World Journal of Orthopedics

Submit a Manuscript: http://www.wjgnet.com/esps/
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
DOI: 10.5312/wjo.v7.i6.355

World J Orthop 2016 June 18; 7(6): 355-360
ISSN 2218-5836 (online)

MINIREVIEWS

Medial ulnar collateral ligament reconstruction of the elbow in major league baseball players: Where do we stand?

Brandon J Erickson, Bernard R Bach Jr, Charles A Bush-Joseph, Nikhil N Verma, Anthony A Romeo

Brandon J Erickson, Bernard R Bach Jr, Charles A Bush-Joseph, Nikhil N Verma, Anthony A Romeo, Midwest Orthopaedics at Rush, Rush University Medical Center, Chicago, IL 60611, United States

Author contributions: Erickson BJ, Bach Jr BR, Bush-Joseph CA, Verma NN and Romeo AA designed this study, wrote and edited the manuscript.

Conflict-of-interest statement: No author has any conflicts of interest that pertain to the submitted article. Other conflicts of interest are listed in the document of conflict-of-interest statement.

Correspondence to: Brandon J Erickson, MD, Midwest Orthopaedics at Rush, Rush University Medical Center, 1611 W Harrison St, Suite 300, Chicago, IL 60611, United States. brandon.j.erickson@gmail.com
Telephone: +1-732-4925775
Fax: +1-312-9422040

Received: January 25, 2016
Peer-review started: January 25, 2016
First decision: February 29, 2016
Revised: March 8, 2016
Accepted: March 24, 2016
Article in press: March 25, 2016
Published online: June 18, 2016

Abstract

The ulnar collateral ligament (UCL) is a vital structure to the overhead athlete, especially the baseball pitcher. For reasons not completely understood, UCL injuries have become increasingly more common in major league baseball (MLB) pitchers over the past 10 years. UCL reconstruction (UCLR) is the current gold standard of treatment for these injuries in MLB pitchers who wish to return to sport (RTS) at a high level and who have failed a course of non-operative treatment. Results following UCLR in MLB pitchers have been encouraging, with multiple RTS rates now cited at greater than 80%. Unfortunately, with the rising number of UCLR, there has also been a spike in the number of revision UCLR in MLB pitchers. Similar to primary UCLR, the etiology of the increase in revision UCLR, aside from an increase in the number of pitchers who have undergone a primary UCLR, remains elusive. The current literature has attempted to address several questions including those surrounding surgical technique (method of exposure, graft choice, management of the ulnar nerve, concomitant elbow arthroscopy, *etc.*), post-operative rehabilitation strategies, and timing of RTS following UCLR. While some questions have been answered, many remain unknown. The literature surrounding UCLR in MLB pitchers will be reviewed, and future directions regarding this injury in these high level athletes will be discussed.

Key words: Ulnar collateral ligament; Ulnar collateral ligament reconstruction; Tommy John; Major league baseball; Pitcher; Baseball

Core tip: The number of ulnar collateral ligament (UCL) tears in major league baseball athletes is increasing with time. UCL reconstruction (UCLR) has become the gold standard for treatment of UCL tears. The outcomes of this surgery in elite level athletes is encouraging, with return to sport rates typically > 80%. Results following revision UCLR are less encouraging. Currently, there is no standardized rehabilitation protocol or timing to return to sport. Future research into graft choice,

surgical technique, management of the ulnar nerve, and rehabilitation protocols must be done to achieve the best possible results in this elite group of athletes.

Erickson BJ, Bach Jr BR, Bush-Joseph CA, Verma NN, Romeo AA. Medial ulnar collateral ligament reconstruction of the elbow in major league baseball players: Where do we stand? *World J Orthop* 2016; 7(6): 355-360 Available from: URL: http://www.wjgnet.com/2218-5836/full/v7/i6/355.htm DOI: http://dx.doi.org/10.5312/wjo.v7.i6.355

INTRODUCTION

The ulnar collateral ligament (UCL) is one of the most important structures about the elbow in the overhead athlete, especially the baseball pitcher[1,2]. While the UCL is not commonly stressed during activities of daily living, the baseball pitch imparts a significant amount of stress on the UCL, specifically the posterior band of the anterior bundle as it is this part of the UCL that sees the most stress at higher degrees of elbow flexion, causing the UCL to approach failure with each pitch[3-5]. Without the secondary osseous and soft tissue restraints about the elbow, the UCL would fail after each pitch as the valgus force generated at the elbow with each pitch is approximately 64 nmol/L, while the ultimate load to failure of the native and reconstructed UCL is 34.29 nmol/L, and 30.55 nmol/L, respectively[3].

Diagnosis of UCL tears is accomplished through patient history, physical exam maneuvers, and diagnostic imaging[6]. Baseball pitchers who sustain tears to the UCL often report a decrease in velocity as well as a loss of accuracy in the time leading up to their injury[7]. Some patients will have concomitant ulnar nerve symptoms, such as numbness/tingling of the pinky and ulnar half of the ring finger, weakness of the first dorsal interosseous muscle, and others. On physical exam, these patients can have pain along the course of the UCL. They may also have an increase in elbow valgus laxity compared to the contralateral arm, although this can be physiologic in baseball pitchers[8]. Special physical exam maneuvers, including the moving valgus stress test and milking maneuver, are often positive in these patients as these tests stress the UCL in the position of throwing[6,9,10]. Although anteroposterior, lateral, and external oblique radiographs are useful to rule out calcifications in the UCL as well as other pathology, magnetic resonance imaging (MRI) with or without arthrography is the current imaging modality of choice to diagnose a UCL tear[11,12]. It seems that the increase in diagnosis of UCL tears is likely secondary to sports specialization in adolescents leading to an increase in the true number of UCL tears rather than an overdiagnosis on MRI like has been shown with superior labral tears[13-15].

Should the UCL fail, the current gold standard treatment option for elite level overhead athletes who wish to return to sport (RTS) at a high level after failing non-operative management is an UCL reconstruction (UCLR). Although repair of the UCL has been described with encouraging results for properly indicated adolescents, the results of repair have reproducibly been inferior to UCLR in major league baseball (MLB) athletes, and so UCLR has become to standard of care[7,16,17]. UCLR was initially described by Jobe *et al*[18] in the literature in 1986, although the index surgery was performed on September 25, 1974 on then Los Angeles Dodgers pitcher, Tommy John.

The initial technique by Jobe *et al*[18] called for an elevation of the flexor pronator mass with a submuscular transposition of the ulnar nerve and a figure of eight graft configuration in which the graft was sutured to itself. Results of the initial Jobe technique demonstrated that greater than 60% of elite throwing athletes were able to RTS at their pre-surgical level of participation[16]. However, 21% of these patients had a post-operative ulnar neuropraxia, all of which resolved by seven years[16]. Following this initial description, concern arose over the treatment of the flexor pronator mass, as well as the routine submuscular transposition of the ulnar nerve. Therefore, since the initial description by Dr. Jobe, many modifications have been made to improve patient outcomes and decrease complications following UCLR; these modifications include a split in the flexor pronator mass, subcutaneous ulnar nerve transposition, and varying ways to secure the graft both on the ulna as well as humerus[7,19-24].

EPIDEMIOLOGY OF UCLR IN MLB

Several studies have shown a recent increase in the number of UCL tears, and more specifically, the number of UCLR in MLB pitchers[2,25-27]. Recent studies have also shown an increase in the number of UCLR performed in adolescent athletes, specifically those between the ages of 15-19 years[28]. When evaluating MLB players, as expected, UCLR is significantly more common in MLB pitchers than any other position. When Conte *et al*[2] surveyed 5088 professional baseball players, there was a 16% prevalence of UCLR amongst pitchers compared to only 3% amongst all other position players. Interestingly, this survey study by Conte *et al*[2] found that 25% of al MLB pitchers admitted to a history of UCLR, while 15% of minor league pitchers had undergone UCLR. No difference was seen in the prevalence of UCLR between pitchers born in the United States *vs* those born in Latin America countries[2]. Erickson *et al*[25,26] showed a significant increase in the number of UCLR in MLB pitchers from 2000 to 2012 (P = 0.014), and further studies have demonstrated that the number has continued to rise in 2013 and 2014[2]. Interestingly, there was no statistically significant increase in the number of UCLR in MLB pitchers between the 1980s and 1990s[25]. MLB pitchers who underwent primary UCLR played an average of 5.27 ± 4.34 seasons prior to surgery[25]. Furthermore, pitchers who grew up in warm weather climates were more likely to undergo UCLR earlier in their MLB career than

those from cold weather climates[26]. While the increase in UCLR has been clearly documented, the reason for this increase remains unknown. There have been no prospective studies in the literature to date that have definitively shown what the cause of this increase in the number of UCLR is.

Several studies have, however, demonstrated risk factors for elbow injuries in adolescent athletes including pitching more than 100 innings per year, high pitch counts, pitching on consecutive days, pitching for multiple teams, pitching while fatigued, pitching year round, pitching with higher velocity, pitching with supraspinatus weakness, geography, pitching with a glenohumeral internal rotation deficit, and most recently pitching with a loss of total arc of motion, especially decreased external rotation[26,29-38]. While these risk factors have been well established, there have been no studies to date that have been able to show a risk reduction in the number of UCLR by implementing programs to limit these risk factors. This is an area that requires further attention in the coming years as there does not appear to be an end in sight to the growing number of UCLR, and injury prevention must be at the forefront of current research to protect both MLB and adolescent pitchers[39].

Although the increase in the number of primary UCLR in MLB pitchers is worrisome, a more pressing concern is the increase in the number of revision UCLR in these athletes[2,40-42]. Wilson *et al*[42] evaluated 271 professional baseball pitchers who underwent primary UCLR and found that 40 (15%) required at least one revision UCLR during their pitching career while three pitchers required a second revision. The revision surgery occurred an average of 5.2 ± 3.2 years following the index UCLR, although there was a wide range from 1-13 years. As pitchers are beginning to undergo UCLR at earlier ages, it begs the question if the longevity of these athletes is going to decrease with time. Some would argue that a pitcher has a finite number of innings he can throw. If adolescent athletes are throwing year round and not following the rules set forth for their protection regarding inning and pitch count limits, these athletes could begin to undergo their index UCLR at earlier ages, causing the likelihood of a revision UCLR to rise, thereby limiting the ultimate number of years they can pitch in MLB.

OUTCOMES FOLLOWING PRIMARY AND REVISION UCLR IN MLB PITCHERS

Primary

There have been many studies that have looked at publically available data to determine the outcomes following UCLR in MLB pitchers as it relates to RTS as well as overall performance upon RTS[25,43]. Erickson *et al*[25] evaluated all MLB pitchers from 1974 to 2012 who underwent UCLR using publically available data, team injury reports, *etc.*, and compared this group to a matched control group of healthy MLB pitchers. The authors found a total of 179 pitchers who underwent UCLR having pitched at least one game in MLB. Of these 179 pitchers, 148 (83%) were able to RTS and pitch in at least one MLB game following UCLR, 174 (97.2%) were able to RTS in either the major or minor leagues, and only 5 pitchers (2.8%) were unable to pitch again in the major or minor leagues. The pitchers were able to RTS at an average of 20.5 ± 9.72 mo following their UCLR and pitched for an average of 3.9 ± 2.84 years after their RTS. The number of years pitched after RTS may have been falsely low as 56 of these pitchers were still active in MLB at the time the study was conducted.

When the authors evaluated the performance of these MLB pitchers upon RTS they found that pitchers pitched fewer innings in season following their UCLR and had fewer wins and losses per season compared to before surgery[25]. Furthermore, pitchers had a significantly lower earned run average (ERA) and walks plus hits per inning pitched (WHIP) following surgery than beforehand. WHIP is a sabermetric that is calculated by summing a pitcher's total walks and hits for one season and dividing the sum by the number of innings pitched that season. A later study conducted by Jiang *et al*[43] evaluated 28 MLB pitchers between 2008-2010 who underwent UCLR to determine if pitching velocity, as well as performance variables changed compared both to pre-operative levels upon RTS in MLB as well as control group of healthy MLB pitchers. The authors found a statistically significant decrease in mean pitch velocity of both the fastball and changeup in each post-injury year compared to pre-injury velocities. The average decrease in fastball velocity for post-UCLR years 1-3 was 1.3, 1.0, 1.0 miles per hour (mph) respectively. The average decrease in changeup velocity for post-UCLR years 1-3 was 1.2, 1.3, 1.0 mph respectively. Furthermore, a decrease in curveball velocity was seen in post UCLR years 2 and 3 that averaged 1.0 and 1.7 mph respectively. However, despite these differences between pre and post UCLR pitching velocities in the group of pitchers who underwent UCLR, there was no significant difference in mean pitch velocity for any pitch, in any year following UCLR in cases *vs* matched controls[43]. Hence, this could mean that pitchers who sustain UCL tears and undergo UCLR are throwing faster than their peers at baseline. Lansdown *et al*[44] performed a similar study and found similar results; pitchers who underwent UCLR had a significant decrease in mean fastball velocity (91.3 mph *vs* 90.6 mph) (P = 0.003), with the greatest decrease in velocity seen in pitchers older than 35 years of age (91.7 to 88.8 mph) (P = 0.0048). Despite the belief from players, parents, and coaches as shown by Ahmad *et al*[45] that UCLR will improve a pitchers velocity, these two studies clearly demonstrate a small but significant decrease in velocity following UCLR.

Revision

While the results following primary UCLR in MLB pitchers are reliable, the results following revision UCLR in the same patient population are not as encouraging[40]. Marshall *et al*[40] evaluated 33 MLB pitchers who under-

went revision UCLR and compared these pitchers to matched controls to determine if differences existed in performance upon RTS. The authors found that 65.5% of pitchers who underwent revision UCLR were able to return to RTS in MLB while 84.8% were able to RTS in either the major or minor leagues; both rates are lower than RTS rates following index UCLR of 83% for MLB and 97.2% for either major or minor leagues[25]. Interestingly, when Liu *et al*[46] also evaluated 31 MLB pitchers following revision UCLR surgery, the authors found that while 65% were able to RTS in the MLB for one game or more, only 42.8% were able to pitch 10 or more games in MLB. Similar to the reported length of recovery following primary UCLR of 20.5 mo, the average time to RTS following revision UCLR was 20.76 mo[25,46].

When compared to pre-injury performance levels, following revision UCLR pitchers pitched fewer innings, had fewer wins and losses, and let up more walks per nine innings. The only performance parameter that improved was the number of runs allowed per nine innings declined following revision surgery. Furthermore, pitchers who were able to RTS following revision UCLR pitched significantly fewer seasons than matched controls (2.6 *vs* 4.9 seasons)[46]. Following revision UCLR, pitchers had no difference in ERA and WHIP when compared to controls[40]. Unfortunately, following revision UCLR pitchers threw significantly fewer innings, gave up significantly more walks, and had significantly fewer wins (although they also had significantly fewer losses) compared to controls[40].

FUTURE DIRECTIONS

Although there have bee numerous studies that have reported on the RTS rate and outcomes of MLB pitchers following both primary and revision UCLR, there have been no prospective studies in this athlete cohort that have evaluated RTS rate or success upon RTS as it relates to surgical technique, graft choice, management of the ulnar nerve, concomitant arthroscopy, rehabilitation protocol, and timing of RTS[25,40,44,46]. In order to improve outcomes, it is necessary to determine if these variables influence outcomes in MLB pitchers. One topic that has received recent attention is when to allow pitchers to throw for the first time following UCLR. While some protocols wait five months or more, some allow throwing as early as three to four months. Unfortunately, no data exists on the ideal timing, so these protocols have not yet been standardized to efficiently and safely return these pitchers to sport.

Furthermore, large, prospective studies must be designed to follow elite pitchers starting at the Little League level through their career. Although only a small percentage of these athletes will become MLB pitchers, it would be extremely valuable to see if implementing some of the rules and regulations aimed at decreasing elbow injuries were effective, and likewise to see if pitchers who did not adhere to the regulations were at higher risk for undergoing UCLR later in life. This would also give the orthopaedic community an idea if pitchers do in deed have a finite number of innings their body will allow them to pitch, thereby proving to coaches and parents the importance of limiting excessive pitching at early ages.

CONCLUSION

Recent times have seen an increase in the number of UCLR in MLB pitchers. While evidence has shown a greater than 80% RTS rate following UCLR, the RTS rate following revision UCLR is not as high. Further large scale, prospective studies are necessary to help dictate treatment algorithms in these high level athletes.

REFERENCES

1 **Morrey BF**. Applied anatomy and biomechanics of the elbow joint. *Instr Course Lect* 1986; **35**: 59-68 [PMID: 3819430]
2 **Conte SA**, Fleisig GS, Dines JS, Wilk KE, Aune KT, Patterson-Flynn N, ElAttrache N. Prevalence of Ulnar Collateral Ligament Surgery in Professional Baseball Players. *Am J Sports Med* 2015; **43**: 1764-1769 [PMID: 25925603 DOI: 10.1177/0363546515580792]
3 **Morrey BF**, An KN. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med* 1983; **11**: 315-319 [PMID: 6638246 DOI: 10.1177/036354658301100506]
4 **Munshi M**, Pretterklieber ML, Chung CB, Haghighi P, Cho JH, Trudell DJ, Resnick D. Anterior bundle of ulnar collateral ligament: evaluation of anatomic relationships by using MR imaging, MR arthrography, and gross anatomic and histologic analysis. *Radiology* 2004; **231**: 797-803 [PMID: 15105452 DOI: 10.1148/radiol.2313030560]
5 **Dugas JR**, Ostrander RV, Cain EL, Kingsley D, Andrews JR. Anatomy of the anterior bundle of the ulnar collateral ligament. *J Shoulder Elbow Surg* 2007; **16**: 657-660 [PMID: 17583541 DOI: 10.1016/j.jse.2006.11.009]
6 **Erickson BJ**, Harris JD, Chalmers PN, Bach BR, Verma NN, Bush-Joseph CA, Romeo AA. Ulnar Collateral Ligament Reconstruction: Anatomy, Indications, Techniques, and Outcomes. *Sports Health* 2015; **7**: 511-517 [PMID: 26502444 DOI: 10.1177/1941738115607208]
7 **Cain EL**, Andrews JR, Dugas JR, Wilk KE, McMichael CS, Walter JC, Riley RS, Arthur ST. Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes: Results in 743 athletes with minimum 2-year follow-up. *Am J Sports Med* 2010; **38**: 2426-2434 [PMID: 20929932 DOI: 10.1177/0363546510378100]
8 **Ciccotti MG**, Atanda A, Nazarian LN, Dodson CC, Holmes L, Cohen SB. Stress sonography of the ulnar collateral ligament of the elbow in professional baseball pitchers: a 10-year study. *Am J Sports Med* 2014; **42**: 544-551 [PMID: 24473498 DOI: 10.1177/0363546513516592]
9 **Erickson BJ**, Bach BR, Cohen MS, Bush-Joseph CA, Cole BJ, Verma NN, Nicholson GP, Romeo AA. Ulnar Collateral Ligament Reconstruction: The Rush Experience. *Orthop J Sports Med* 2016; **4**: 2325967115626876 [PMID: 26862538 DOI: 10.1177/2325967115626876]
10 **Cain EL**, Dugas JR, Wolf RS, Andrews JR. Elbow injuries in throwing athletes: a current concepts review. *Am J Sports Med* 1985; **31**: 621-635 [PMID: 12860556]
11 **Magee T**. Accuracy of 3-T MR arthrography versus conventional 3-T MRI of elbow tendons and ligaments compared with surgery. *AJR Am J Roentgenol* 2015; **204**: W70-W75 [PMID: 25539278 DOI: 10.2214/AJR.14.12553]
12 **Podesta L**, Crow SA, Volkmer D, Bert T, Yocum LA. Treatment of partial ulnar collateral ligament tears in the elbow with platelet-rich plasma. *Am J Sports Med* 2013; **41**: 1689-1694 [PMID: 23666850

DOI: 10.1177/0363546513487979]
13 **Sheridan K**, Kreulen C, Kim S, Mak W, Lewis K, Marder R. Accuracy of magnetic resonance imaging to diagnose superior labrum anterior-posterior tears. *Knee Surg Sports Traumatol Arthrosc* 2015; **23**: 2645-2650 [PMID: 24985524 DOI: 10.1007/s00167-014-3109-z]
14 **Myer GD**, Jayanthi N, Difiori JP, Faigenbaum AD, Kiefer AW, Logerstedt D, Micheli LJ. Sport Specialization, Part I: Does Early Sports Specialization Increase Negative Outcomes and Reduce the Opportunity for Success in Young Athletes? *Sports Health* 2015; **7**: 437-442 [PMID: 26502420 DOI: 10.1177/1941738115598747]
15 **Myer GD**, Jayanthi N, DiFiori JP, Faigenbaum AD, Kiefer AW, Logerstedt D, Micheli LJ. Sports Specialization, Part II: Alternative Solutions to Early Sport Specialization in Youth Athletes. *Sports Health* 2016; **8**: 65-73 [PMID: 26517937 DOI: 10.1177/1941738115614811]
16 **Conway JE**, Jobe FW, Glousman RE, Pink M. Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. *J Bone Joint Surg Am* 1992; **74**: 67-83 [PMID: 1734015]
17 **Savoie FH**, Trenhaile SW, Roberts J, Field LD, Ramsey JR. Primary repair of ulnar collateral ligament injuries of the elbow in young athletes: a case series of injuries to the proximal and distal ends of the ligament. *Am J Sports Med* 2008; **36**: 1066-1072 [PMID: 18443280 DOI: 10.1177/0363546508315201]
18 **Jobe FW**, Stark H, Lombardo SJ. Reconstruction of the ulnar collateral ligament in athletes. *J Bone Joint Surg Am* 1986; **68**: 1158-1163 [PMID: 3771597]
19 **Vitale MA**, Ahmad CS. The outcome of elbow ulnar collateral ligament reconstruction in overhead athletes: a systematic review. *Am J Sports Med* 2008; **36**: 1193-1205 [PMID: 18490476 DOI: 10.1177/0363546508319053]
20 **Erickson BJ**, Chalmers PN, Bush-Joseph CA, Verma NN, Romeo AA. Ulnar Collateral Ligament Reconstruction of the Elbow: A Systematic Review of the Literature. *Orthop J Sports Med* 2015; **3**: 2325967115618914 [PMID: 26740956 DOI: 10.1177/2325967115618914]
21 **Rohrbough JT**, Altchek DW, Hyman J, Williams RJ, Botts JD. Medial collateral ligament reconstruction of the elbow using the docking technique. *Am J Sports Med* 2002; **30**: 541-548 [PMID: 12130409]
22 **Dines JS**, ElAttrache NS, Conway JE, Smith W, Ahmad CS. Clinical outcomes of the DANE TJ technique to treat ulnar collateral ligament insufficiency of the elbow. *Am J Sports Med* 2007; **35**: 2039-2044 [PMID: 17703003 DOI: 10.1177/0363546507305802]
23 **Morgan RJ**, Starman JS, Habet NA, Peindl RD, Bankston LS, D'Alessandro DD, Connor PM, Fleischli JE. A biomechanical evaluation of ulnar collateral ligament reconstruction using a novel technique for ulnar-sided fixation. *Am J Sports Med* 2010; **38**: 1448-1455 [PMID: 20442324 DOI: 10.1177/0363546510363463]
24 **Andrews JR**, Timmerman LA. Outcome of elbow surgery in professional baseball players. *Am J Sports Med* 1995; **23**: 407-413 [PMID: 7573648]
25 **Erickson BJ**, Gupta AK, Harris JD, Bush-Joseph C, Bach BR, Abrams GD, San Juan AM, Cole BJ, Romeo AA. Rate of return to pitching and performance after Tommy John surgery in Major League Baseball pitchers. *Am J Sports Med* 2014; **42**: 536-543 [PMID: 24352622 DOI: 10.1177/0363546513510890]
26 **Erickson BJ**, Harris JD, Tetreault M, Bush-Joseph C, Cohen M, Romeo AA. Is Tommy John Surgery Performed More Frequently in Major League Baseball Pitchers From Warm Weather Areas? *Orthop J Sports Med* 2014; **2**: 2325967114553916 [PMID: 26535277 DOI: 10.1177/2325967114553916]
27 **Osbahr DC**, Cain EL, Raines BT, Fortenbaugh D, Dugas JR, Andrews JR. Long-term Outcomes After Ulnar Collateral Ligament Reconstruction in Competitive Baseball Players: Minimum 10-Year Follow-up. *Am J Sports Med* 2014; **42**: 1333-1342 [PMID: 24705899 DOI: 10.1177/0363546514528870]
28 **Erickson BJ**, Nwachukwu BU, Rosas S, Schairer WW, McCormick FM, Bach BR, Bush-Joseph CA, Romeo AA. Trends in Medial Ulnar Collateral Ligament Reconstruction in the United States: A Retrospective Review of a Large Private-Payer Database From 2007 to 2011. *Am J Sports Med* 2015; **43**: 1770-1774 [PMID: 26129959 DOI: 10.1177/0363546515580304]
29 **Anz AW**, Bushnell BD, Griffin LP, Noonan TJ, Torry MR, Hawkins RJ. Correlation of torque and elbow injury in professional baseball pitchers. *Am J Sports Med* 2010; **38**: 1368-1374 [PMID: 20400752 DOI: 10.1177/0363546510363402]
30 **Bushnell BD**, Anz AW, Noonan TJ, Torry MR, Hawkins RJ. Association of maximum pitch velocity and elbow injury in professional baseball pitchers. *Am J Sports Med* 2010; **38**: 728-732 [PMID: 20093420 DOI: 10.1177/0363546509350067]
31 **Byram IR**, Bushnell BD, Dugger K, Charron K, Harrell FE, Noonan TJ. Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. *Am J Sports Med* 2010; **38**: 1375-1382 [PMID: 20489215 DOI: 10.1177/0363546509360404]
32 **Dines JS**, Frank JB, Akerman M, Yocum LA. Glenohumeral internal rotation deficits in baseball players with ulnar collateral ligament insufficiency. *Am J Sports Med* 2009; **37**: 566-570 [PMID: 19059890 DOI: 10.1177/0363546508326712]
33 **Fleisig GS**, Andrews JR, Cutter GR, Weber A, Loftice J, McMichael C, Hassell N, Lyman S. Risk of serious injury for young baseball pitchers: a 10-year prospective study. *Am J Sports Med* 2011; **39**: 253-257 [PMID: 21098816 DOI: 10.1177/0363546510384224]
34 **Lyman S**, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *Am J Sports Med* 2002; **30**: 463-468 [PMID: 12130397]
35 **Petty DH**, Andrews JR, Fleisig GS, Cain EL. Ulnar collateral ligament reconstruction in high school baseball players: clinical results and injury risk factors. *Am J Sports Med* 2004; **32**: 1158-1164 [PMID: 15262637 DOI: 10.1177/0363546503262166]
36 **Wilk KE**, Macrina LC, Fleisig GS, Aune KT, Porterfield RA, Harker P, Evans TJ, Andrews JR. Deficits in Glenohumeral Passive Range of Motion Increase Risk of Shoulder Injury in Professional Baseball Pitchers: A Prospective Study. *Am J Sports Med* 2015; **43**: 2379-2385 [PMID: 26272516 DOI: 10.1177/0363546515594380]
37 **Wilk KE**, Macrina LC, Fleisig GS, Aune KT, Porterfield RA, Harker P, Evans TJ, Andrews JR. Deficits in glenohumeral passive range of motion increase risk of elbow injury in professional baseball pitchers: a prospective study. *Am J Sports Med* 2014; **42**: 2075-2081 [PMID: 24944295 DOI: 10.1177/0363546514538391]
38 **Yang J**, Mann BJ, Guettler JH, Dugas JR, Irrgang JJ, Fleisig GS, Albright JP. Risk-Prone Pitching Activities and Injuries in Youth Baseball: Findings From a National Sample. *Am J Sports Med* 2014; **42**: 1456-1463 [PMID: 24627578 DOI: 10.1177/0363546514524699]
39 **Erickson BJ**. The epidemic of Tommy John surgery: the role of the orthopedic surgeon. *Am J Orthop* (Belle Mead NJ) 2015; **44**: E36-E37 [PMID: 25566564]
40 **Marshall NE**, Keller RA, Lynch JR, Bey MJ, Moutzouros V. Pitching performance and longevity after revision ulnar collateral ligament reconstruction in Major League Baseball pitchers. *Am J Sports Med* 2015; **43**: 1051-1056 [PMID: 25862037 DOI: 10.1177/0363546515579636]
41 **Dines JS**, Yocum LA, Frank JB, ElAttrache NS, Gambardella RA, Jobe FW. Revision surgery for failed elbow medial collateral ligament reconstruction. *Am J Sports Med* 2008; **36**: 1061-1065 [PMID: 18443277 DOI: 10.1177/0363546508314796]
42 **Wilson AT**, Pidgeon TS, Morrell NT, DaSilva MF. Trends in Revision Elbow Ulnar Collateral Ligament Reconstruction in Professional Baseball Pitchers. *J Hand Surg Am* 2015; **40**: 2249-2254 [PMID: 26328904 DOI: 10.1016/j.jhsa.2015.07.024]
43 **Jiang JJ**, Leland JM. Analysis of pitching velocity in major league baseball players before and after ulnar collateral ligament reconstruction. *Am J Sports Med* 2014; **42**: 880-885 [PMID: 24496506 DOI: 10.1177/0363546513519072]
44 **Lansdown DA**, Feeley BT. The Effect of Ulnar Collateral Ligament

Reconstruction on Pitch Velocity in Major League Baseball Pitchers. *Orthop J Sports Med* 2014; **2**: 2325967114522592 [PMID: 26535301 DOI: 10.1177/2325967114522592]

45 **Ahmad CS**, Grantham WJ, Greiwe RM. Public perceptions of Tommy John surgery. *Phys Sportsmed* 2012; **40**: 64-72 [PMID: 22759607 DOI: 10.3810/psm.2012.05.1966]

46 **Liu JN**, Garcia GH, Conte S, ElAttrache N, Altchek DW, Dines JS. Outcomes in revision Tommy John surgery in Major League Baseball pitchers. *J Shoulder Elbow Surg* 2016; **25**: 90-97 [PMID: 26687472 DOI: 10.1016/j.jse.2015.08.040]

P- Reviewer: Angoules A, Guerado E, Metzger PD
S- Editor: Gong XM **L- Editor**: A **E- Editor**: Li D

Published by **Baishideng Publishing Group Inc**
8226 Regency Drive, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com