL)
LQ-YBT					
R Composite Score[e]	113.7 (6.6)	116.8 (9.9)	110.2 (9.3)	101.2	92.7
L Composite Score[e]	113.3 (6.8)	116.3 (10.5)	109.8 (9.2)	101.5	94.9
LQ Asymmetry[f]				No	Yes (Ant)

n, numbers; UE, upper extremity; M, mean; SD, standard deviation; RHP, right-handed pitchers; LHP, left-handed pitchers; FMS, Functional Movement Screen; SR, shoulder reach; ASLR, active straight leg raise; UQ-YBT, upper quarter Y balance test; LQ-YBT, lower quarter Y balance test; IL, interior-lateral reach; SL, superior-lateral reach; Ant, anterior reach.

[a] FMS Composite Score = sum of the final scores for all 7 subtests, the best composite score is 21; Final Score = the lowest score of the raw scores for each side (right and left) for 5 out of 7 subtest; Raw Score = score received for right and left sides for 5 out of 7 subtests.

[b] FMS Asymmetry was defined as differences in raw scores between right and left sides.

[c] UQ-YBT Composite Score for Right and Left = greatest reach distance for each reach direction (medial, infero-lateral, and supero-lateral) are summed and divided by 3 times the limb length (measurement from the C7 vertebra to the tip of the right longest finger).

[d] UQ-YBT Asymmetry was defined as > 4 cm in all reach directions (medial, infero-lateral, and supero-lateral).

[e] LQ-YBT Composite Score for Right and Left = greatest reach distance for each reach direction (anterior, postero-medial, and postero-lateral) are summed and divided by 3 times the limb length (measurement from right distal anterior superior iliac spine to the right distal aspect of the medial malleolus).

[f] LQ-YBT Asymmetry was defined as > 4 cm in the anterior reach and > 6 cm in the postero-medial and postero-lateral directions.

Discussion

Both participants with UCL injuries demonstrated imbalances between the right and left sides during upper and lower quarter movement patterns and reduced ability to access all the available glenohumeral ROM during UE movement actively. The inability to actively move into an available range of motion may indicate the presence of motor control deficits, which suggests impaired dynamic motor control and performance during functional movements. The design of this study prohibits the conclusion that preseason functional movement assessment scores can predict UCL injury in collegiate baseball players.

Findings from prior research can explain the findings from this observational study. Current literature has established the relationship between lower scores on functional movement assessments with increased risk of injury in athletes. Kiesel et al. (2007) concluded that a cut-off score on the FMS of 14 or less indicated the presence of dysfunctional movement patterns, which may be a predictive risk factor for future injury (Kiesel et al., 2007). In addition, previous studies have found a significant correlation between lower scores on the FMS and increased risk of injury in athletes (Chorba et al., 2010), while others have failed to identify correlations between the FMS and lower extremity strength (Soyal et al., 2023). In this study, the FMS did not appear to be relevant to risk of injury, as the injured pitchers scored at the mean of the cohort group and would not have been flagged as at risk for injury by their FMS scores.

When implementing functional movement screens to identify baseball players at risk for elbow injury, one must consider all potential factors including position, shoulder ROM, core function and stability, movement at the various joints during throwing motion, the volume of throwing, and ball velocity (Kibler et al., 2022; Mine et al., 2021). A recent systematic review and meta-analysis study looked at risk factors for UCL injury. They concluded that greater shoulder IR ROM differences in the non-dominate throwing upper extremity was strongly correlated with UCL injury risk ($p < .001$); while dominate throwing arm total arc of motion, ER ROM, or IR ROM were not injury risk predictors (Reiman et al., 2019). In contrast, the two pitchers sustaining UCL injuries in this study demonstrated differences in both internal and extern motion. In fact, participant 2, requiring surgical repair of the throwing arm UCL, presented with greater differences in glenohumeral ROM with almost three times greater difference in Total Arc active and passive ROM compared to participant 1.

Differences in rotational ROM measurements may occur based on test performance and parameters. Shoulder internal and external rotational testing, as described by Wilk et al. (2011), is typically tested and measured passively to the end of available motion (Wilk et al., 2011).However, differences of opinion have been raised regarding the accuracy of stabilizing the coracoid and shoulder to the table while passively testing the available rotational motion. Kibler et al. (2022) measured shoulder rotational motion by taking un-stabilized isolated rotational measures. They measured after allowing the isolated motion in the testing position to reach the end of available active motion without applying overpressure. Overpressure, without stabilization of the shoulder complex, permits increased motion; the difficulty in controlling for compensating movements may skew isolated rotational measurements and may be therapist dependent.

This study utilized both strategies in the rotational motions. The AROM testing followed the method used by Kibeler et al. (Kibler et al., 2022), which allowed measurement of the available mobility without passive overpressure. The PROM measurements followed that described by Wilk et al. (Wilk et al., 2011), so the joint was moved to the full isolated mobility. The differences in these measures are clearly noted within the professional literature, but the clinical utility of the difference has yet to be explored. One goal of this study was to compare the differences between A/PROM in both IR and ER, which may provide a better predictor of injury by enabling the clinician to compare the difference between a participants active and passive isolated shoulder ROM, resulting in better clinical utility.

The more dynamic YBT postural control test, which was designed to identify motor control deficits within the kinetic chain, might be a more accurate predictive tool for identifying those at risk for elbow injury. Garrison et al. (2013) identified a correlation between lower LQ-YTB scores and subsequent UCL injuries in baseball players when compared to the LQ-YTB scores in non-injured players (Garrison et al., 2013). Butler et al. (2016) showed that that healthy baseball players have symmetical performance scores when comparing right and left sides during the LQ-YBT, while Tsvetkova-Gaberska & Pencheva (2022) demonstrated that symmetry is also noted in healthy controls. Both participants 1 and 2 in this study had lower LQ-YBT scores when compared to their respective pitching group and when compared to the entire non-injured cohort. Of note, athlete 2, who required surgical repair, was dramatically below the mean for LQ-YBT and asymmetrical between sides. Furthermore, athlete 2 was also substantially below the mean for the UQ-YBT with asymmetry between sides when compared to their LHP group and to the entire non-injured cohort.

Westrick et al. (2012) assessed the value of using upper extremity closed kinetic chain testing for any differences between throwing athletes dominate and non-dominate arms. They found no significant difference in performance between dominant and nondominant upper extremities in healthy college students. Their study supported the potential clinical utility of the UQ-YBT as a useful tool to assess return to play readiness comparing baseline metrics to post-injury performance (Westrick et al., 2012). This study utilized this concept to apply UQ-YBT differences in baseline performance as a potential upper quarter injury risk metric. Participant 2 (LHP), who required surgical repair of the UCL, demonstrated dramatically poorer performance on the UQ-YBT at baseline; participant 1, who had UCL inflammation, did not have a composite score difference when compared to their cohort. However, both injured pitchers demonstrated an upper quarter asymmetry in one of the three reach directions. The use of the YBT to identify baseball players at risk of injury requires further research to determine reliable normative scores specific to the baseball population. Future research is warranted to identify the association of motor control deficits in upper quarter active and passive glenohumeral joint ROM compared to dynamic upper and lower quarter motor control tasks.

The main limitation of this study is the observational design, which precludes claims of any correlation between functional movement performance. Another limitation in this study involves the duration of time between baseline measurements and when the injury of each participant occurred. It is possible functional movement patterns changed during the competitive season; however, the baseline scores were so poor compared to the mean, it is unlikely the movement patterns improved after baseline measures. This study is vulnerable to the same limitations as the Wilk et al. (2011) manuscript in this regard. The approach for sample selection used in this study suffers from the limitation of increased risk of bias, since it included one team and one set of pitchers, which may have influenced the findings.

Conclusions

This case series presents preliminary information regarding the value of adding differences in active and passive shoulder internal and external range of motion with dynamic postural control performance to identify the risk of potential elbow ligament injury. This study was conducted in preparation for future randomized clinical trials. This single cohort observational study identified decreased performance on baseline metrics for pitchers with UCL injuries compared to the non-injured pitchers. Both participants had more significant pre-injury differences between active and passive ROM than the non-injured pitcher group, indicating a possible motor control deficit resulting in the inability of the pitchers to access all available glenohumeral ROM actively. Thus, the UCL-injured pitchers had more glenohumeral rotation motion that they could not actively access or control, which was associated with a decreased lower quarter performance of dynamic balance control. Findings indicate possible motor control deficits in both the upper and lower extremities in those who eventually sustained a UCL injury. The observations in this study indicate a potential for further research into the value of comparing active and passive ROM in conjunction with a dynamic UQ and LQ functional assessment to evaluate the risk of injury in baseball pitchers. Further prospective clinical trials are warranted to elucidate these observations fully.

Presently, there is no consensus on effective or reliable functional movement screens that can predict the severity of future injuries. A conundrum exists during the arm cocking phase of pitching where shoulder ER is required, yet maximum or excessive shoulder ER mobility will increase valgus torques at the medial elbow. Thus, a sufficient amount of ER is desired, but an excessive amount is undesirable. Whitt et al. (2019) assessed shoulder abduction ROM and found that those with UCL tears had increased shoulder abduction with differences between the throwing and non-throwing side. This opposed their hypothesis, which was that there would be decreased shoulder mobility to minimize elbow valgus stress. Unfortunately, Whitt et al. only took passive measurements. This case series identified two pitchers who had dramatic differences between the ROM they could actively control versus the ROM available passively. Perhaps the body's nervous system creates stiffness to decrease the degrees of freedom in an attempt to limit valgus forces to the medial elbow, and, likewise, that a decreased ability to stabilize one's base of support during a single-leg balance activity, like the LQ-YBT, is a secondary indication of such motor control deficits and likewise, both findings of which may indicate a protective response. Future research should examine the relationship between functional movement screens and dynamic motor control to identify collegiate baseball athletes at risk for UCL injury and to identify factors correlated with greater severity of the injury.

Author Contributions

Conception and design, B.H.; methodology, B.H.; acquisition, B.H., analysis and interpretation of data, B.H., L.B., M.J., B.J.; writing—original draft preparation, B.H., L.B., M.J., B.J.; writing—review and editing, B.H., L.B., M.J., B.J.; project administration, B.H.; All authors have read and agreed to the published version of the manuscript. All authors agree to the accountability of this work for accuracy and integrity which was appropriately investigated.

Funding

This research received no external funding

Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Radford University (protocol code IRB-15-004).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be make available by the corresponding author upon reasonable request.

Acknowledgments

We are thankful to the players, coaches, and athletic trainers who supported this study. We are thankful to Sonya Harper for supporting the manuscript editing process. We wish to thank all the participant in the present study and the school where the study took place.

Conflicts of Interest: The authors declare no conflict of interest.

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