**Valgus Overload of the Elbow Ulnar Collateral Ligament in Throwers**

**Ulnar Collateral Ligament of the Elbow**

The ulnar collateral ligament of the elbow, sometimes referred to as the medial collateral ligament, is composed of three bundles that are named for their direction of orientation and position relative to the humeroulnar joint (see Fig. 1). While ligaments typically have fibers arranged in spiral bands to aid in joint stability for six degrees of freedom movement, the anterior bundle, posterior bundle and oblique bundle (transverse ligament) comprise a ligamentous complex that functions predominantly to resist valgus stresses at the elbow1,3.

The anterior portion, with a mean width of 4-5 mm is considered the strongest of the three bundles, with a mean load to failure of 260 N4,5. Comprised of two functional bands, the anterior band of the anterior bundle is taut for the first 60 degrees of flexion and the posterior band is taut from 60-120° of flexion (see Fig. 2)4. Histologically, there are also two layers. One of which is described as the deeper layer that is composed of collagen bundles contained within the capsule while the more superficial layer is not contained within the capsule. This bundle originates from the anteroinferior edge of the medial humeral epicondyle and inserts at a mean of 18 mm distal to the coronoid tip, along the medial aspect of the coronoid process, near the sublime tubercle of the ulna1,4.

Conversely, the posterior bundle is more “fan shaped” as it is a thickening of the joint capsule medially with a width in the midportion approximately 5-6 mm4. It is considered to be thinner than the anterior bundle as well as it originates from the posteroinferior aspect of the medial humeral epicondyle and has a broad insertion on the medial edge of the olecranon of the ulna1,4. The transverse ligament tends to be more variable in both size and presentation, extending from the inferomedial margin of the coronoid process to the medial edge of the olecranon as well1. It consists of horizontal capsular fibers and is generally considered to not contribute significantly to elbow stability as it attaches to 2 parts of the same bone4.

Elbow stability is not solely the responsibility of the ulnar collateral ligament. Obviously, medial soft tissues are subjected to tensile forces with valgus stress imposition. However, the reliance on the UCL and each individual bundle alone varies relative to the degree of elbow flexion. There is inherent osseous restraint between the olecranon of the ulna and the trochlea of the humerus. In full extension, approximately one-third of valgus stress resistance is borne by the UCL, one-third by the anterior capsule, and one-third by bony architecture. At 90° of elbow flexion the UCL approximates over half of its relative contribution (54%) whereas the anterior capsule decreases significantly (10%) and bony architecture remains relatively unchanged4,6. Within the range of 20-120° of elbow flexion the anterior bundle serves as the primary valgus stabilizer. Studies have also shown that the posterior bundle serves as a significant stabilizer with the anterior bundle at 120° elbow flexion angle and a secondary restraint at 30° and 90°2,4. Moreover, due to the posterior positioning of the anterior and posterior bundles there is amplified tension created with increased elbow flexion4. As a result, the anterior band has been shown to be more susceptible to valgus overload than the posterior and transverse bands in positions of relative elbow extension1,2. More specifically, the anterior portion is more prone to injury with valgus stress between 0-90° of flexion4.

**Overhead Throwing**

Elbow biomechanics play a vital role in the performance of overhead throwing in many sports such as baseball, football, and javelin but is especially pronounced in pitching. Repetitive overhead throwing creates high magnitude valgus stress at the elbow as a result of high magnitude angular acceleration combined with a high moment of inertia for the distal limb created by the mass of the object in the hand, the hand and forearm3.

***Pitching***

Pitching mechanics consist of six pitching phases: 1) wind up, 2) early-cocking(stride), 3) late-cocking, 4) arm acceleration, 5) arm deceleration, 6) follow-through (see Fig 3)6,7. Stability is a hallmark of the initial wind up phase where the pitcher attempts to balance his weight over his rear leg. Early cocking follows when the lead leg begins to descend towards home plate and the two arms separate from each other. During the beginning and middle portions of this stage the elbow is extended with transition to elbow flexion towards the end of the stage. Stride foot contact distinguishes early-cocking from late-cocking and typically occurs with the elbow flexed between 80-100°7. Following lead foot contact, the pelvis and upper trunk begin to rotate creating elbow torque of approximately 0-32 Nm7 throughout the arm-cocking phase. The upper trunk and pelvis continue to rotate forward while the shoulder externally rotates leading to a large valgus torque of the distal upper extremity at the elbow. The elbow must generate a varus torque onto the forearm prior to maximum external rotation of the shoulder. This is accomplished through ligamentous stabilization, bony architecture, and elbow capsule support mentioned in addition to contraction of flexor pronator muscles of the forearm (i.e. flexor carpi ulnaris, flexor digitorum superficialis, flexor carpi radialis, and pronator teres). Valgus stresses here create large tensile stresses on the medial elbow and compressive stress on the lateral elbow. Arm acceleration follows characterized by elbow extension at a velocity of approximately 2100-2700 °/sec combined with continued trunk rotation1,6,7 (see Fig 4.). During this phase, substantial varus torque is generated to resist increased valgus stresses in order to accelerate the distal extremity and ball. Following ball release arm deceleration is initiated and completed at maximum internal rotation. This phase is characterized by dissipation of energy at the shoulder and elbow and elbow flexion torque to decelerate elbow extension to resist distraction following release. Finally, follow-through occurs when the shoulder reaches maximum internal rotation and is characterized by continued motion of the larger body structures (i.e. trunk and lower extremities) to continue to help dissipate energy in the throwing arm1,6,7.

**Ulnar Collateral Ligament Injury and Valgus Overload**

A combination of high valgus torque and rapid elbow extension produces the risk for pathological injury pattern known as valgus extension overload where there are high tensile stresses at the elbow, high compressive stresses at the lateral elbow and high shear stress in the posterior elbow1,3,6,7,8,9.

As the ulnar collateral ligament is one of the primary stabilizers to resist valgus stress, it is often injured during throwing1,8. Morrey et al. demonstrate that the UCL produces 54% of the varus torque to resist valgus stress at the elbow at 90° flexion. Yet, during the acceleration phase valgus torque can reach up to 65 Nm, exceeding ultimate tensile strength of the UCL1,9. Furthermore, during late cocking/early acceleration there are significant compressive forces acting on the radiocapitellar joint as a result of joint space narrowing from medial valgus stress imposition, leading to the potential for osteoarthritis, chondromalacia, and other pathologies1,3. Ulnar collateral ligament valgus resistance combined with flexor-pronator mass resistance during throwing seeks to prevent excessive distraction and impingement of the posteromedial aspect of the olecranon process within the fossa1. However, with repetitive microtrauma and high injurious loads these structures often become insufficient to prevent such, resulting in pathological forces acting upon all structures,6,11. Accompanying injuries associated with tensile strain in the ulnar collateral ligament include medial epicondylitis and flexor-pronator strains as the flexor pronator mass plays a significant contributory role in dynamic stabilization1,6,9. Osbahr et al. estimate approximately 4.3 to 12.8% of UCL injuries are found to have concomitant flexor-pronator mass injuries, with elevated age as a significant risk factor1,10.

**Risk Factors Associated with Valgus Overload**

Many studies have been performed to help identify risk factors associated with increased risk of ulnar collateral ligament injury and development of valgus overload. Aguinaldo and Chambers found that elbow valgus torque is most significantly influenced by three parameters including maximum shoulder external rotation, elbow flexion at peak valgus torque and elbow valgus loading rate. More specifically, they noted that individuals who exhibited increased trunk rotation prior to foot contact, individuals who threw with a sidearm delivery, and those who threw with increased elbow extension demonstrated elevated elbow valgus torque3,12. They hypothesize that the extended elbow induces a bending moment at the elbow as the throwing arm lags in early acceleration due to the moment of inertia created by the mass of the ball, hand and forearm. Moreover, they note those who initiate trunk rotation early (prior to foot contact) result in decreased torque generation in the trunk and lower extremities to overcome the inertia of the distal upper extremity leading to a “whipping action”. Lastly, a sidearm delivery may exacerbate this by demonstrating a lower shoulder abduction angle as a result of increased trunk lean, decreased shoulder abduction and decreased elbow flexion12. Werner et al. also note similar kinematic risk factors associated with increased ulnar collateral ligament valgus stress including decreased shoulder abduction angle at stride foot contact, decreased elbow flexion angle at instant of peak valgus stress, and peak shoulder external rotation torque. They note a more extended elbow at instant of peak valgus torque and lesser magnitudes of peak shoulder external rotation resulted in an increased elbow valgus stress13.

Other studies have sought to identify other factors outside the scope of biomechanical and kinematic factors. Fleisig et al. found there is an increased risk among youth pitchers that competitively pitch more than 85 pitches per game, more than eight months out of the year, or with arm fatigue14. Lyman et al. further note that pitch selection can influence the risk for injury. They found that throwing sliders is associated with an increased risk for medial elbow pain of 86%. Furthermore, they found that there is a significant association between the number of pitches thrown in a game and the severity of elbow pain and noted an increased risk also found with increased age as a result of cumulative stress (see Table 1)15.

Petty et al. define factors related to overuse as year-round throwing (less than 2 full months of rest), seasonal overuse (violation of USA Baseball Medical & Safety Advisory Committee recommendations for maximum pitch counts and minimus rest)(see Table 2), and event overuse. Additionally, they hypothesized further risk factors of throwing breaking pitches before the age of fourteen, inadequate warm up and throwing with a fastball velocity greater than 80 mph. They found that nearly all the athletes who required UCL reconstruction had multiple risk factors with the greatest being overuse. High fastball velocities have been shown to create increased elbow varus torque as well as they reference a study where increasing velocity from 73 to 79 mph increased the torque from 44 N/m to 54 N/m. As such, since the UCL contributes to approximately half of the valgus resistance in the elbow it is estimated that this increases in valgus stress at the UCL from 22 Nm to 27 Nm. Moreover, they comment on how overuse creates repeated microtrauma to static restraints of the elbow without offering adequate time for healing16.

**Evaluation/Diagnosis**

***History***

A comprehensive evaluation is necessary to adequately assess throwing athletes. Typically with ulnar collateral ligament injuries, there is a gradual onset of medial elbow pain. However, if complete rupture occurs, there may occur a sharp pain along the medial elbow in conjunction from a “popping” sensation. This pain will be usually felt during arm acceleration phase of throwing1. Other symptoms sometimes involved with valgus extension overload include pain at the posteromedial tip of the olecranon process, and potential pain at the radiocapitellar joint of the lateral elbow1,17. Consideration should be given to information regarding the athlete’s sport, level of participation, and any changes in recent training or participation. With regards to pitchers in particular, pitch count, pitch type, and number of innings pitched should also be questioned. Moreover, if there are any functional declines in performance such as reduced ball velocity, alterations necessary in pitching mechanics to limit pain, and/or diminished strength these should also be noted. Other potential signs and symptoms may include vascular complaints, cold intolerance and numbness or tingling that radiates to the fourth and fifth digits of the hand as a result of ulnar nerve involvement1. Additionally, potential differential diagnoses should also be considered and ruled out including: flexor-pronator tendon injury, UCL instability, ulnar neuropathy, ulnar nerve subluxation, medial triceps subluxation, medial epicondyle avulsion, and medial antebrachial cutaneous nerve injury11.

***Examination***

Physical examination features that may suggest UCL injury include point tenderness directly over the MCL or toward its insertion sites, positive stress testing, loss of range of motion, and pain with movement1,11,18. First, palpation should be performed with the elbow in 50-70° flexion in order to displace the flexor-pronator mass anterior to the UCL. Pain with palpation has been shown to demonstrate 81-94% sensitivity for UCL injury but is not very specific (22%)1. As paresthesias may accompany such an injury, it is possible there will be a positive Tinel’s sign as generated by gentle percussion indicating ulnar nerve involvement1,11,18. Passive and active elbow motion should be compared to the opposing extremity as it is not uncommon to observe a loss of elbow extension (6-7.9°), flexion (4-5.5°) and supination (5°), which has been reported in several studies1. Pain may also be elicited with these movements in the posterior and lateral compartment, which may indicate valgus extension overload11.

Stress testing should be utilized to assess the integrity of the ulnar collateral ligament as well. The proximal arm should be stabilized against the examiner with the elbow flexed 30 degrees to unlock the olecranon from its fossa and a valgus stress should be applied distal to the elbow to encourage gapping isolated at the humeroulnar joint1. If pain or increased laxity is found compared to the opposite extremity it is a positive11,18. A relatively new stress test, called the “moving valgus stress test” is considered to be highly sensitive and more specific for testing1,3,19. In fact, O’Driscoll details 100% sensitivity and 75% specificity. By comparison, static valgus stress testing in this study demonstrated a specificity of 50% and sensitivity of 65%19. In this test, a valgus torque is maintained at the elbow in full flexion while quickly extending the elbow to generate a shear force at the UCL in order to simulate the valgus force observed during overhead throwing. A positive is considered if pain is elicited within the 70-120 degree arc of flexion (see Fig 5)3,19.

***Imaging***

Diagnostic imaging can be utilized to further confirm physical findings. Anterior-posterior, lateral and axial views of the elbow can assess for joint space narrowing, UCL ossification, osteophytes, and loose bodies1,11. These results can be improved by performing valgus stress radiographs in 25 to 30 degrees flexion to measure the medial joint line opening, in which an opening of greater than 3 mm11, or a side-to-side difference greater than 0.5 mm1 is typically considered as diagnostic criteria for valgus instability. Wright et al. note that UCL ossification, found in approximately 10.7% of Major League Baseball pitchers, has been typically recognized as a key finding with chronic UCL injury1,20.

Magnetic resonance imaging (MRI), offering exception soft-tissue contrast, can help to identify associated intra-articular pathology as it may reveal irregularity in the ligament as a result of hemorrhage/edema1. While plain non-contrast MRI has a specificity of 100%, its sensitivity is only approximately 57-79%. Therefore, MR arthrography may be used for improved sensitivity1,11.

**Conservative Intervention**

Treatment options for deciding between conservative and operative management requires consideration of each athlete’s specific factors such as sport demand, degree of injury, and results of non-operative treatments11. Preventative techniques include appropriate instruction of pitching mechanics and reduced overuse risk through adherence to supported recommendations. Pitching mechanics such as increased elbow flexion at ball release, stride foot contact prior to trunk rotation, and avoidance of side arm throwing have been shown to reduce valgus stress at the elbow3,6,12. Additionally, adequate warm up along with adherence to USA Baseball recommendations may also help to avoid UCL injury through improved strength and extensibility prior to failure and avoidance of overuse3,16.

General requirements for optimum healing of ligaments include facilitation of a good blood supply (such as through ultrasound or other heating modalities), controlled mobilization, and protection from injurious stresses through external support, and activity modification/redirection. Deliberation should also be given to the biomechanics that most likely caused the injury and potential movement patterns that could delay or prevent healing3,18. Broad protocol dictates that rest is an integral component for conservative management, as overuse has been shown to be such a high-risk factor16. Following rest plus reduction of inflammation and pain through anti-inflammatory medications and modalities, it is appropriate to begin strengthening of dynamic stabilizers, such as the flexor-pronator mass. Strengthening should begin in pain-free ROM with progression to end ranges as allowed11,18. More specifically, Rettig et al. described a conservative regimen to compare prognosis for return to sport based on time to return between conservative and surgical management. Rettig’s protocol included 2-3 months of rest from throwing, anti-inflammatory medication/modalities, controlled mobilization via long-arm splinting and progression to strengthening following achievement of pain free motion while finally beginning throwing progression at three months (see Table 3). They conclude that there was no significant delay in return between those subjects who received conservative management compared to operative management as 42% of the athletes returned to their prior level of function in their sport with an average of 24 weeks for return following diagnosis. Moreover, they found no difference in individuals with acute vs. chronic UCL injury21. Wilk et al. also define general protocol that includes 1) acute phase (improve motion, reduce pain, retard atrophy), 2) subacute phase (normalize motion, improve strength/power/endurance), 3) intermediate phase (preparation for return to functional activity), 4) advanced (return to throwing) dictated by criterion-based progression (see Fig. 8)30.

**Operative Intervention**

Surgical management for UCL reconstruction has continued to advance since Jobe first introduced the autograft via the palmaris longus, plantaris, or Achilles tendon. Early studies of such by Conway et al. noted 63% of athletes returning to prior level of competition within 11-19 months1,22. With new modern technical improvements, 82-95% of athletes now demonstrate excellent results following reconstruction (see Table 4)1,22,23. The original technique required reflexion of the flexor-pronator mass and creation of humeral tunnels that penetrated the posterior humeral cortex11. New improvements include the Jobe Modification, ASMI Modification, Docking Technique, interference screw (DANE TJ) technique and the suture anchor method (hybrid technique)1,11. The modified Jobe now implemented a muscle splitting approach and eliminated ulnar nerve transposition while the docking technique is said to simplify the graft passage, tensioning and fixation11. Thompson et al. found success rates to be 93% for excellent results at 2-4 year follow up with the improved modification of muscle splitting without transposition of the ulnar nerve, an improvement over the initial 63% with the original Jobe approach26. Moreover, the hybrid technique seeks to achieve ulnar sided fixation through single-bone tunnel with an interference screw and humeral fixation via docking; making it less technically demanding due to a reduced number of holes to drill. In addition to a decreased chance for surgical error there is less inflammation secondary to surgical trauma, with Hechtman et al. and Bowers et al. reporting between 85-90% return to pre-injury level of performance11,28,29.

Typically, following surgery the elbow is immobilized for 7-10 days in a splint to allow soft tissue healing of the UCL and soft tissue slings if nerve transposition is utilized11,27. During periods of immobilization extensive consideration is given to active wrist ROM and strengthening of grip along with monitoring of the ulnar nerve27. Next, passive and active ROM begins, with strengthening allowed at 4-6 weeks post-op and avoidance of valgus stress until at least 4 months. Proprioception exercises are also a must in order to replicate angular and end-range joint awareness, as loss of kinesthetic awareness can occur following injury and surgery27. Throwing may begin around 4 months postoperative with gradually progression up to about half speed at 7 months. Pitchers may begin pitching around 8 or 9 months with continued progression. Finally, throwing in competition is permitted after one year provided that the shoulder, elbow and forearm are all pain-free11. Another option is implementation of the “Thrower’s Ten Program” around 6-8 weeks after surgery(see Fig. 7)27.

As evidenced by Rettig, Conway, Thompson, etc. the main outcome often assessed in all studies is return to sport. Following surgical reconstruction, major criteria assessed includes the Conway-Jobe rating, which grades players in terms of excellent, good, fair, or poor in regards to return to sport. A result is considered excellent if the patient can compete at same level or higher level than before the injury for greater than 12 months. Furthermore, rate of complication is also assessed. As a whole, 82% of all reconstructions have been rated as producing excellent results with a concomitant overall rate of complications at 10%. The most successful results appear to utilize a muscle-splitting approach to the flexor-pronator mass, avoiding transposition of the ulnar nerve and use of docking, with an associated 95% rate of excellent return to sport22,23. Conversely, conservative measures are typically less standardized with reliance mostly on ROM, subjective reports of pain. However, several options exist for assessment of elbow pathology including the Disabilities of the Arm, Shoulder and Hand (DASH) scale, specifically the DASH sports module (see Fig 6)24. The DASH may be a potential tool for assessment of elbow pathology as it has been found to be valid in scale and able to demonstrate appropriate reliability25.

Conclusively, ulnar collateral ligament injuries are common in overhead athletes, especially among those who pitch in baseball1,3,6,7,8,10,11,12,13,14,15,16,17,21,23. Appropriate prevention strategies including proper pitching mechanics and avoidance of overuse patterns may help reduce the risk for injury3,6,12,13,14,15,16. If an injury does occur, assessment followed by conservative treatment is often attempted initially and may be adequate for return to sport1,11,17,19,20,21,30. However, if surgical methods are attempted, patients should be aware of the advancing techniques that have resulted in excellent outcomes and return to sport1,11,22,23,27,28,29. Furthermore, use of standardized outcomes can aid all healthcare professionals in assessment of such individuals22,23,24,25.

References

1. Jones, KJ; Osbahr, DC; Schrumpf, MA; Dines, JS; Altchek, DW. Ulnar Collateral Ligament Reconstruction in Throwing Athletes: A Review of Current Concepts: AAOS Exhibit Selection. *J Bone Joint Surg Am.* 2012 Apr; 94(8):1-12.
2. Callaway,GH;  Field, LD;  Deng, XH;  Torzilli, PA;  O’Brien, SJ;  Altchek, DW; Warren, RF. Biomechanical evaluation of the medial collateral ligament of the elbow. *J Bone Joint Surg Am*.  1997;79: 1223-31.
3. Gross, Mike. Voice thread Lecture Ligament: Composition, Structure, Function, Mechanical Properties, and Healing. PHYT 875 – Advanced Orthopaedic Assessment and Intervention. University of North Carolina at Chapel Hill. Accessed November 19, 2012.
4. Safran, MR; Baillargeon, D. Soft-tissue stabilizers of the elbow. *J Shoulder Elbow Surg.* 2005 Jan-Feb; 14(1 Suppl S): 179S-185S.
5. Regan, WD; Korinek, SL; Morrey, BF; An, KN. Biomechanical study of ligaments around the elbow joint.  *Clin Orthop.* 1991; 271: 170-179.
6. Lewek, Mike. Lecture Upper Extremity Biomechanics. PHYT 730: Kinesiology. University of North Carolina at Chapel Hill. Accessed November 20, 2012.
7. Loftice, J; Fleisig, GS; Zheng, N; Andrews, JR. Biomechanics of the elbow in sports. *Clin Sports Med.* 2004; 23: 519-530.
8. Gibson, BW; Webner, D; Huffman, R; Sennett, BJ. Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers. *Am J Sports Med.* 2007 Apr; 35(4): 575-581.
9. Morrey, BF; An, KN. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med.* 1983; 11:315-319.
10. Osbahr, DC; Swaminathan, SS; Allen, AA; Dines, JS; Coleman, SH; Altchek, DW. Combined flexor-pronator mass and ulnar collateral ligament injuries in the elbows of older baseball players. *Am J Sports Med.* 2010; 38: 733-739.
11. Rahman, RK; Levine, WN; Ahmad, CS. Elbow medial collateral ligament injuries. *Curr Rev Musculoskelet Med.* 2008 Dec; 1(3-4): 197-204.
12. Aguinaldo, AL; Chambers, H. Correlation of Throwing Mechanics With Elbow Valgus Load in Adult Baseball Pitchers. *Am J Sports Med.* 2009 Oct; 37(10): 2043-2048.
13. Werner, SL; Murray, TA; Hawkins, RJ; Gill, TJ. Relationship between throwing mechanics and elbow valgus in professional baseball pitchers. *J Shoulder Elbow Surg.* 2002 Apr; 11(2): 151-155.
14. Fleisig, GS; Weber, A; Hassell, N; Andrews, JR. Prevention of elbow injuries in youth baseball pitchers. *Curr Sports Med Rep.* 2009 Sep-Oct; 8(5): 250-4.
15. Lyman, S; Fleisig, GS; Andrews, JR; Osinksi, 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 Jul-Aug; 30(4): 463-468.
16. Petty, DH; Andrews, JR; Fleisig, GS; Cain, EL. Ulnar Collateral Ligament Reconstruction in High School Baseball Players. *Am J Sports Med.* 2004; 32(5): 1158-1164.
17. Dugas, JR. The Athlete’s Elbow Valgus Extension Overload: Diagnosis and Treatment. *Clin Sports Med.* 2010 Oct; 29(4): 645-654.
18. Hacke, Jon. Lecture: The Elbow Joint. PHYT 734: Musculoskeletal II. University of North Carolina at Chapel Hill. Accessed November 16, 2012.
19. O’Driscoll, SW; Lawton, RL; Smith, AM. The “moving valgus stress test” for medial collateral ligament tears of the elbow. *Am J Sports Med.* 2005 Feb; 33(2): 231-239.
20. Wright, RW; Steger-May, K; Klein, SE. Radiographic findings in the shoulder and elbow of Major League Baseball Pitchers. *Am J Sports Med.* 2007; 35: 1839-1843.
21. Rettig, AC; Sherrill, C; Snead, DS; Mendler, JC; Mieling, P. Nonoperative Treatment of Ulnar Collateral Ligament Injuries in Throwing Athletes. *Am J Sports Med.*  2001 Jan; 29(1): 15-17.
22. 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.
23. Vitale, MA; Ahmad, CS. The Outcome of Elbow Ulnar Collateral Ligament Reconstruction in Overhead Athletes: A Systematic Review. *Am J Sports Med.* 2008 Jun; 36(6): 1193-1205.
24. Disabilities of Arm, Shoulder and Hand Questionnaire. From the Institutes for Work & Health. <http://www.dash.iwh.on.ca/system/files/dash_questionnaire_2010.pdf>. Accessed December 1, 2012.
25. MacDermid, JC. Outcome Evaluation in Patients with Elbow Pathology: Issues in Instrument Development and Evaluation. *J Hand Ther.*  2001 Apr-Jun; 14(2): 105-114.
26. Thompson, WH; Jobe, FW; Yocum, LA; Pink, MM. Ulnar collateral ligament reconstruction in athletes: muscle-splitting approach without transposition of the ulnar nerve. *J Shoulder Elbow Surg.* 2001 Mar-Apr; 10(2): 152-157.
27. Ellenbecker, TS; Wilk, KE; Atlchek, DW; Andrews, JR. Current Concepts in Rehabilitation Following Ulnar Collateral Ligament Reconstruction. *Sports Health.* 2009 Jul; 1(4): 301-313.
28. Hechtman, KS; Zvijac, JE; Wells, ME; Botto-van Bemden, A. Long-term results of ulnar collateral ligament reconstruction in throwing athletes based on a hybrid technique. *Am J Sports Med.* 2011 Feb; 39(2): 342-347.
29. Bowers, AL; Dines, JS; Dines, DM; Altchek, DW. Elbow medial ulnar collateral ligament reconstruction: clinical relevance and the docking technique. *J Shoulder Elbow Surg.* 2010 Mar; 19(2 Suppl): 110-117.
30. Wilk, KE; Reinold, MM; Andrews, JR. Rehabilitation of the thrower’s elbow. *Clin Sports Med.* 2004;23: 765-801.