Ulnar Collateral Ligament Injury in Female Athletes

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Introduction

Traditionally, injury to the ulnar collateral ligament (UCL) of the elbow has been associated with the male baseball pitcher. This is emphasized by the fact that the eponym for the classic reconstruction of this ligament is known as "Tommy John" surgery, named for the then Los Angeles Dodgers pitcher who underwent surgery by Dr. Frank Jobe in 1974. However, while less commonly reported, injuries to the UCL have now been described in the female athlete population. Recognition of this injury and knowledge of treatment options in female athletes is vital to achieve optimal results.

Epidemiology and Pathoanatomy

The function of the UCL has been well described in this text and elsewhere. In brief, the anterior bundle of the UCL serves as the primary stabilizer against valgus stress to the elbow within a functional range of motion, from 25 to 125° of flexion. In response to valgus load at the elbow, the UCL helps to provide a stabilizing varus force. No matter the specific sport, recurrent valgus stress at the elbow results in a triad of pathologic lesions: traction to the medial structures, compression of the lateral structures and posteromedially directed shear, and compression of the olecranon.

While the function of the UCL is thought to be similar in both sexes, there have not been any studies comparing the biomechanical properties of female UCL to those of the better studied male UCL. However, as previous study of females' anterior cruciate ligaments has demonstrated significant differences, including a lower percentage of collagen [1], less elasticity and failure at 30% less load than males' [2], it is reasonable to think that there may be similarly important differences in the UCL. Additionally, certain important anatomic differences in the male and female body do exist. The upper torso and arm of female athletes typically possess less muscle mass and strength than the male athlete, and as such, female athletes generate less muscle torque and power. At the elbow, the carrying angle is greater, and there is often more ligamentous laxity in female athletes. It is important to keep these differences, known and potential, in mind when considering risk factors for UCL injury and its treatment.

Injuries to the UCL in female athletes, as in their male counterparts, typically occur through one of two mechanisms. The first is a single extraordinary valgus force to the elbow that causes an acute rupture of the ligament. In these rarer cases of an acute, traumatic rupture, some patients, particularly those of younger age, may experience a bony avulsion of the ligament from

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the sublime tubercle of the ulna. The more common mechanism is chronic microtrauma, which leads to microtears and eventual ligament attenuation or complete tearing. With or without partial tearing at the proximal or distal attachments, this may render the ligament nonfunctional.

Biomechanics of UCL Injury in Women

Since 1946, when Waris [3] first described injury to the UCL in a group of 17 elite javelin throwers, many other sports have been implicated (Table 24.1). Female athletes participating in the following sports have been reported to have suffered UCL injuries: softball [4], gymnastics [5, 6], baseball [5], calf roping [4], cheerleading [4], javelin [3, 5], tennis [4, 5], baton twirling [4], judo [5], swimming [5], equestrian [5], alpine skiing [4], and handball [5]. In the largest published study of UCL injuries in female athletes, none of the patients competed professionally [4].

Of all overhead athletic motions, the baseball pitch is considered to be one of the most violent in its effect on the shoulder and elbow. As such, the baseball pitching motion has been extensively studied. It has been repeatedly shown that the greatest varus torque occurs during the late cocking and early acceleration phases of pitching, when varus torque is necessary to prevent valgus extension of the elbow. Werner et al. showed that while the UCL is thought to be the primary contributor to varus torque, contraction of the wrist flexor-pronator group also provides a stabilizing force. In their study, Werner et al. found a maximum varus torque of 120 Nm in their cohort of male baseball pitchers. This high value is thought to exceed the intrinsic strength of the UCL, thus explaining the high incidence of UCL injuries in this population.

Table 24.1 Sports with reported UCL injuries in female athletes

Softball	Gymnastics
Baseball	Calf roping
Cheerleading	Javelin
Tennis	Baton twirling
Judo	Swimming
Equestrian	Alpine skiing
Handball	–

Chu et al. [7] performed a biomechanical comparison of the pitching motions of elite male and female baseball pitchers. They found that female athletes displayed significantly slower ball velocity, which is not surprising considering that the women had a smaller body height and mass than their male counterparts. There were other differences in the kinetics and kinematics of the female baseball pitch, including a maximum elbow varus torque of approximately 75% of males' values, at 46 Nm. While this value is likely below the load limit of the male UCL, without specific knowledge of the biomechanical properties of the female UCL, it is impossible to know if this can adequately explain the relative paucity of UCL injuries in female athletes. Chu et al. did find that when normalized for body height and weight, the peak varus torque values were very similar between the genders.

Barrentine et al. [8] have described the softball windmill pitch in a way similar to that of the baseball pitch, as is shown in Fig. 24.1. The motion is separated into four phases: wind-up, stride, delivery, and follow through. In their study of eight healthy female softball pitchers, they demonstrated that there is significantly less varus torque produced during windmill pitching than in baseball pitching, and theorized that this is the reason why UCL injuries are rarely seen in these athletes. Their data is presented in Fig. 24.2. In fact, in his report of UCL injuries in women, Argo [4] found that of eight injured softball players, only one was a pitcher.

There have been several studies that have investigated the biomechanics of javelin throwing, although they have focused primarily on performance rather than joint stress or load [9, 10]. The elbow is held in extension until the moment of the final foot strike, in order to lengthen the acceleration path of the javelin and thus generate a higher release speed. From the instant of final foot strike to release, called the thrust phase, the elbow flexes rapidly. As much as 70% of the release speed of the javelin spear is generated in the last 0.1 s, during which the elbow flexion velocity nears 1900°/s [10]. Unfortunately, there has not

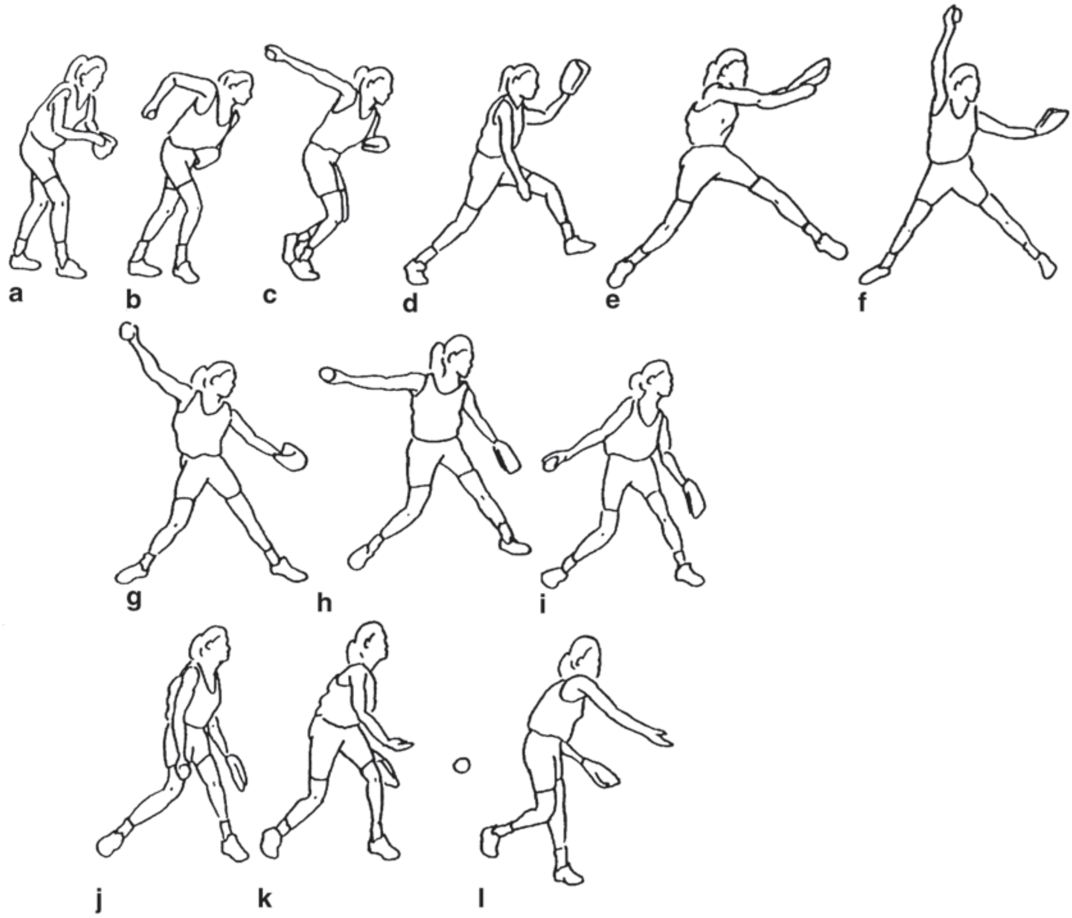

Fig. 24.1 Sequence of motion in windmill pitching. **a–c** Wind up. **d–f** Stride. **g–j** Delivery. **k–l** Follow through. (From Barrentine et al. 1998, used with permission)

been specific measurement of the varus torque generated during javelin throwing. In Dines' [11] report of UCL reconstruction in javelin throwers, he offered the similar observation that while the at-risk position during baseball pitching is during the late-cocking and early acceleration phases, in javelin throwers, maximum angular velocities occur during the thrust phase of the throw. There have been no studies specifically examining the biomechanics of female javelin throwers, and thus injury mechanism must be inferred from these male studies.

Tennis remains a very popular overhead sport for both sexes. Elliott et al. [12] investigated the loading of the shoulder and elbow joint during the tennis serve in male and female athletes. Men recorded significantly higher service speeds and had higher peak absolute elbow varus torque (78.3 vs. 58.2 Nm). They also noted that players who flexed the front knee by 7.6° in the backswing phase of the serve, while having a similar serve speed, demonstrated larger normalized varus torque when the arm was in the maximally externally rotated position, when compared with those players who flexed the front knee by 14.7°. The reason why a more effective knee bend decreases elbow varus torque in unclear.

The biomechanics of gymnastics have also been studied to explain the risk for UCL injury in these athletes. Elements such as the back handspring or handstand transform the elbow into a weight-bearing joint. During the performance

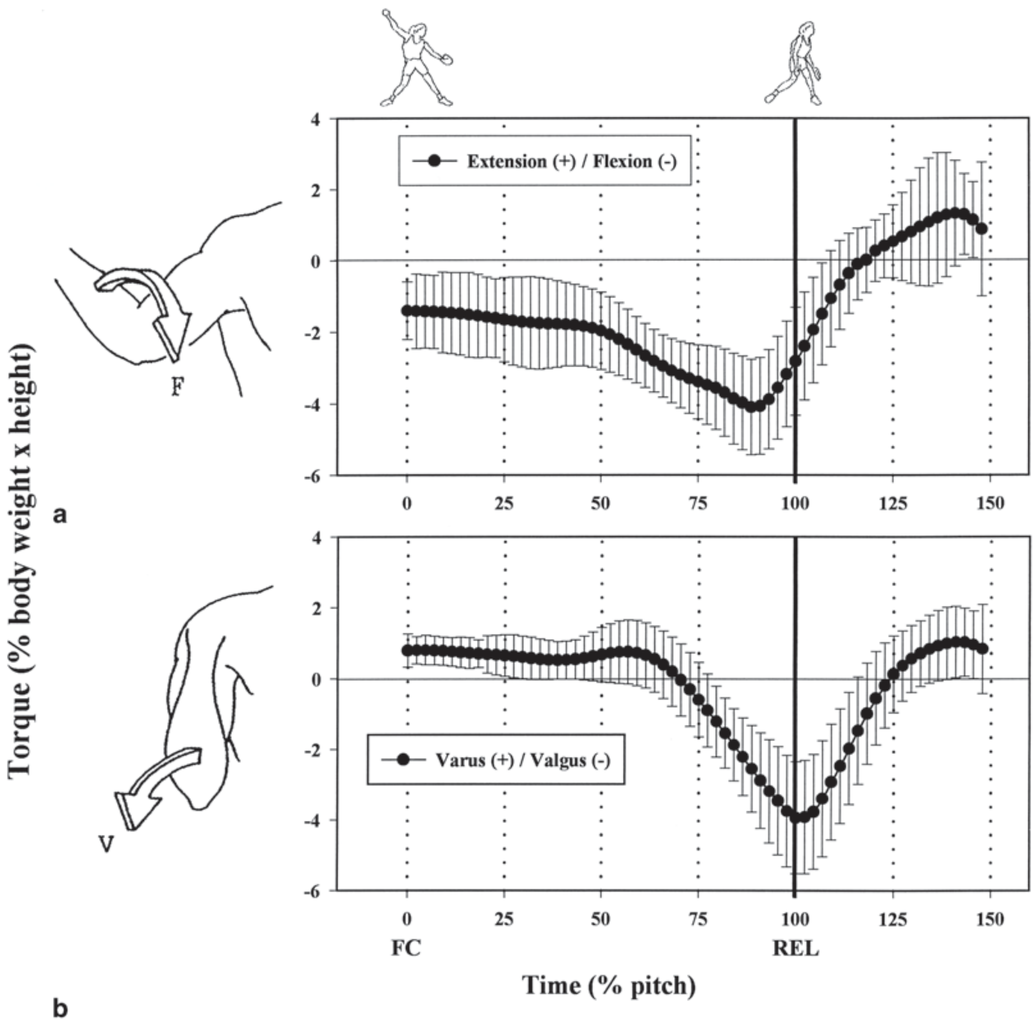

Fig. 24.2 Torque applied to the forearm at the elbow for varus(+)/valgus(−) vs. time. Graphs represent mean and standard deviation data for all subjects. The instances of foot contact (*FC*) and ball release (*REL*) are shown. (From Barrentine et al. 1998, used with permission)

of these skills, a compressive and valgus load is transmitted through the elbow joint [4]. Fortunately, it is thought that the majority of the force is concentrated on the lateral aspect of the joint [13], thus explaining why UCL injury is relatively rare in these athletes.

Reeser et al. [14] examined the biomechanics of the upper limb during the volleyball spike and serve in an effort to understand this popular women's overhead sport. They found that maximum elbow varus torque was produced near the time of maximum external rotation of the arm, during which arm cocking is decelerated and forward rotation is initiated. Of all skills tested, cross-body spike, straight-ahead spike, roll shot, jump serve, and float serve, the highest elbow varus torque was found to occur during the jump serve (43.3 Nm). This value is lower than the maximum varus torque seen in female baseball pitchers as discussed above and helps to explain why UCL injuries have not been reported to occur in this dynamic overhead sport.

Presentation and Evaluation

As with all patients, initial evaluation of female athletes with a suspected UCL injury starts with a thorough history. This includes the patient's sport and level of participation. The events surrounding the initial onset of symptoms and their chronicity are critical. Patients should be questioned regarding the details of current symptoms, including pain, popping sensation during activity and paresthesias. Previous treatment, such as rest, injections, and surgery, and its effect should be noted. Also important are details regarding the athlete's performance since the time of injury, such as speed and accuracy of throwing and ability to perform sport-specific skills.

The physical examination of male and female patients with medial elbow pain is similar and should include inspection, palpation, and motion of the bilateral upper extremities and neck. Female patients with UCL injuries commonly have point tenderness just distal to the medial epicondyle. It is important to thoroughly evaluate for the presence of epicondylitis, although UCL injury and medial epicondylitis may be present concurrently. The integrity of the ligament should be carefully evaluated. Typically this occurs with the humerus stabilized while a valgus force is applied to a slightly flexed elbow (30°). The clinician then evaluates for the presence of tenderness overlying the UCL and joint space opening. Other tests, such as the "milking maneuver" and "Mayo Valgus Stress Test" may be utilized as well. A neurovascular examination, specifically of the ulnar nerve, is also critical. It is important to note the presence or absence of the palmaris longus tendon, in case it may be needed for reconstruction.

Imaging of the elbow may include plain radiographs with or without valgus stress, dynamic ultrasound, arthrograms, and contrast or noncontrast computed tomography (CT) and magnetic resonance imaging (MRI). X-rays may reveal avulsion fracture, or secondary findings suggestive of chronic instability such as ossification of the ligament, loose bodies or marginal osteophytes. Instability may be demonstrated on stress radiographs or dynamic ultrasound. It should be noted that it may be necessary to evaluate the uninjured elbow as well, in order to provide a comparison. The use of contrast dye in arthrograms, CT or MRI may aid in the evaluation of the UCL by highlighting medial capsule rupture or even partial, undersurface tears in the case of CT or MRI.

Indications and Procedures

As with male patients, the initial treatment of all UCL injuries in female athletes is nonoperative. Consisting primarily of overhead activity cessation and a progressive rehabilitation program, this is an imperative part of the treatment algorithm. It is generally recommended that athletes undergo at least 3–6 months of nonoperative treatment. In a report of 31 throwing athletes, Rettig et al. [15] evaluated patients with UCL injuries that were all treated nonoperatively. His protocol involved an initial phase of throwing rest for 2–3 months with anti-inflammatories and therapeutic modalities to treat symptoms. Athletes were also placed into a long-arm splint or brace at 90° at night as needed to control pain. Once the athlete became pain-free, the splint or brace was discontinued. A progressive upper extremity strengthening was initiated with a throwing program instituted at 3 months. In this study, 42 % of patients were able to return to their previous level of competition at an average of 24.5 weeks (range 13–54 weeks). There were only three women in this study and the specific results for these patients were not reported. Additionally, there were no predictive findings in either the patient's history or physical exam that was useful in predicting the success of nonoperative treatment.

If symptoms persist despite an adequate course of conservative treatment, then operative intervention may be considered. Understanding the pathoanatomy that underlies these injuries is essential when making treatment decisions. When an avulsion is present, repair through drill holes, or using suture anchors may be possible, as the ligamentous tissue itself is often not extensively injured. However, in cases of ligament attenuation, with or without partial tearing, the

Table 24.2 Women included in major studies of the treatment of UCL injuries

Authors	Data collection	Overall number of UCL patients	Number of female patients	Treatment for female patients
Andrews and Timmerman [18]	1986–1990	14	0/14	N/A
Argo et al. [4]	1994–2001	19	19/19	1/19 recon; 18/19 repair +/− augment
Azar et al. [19]	1988–1994	91	0/91	N/A
Cain et al. [17]	1988–2006	1281	28/1281	Not reported
Conway et al. [16]	1974–1987	70	1/70	1/1 recon
Dines et al. [20]	2006–2009	25	Not reported	Not reported
Dodson et al. [21]	2000–2003	100	0/100	N/A
Kodde et al. [5]	2001–2007	20	13/20	13/13 recon
Koh et al. [22]	Not Reported	20	0/20	N/A
Paletta and Wright [23]	1998–2000	25	0/25	N/A
Petty et al. [24]	1995–2000	27	0/27	N/A
Rettig [15]	1994–1997	31	3/31	3/3 non-op
Rohrbough [25]	1995–1999	36	1/36	1/1 recon
Savoie et al. [26]	1994–2001	60	13/60	13/13 recon
Thompson et al. [27]	1992–1996	83	1/83	1/1 recon
Total		1902	79	30 recon; 18 repair +/− augment; 3 non-op

condition of the injured ligament must be closely assessed. If the tissue remaining is of good quality, then primary repair, with possible augmentation, may be considered. In their report of 14 direct ligament repairs in college and professional male baseball players, Conway and Jobe [16] found that while ten of 14 players had a good or excellent result, only 50 % were able to return to their previous level of play.

If the tissue has been extensively damaged, or if there is a complete tear of the ligament, then a classic reconstruction with grafting should be performed. There have been multiple surgical techniques described in the literature, which have been detailed elsewhere in this text. It is this author's preference to perform the reconstruction with a palmaris autograft when possible, utilizing a docking technique. And, while it is our practice to perform a nerve transposition only when preoperative ulnar nerve symptoms are present, this issue remains controversial within the orthopaedic community. Current literature has not shown a benefit of one reconstruction technique over another in the treatment of female patients with UCL injury, and thus the chosen method should be based on surgeon preference.

Unfortunately, very little has been written about the specific treatment of UCL injuries in women. In the largest single report of the operative treatment of UCL injuries, Cain's [17] cohort of 1281 procedures included only 28 female patients. Similarly, in Vitale's [13] review of 285 patients, 99 % were male. Unfortunately, neither study stratified their results by gender. However, while bearing in mind the gender differences mentioned previously, one may use the male-dominated literature for guidance on treatment and outcomes. Table 24.2 summarizes the findings of the largest UCL outcomes studies, with special attention paid to any included female patients. In most of the studies, the female patients have been treated according to the algorithm applied to the male patients. With the exception of Argo et al., when surgery was necessary, a reconstruction was performed utilizing the preferred technique of the author.

Argo [4] published the largest study of the treatment of UCL injuries in female patients, reporting on 19 women. They played sports including softball, gymnastics, and tennis. The most common pathology in this group was a distal soft tissue avulsion, occurring in eight of 19 patients. These were repaired with suture anchors. He also commonly encountered central ligament attenuation, sometimes with partial tearing. He treated these athletes by plication of the ligament, with anchor reinforcement or flexor-pronator mass augmentation as necessary. In only one of 19 cases was a traditional UCL reconstruction performed, in this case using a palmaris autograft; the fixation technique was not described. This tendency toward ligament repair with potential augmentation, and away from reconstruction, is in contrast to that the treatment that has been described in the male athlete population, and represents a potential key difference in the treatment of male and female patients with UCL injuries.

Rehabilitation

Rehabilitation after UCL reconstruction in a female athlete does not differ from that of the male population, which is discussed extensively elsewhere in this text. Typically patients are placed into a hinged elbow brace for 6–8 weeks postoperatively, allowing progressive increase in the range of motion of the elbow. Strengthening of the wrist and forearm, along with scapular stabilization and shoulder isometric muscle training, begins soon after surgery. Isotonic exercises of the wrist and elbow are begun approximately 1 month after surgery, with eccentrics starting 1 month later. Plyometrics are introduced at 10 weeks postoperatively, and a throwing program is typically delayed until 14 weeks postoperatively.

The benefit of a primary repair, when possible, is that it allows for an accelerated rehabilitation program. In his protocol, Argo's [4] female UCL repair patients were progressed along 4 weeks ahead of those who underwent reconstruction. They were started on a sport-specific program within the brace, including a throwing progression when appropriate, at 4–6 weeks postoperatively. Perhaps as a result of this, he found that his repair patients were able to return to full athletic participation at an average of 2.5 months, whereas in Cain's [17] large report of reconstruction patients, the athletes did not return to full competition for an average of 11.6 months. Argo attributed this quick recovery to the less invasive nature of repair as compared to reconstruction. Additionally, as was discussed earlier in this chapter, due to anatomic gender differences in muscle mass and strength, as well as sport-specific demands, female athletes tend to place less strain on the UCL. This likely allows earlier return to "full function" when compared to their male counterparts.

Conclusion

Though infrequently reported, female athletes do suffer injuries to the UCL of the elbow. These occur during participation in a wide variety of sports, including softball, tennis, javelin and gymnastics. The mechanism of injury is often chronic microtrauma; however, ligament avulsion is commonly seen as well. An extensive damage to the ligament necessitates reconstruction. To this point, there has not been any research to suggest a different approach to reconstruction in the female athlete, and thus the procedure performed is the same one classically described in the male athlete. However, when the ligament is not as extensively injured, Argo has reported excellent results with primary repair, although his study is limited by a small sample size. For this reason, in contrast to current literature regarding the treatment of male throwers, repair should be considered in these female patients competing at or below the college level. This offers the benefit of a less invasive procedure and potentially an earlier return to sport. However, treatment recommendations for the female athlete with a UCL injury are limited by the paucity of literature regarding both the biomechanics of the female ligament as well as outcome data in this patient population.

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