

Risk Factors and Rehabilitation Training for UCL Injuries in Adolescent Baseball Players

Handuan Cui

*Komazawa University Tomakomai High School, Tomakomai, Japan
dccuihanduan@uest.edu.gr*

Abstract. The Ulnar Collateral Ligament (UCL) injury is frequently seen in baseball players, it generally causes baseball players to rest for one season or more. In the global context, due to the continuous increase in the number of young people participating in baseball, the proportion of UCL injuries among teenage baseball players has also been increasing. Currently, insufficient attention is paid to UCL injuries in teenage baseball players, which affects their sports experience and career longevity. This study aims to raise awareness among more people about the differences between UCL injuries in teenagers and those in adults, including the risk and severity of the injuries. The purpose is to help adolescent baseball players return to the playing field through appropriate treatment methods and rehabilitation training, to restore their physical functions and the same playing level as before the injury. This not only affects their sports experience but also their sports lifespan. The purpose of this study was to enable more people to understand the severity, risk of injury, rehabilitation training and methods for adolescent UCL injury. Through this study, more people can learn about and pay attention to the UCL injury diseases of adolescent baseball players.

Keywords: UCL Injury, adolescent, baseball Players, rehabilitation.

1. Introduction

With the popularization of youth baseball, training and competitions have become professional. Due to high-intensity repetitive throwing, improper biological movements and insufficient recovery, the incidence of ulnar collateral ligament (UCL) injuries in adolescent baseball players has skyrocketed. Studies show that teenage athletes face a higher risk of injury, which is related to their immature skeletal systems, muscle imbalances, and the increasing trend of early specialized sports. In athletes aged 15 to 19, the yearly incidence of UCL reconstructions is expected to rise from 6.3 per 100,000 to 14.6 per 100,000 by 2025, per the study by Mahure et al. Adolescents (ages 15 to 19) made up 56.8% of all UCL reconstructions, with an annual increase rate of 9.84%, according to another study that examined the demographic distribution of UCL reconstructions from 2007 to 2011 [1]. Camp et al. confirmed through epidemiological database research that the incidence of UCL injury in patients aged 15-19 is five times higher than that in the general population.

The function of UCL is to stabilize the elbow joint and resist the outward rotation stress generated during throwing movements. The main mechanism of UCL injury is that during the

anaphase of throwing the ball, when the elbow joint is subjected to excessive eversion stress during the build-up and acceleration phases, it leads to micro-injury and eventually causes ligament injury or rupture. Unlike adults, teenagers face a unique challenge - among young throwing athletes, the excessive outward rotation stress on the UCL can cause significant tension on the medial epicondyle of the humerus. Particularly vulnerable to inflammation and dissociation from the distal humerus is the unfused medial epicondyle apophysis. Patients run the danger of suffering an avulsion fracture if they don't get enough rest.

After having the UCL injury, regaining strength lost during healing and preventing injury recurrence are two goals of physical therapy. A direct comparative study of early and delayed rehabilitation after UCL reconstruction surgery shows that early progressive rehabilitation can enable athletes to return to play(RTP) earlier, with similar outcome scores [2]. Nowadays, rehabilitation plans vary significantly due to factors such as the severity of the injury. Effective rehabilitation should be based on expert consensus and existing evidence to formulate suggestions, and be implemented in combination with factors such as the physiological characteristics and training load of adolescent athletes to ensure their safety during RTP.

2. Etiology of UCL injury

2.1. Anatomy and function of UCL injury

The UCL is located on the interior side of the elbow. It is a tough fiber tape connect at the distal end of humerus and the proximal ulna, divide into the anterior oblique ligament (AOL), it is originates from the medial epicondyle of the humerus and inserts into a high tubercle on the medial side of the coronoid process of the ulna, the transverse ligament begins at a high tubercle and terminates at the medial side of the olecranon of the ulna, while the posterior oblique ligament (POL) begins at the inferior surface of the medial epicondyle of the humerus. The main functions of UCL include four aspects: anti-eversion stress is provided during the deceleration stage of throwing, UCL provides stability by slowing down the extension of the elbow joint and generating inversion torque to counteract the eversion force caused by throwing actions [3]. The dynamic stability function works in synergy with the flexor muscle groups (such as the pronator teres and radial wrist flexor muscles) to dynamically regulate joint stability during exercise. Limiting excessive extension function is when the posterior oblique ligament tightens to prevent injury when the elbow joint is close to full extension. During the throwing process, the outward torque borne by the elbow joint may exceed the ultimate strength of the UCL, potentially leading to minor injuries or a complete fracture.

2.2. Injury mechanics

During the baseball players' throwing motion, the UCL provides the stabilization of the elbow joint from the valgus stress. The UCL supplies around 54% of the internal varus torque when the elbow is flexed [4]. There is a lot of valgus stress on the elbow when pitching during the cocking phase [2]. With various speeds from different periods of the people, the forces that focus on the UCL are different. Young pitchers receive roughly 28 Nm of valgus stress, high school and collegiate pitchers 48 and 55 Nm, respectively, and professional players 64 Nm [5]. It was discovered in a cadaveric investigation that the UCL could only withstand about 32 Nm of valgus stress [6]. The literature shows that during the throwing motion UCL limits the valgus angle to the greatest extent and bears the valgus force. Long-term overhead throwing causes accumulated UCL fatigue. Prior

investigations have found that after repeated subfailure loads, there is an increase in joint laxity and a decrease in the ligament's peak force [7-9].

2.3. Risk factors

The risk factors for UCL injuries are mainly divided into four categories, namely athlete demographic characteristics, poor throwing mechanics, high-speed throwing, and high throwing volume or high-intensity training competitions [10]. High-speed throwing causes the UCL to bear high stress. Multiple studies have shown that high-speed and wide range movements, as well as outward torque, have adverse effects on the stable structure of the elbow joint, which may cause changes in the elbow joint structure, damage the integrity of the UCL, and lead to its degeneration and damage [3]. High-throwing or high-intensity training competitions can lead to excessive use of the UCL, and the accumulation of minor injuries in the UCL can reduce its ultimate tensile load and increase the risk of fracture. Furthermore, the ulnar periosteum of the immature elbow joint is thought to be an extension of the UCL during adolescent development, and the signal intensity characteristics at its endpoint differ from those of mature ligaments. However, there isn't any conclusive research to back up this claim at this time [11]. Total shoulder range of motion, number of throws, throwing choice, Y-balance score, and lateral release position are the most reliable modifiable risk factors [10].

3. Rehabilitation and treatment

3.1. Treatment options

3.1.1. Conservative treatment

Although conservative treatment methods often offer the benefit of a quicker recovery, they ultimately depend on the athlete's sport, level of participation, and extent of surgery. If surgery or conservative treatment is available, athletes tend to choose conservative treatment because they believe that they may lose several years of competition time after surgery. Athletes can describe their perceived level of mental and physical preparedness using patient-reported outcomes (PROs). A less desired result could arise if an athlete RTPs from successful biological healing but is not psychologically prepared. When most players return to the game, they might need protective gear to support them, it depends on their level of play, sport and position. Although most literature currently focuses on failed cases of conservative treatment for baseball players (especially pitchers), conservative treatment is still applicable for low-level partial tears, including rest, physical therapy, and progressive throwing recovery plans. Platelet-rich plasma (PRP) injection is often used in combination with rehabilitation programs and has shown effectiveness in various musculoskeletal disorders, possibly for partial tearing, but evidence is limited.

3.1.2. Surgical treatment

Zaremski et al. showed that complete rupture or high-grade tears that fail nonoperative treatment require UCL reconstruction (Tommy John surgery). In recent years, UCL repair techniques such as internal support augmentation have shown good results and shorter recovery times. For those overhead throw athletes who return to the field after the full-thickness UCL tear or patients with partial tears who develop persistent medial elbow pain or valgus laxity during appropriate nonoperative treatment should still consider surgical treatment. Tommy John surgery is the most

common surgery for overhead throwing athletes, and its effects on the performance and value of baseball pitchers after the surgery [12].

3.2. Rehabilitation program

3.2.1. Early phase

The goals in the early phase of UCL injury are to protect healing tissue, reduce pain and inflammation, avoid further aggravation of the injury by valgus stress and initially restore the basic strength and mobility of the scapular girdle, rotator cuff and forearm muscles. During this stage, it is necessary to strictly avoid movements that may cause elbow valgus stress and focus on non-weight-bearing or low-load muscle strengthening exercises, such as side-lying dumbbell external rotation, prone "T" exercises, forearm radioulnar deviation training, and eccentric pronation/supination exercises. However, regardless of whether UCL injuries are treated surgically or nonoperatively, athletes who suffer from them are likely to benefit from early flexor-pronator strengthening and focused, targeted instructions [2]. Through training, patients are helped to improve flexibility and their core and grip stability are strengthened with the help of kettlebell movements. It should be noted that the entire process must be carried out within the pain-free range under the supervision of a therapist. If pain occurs, the training intensity or method should be adjusted in time.

3.2.2. Mid phase

The focus of mid-term rehabilitation for UCL injuries is to gradually increase the training load, introduce controlled valgus stress, and improve movement speed and compound movement ability to lay the foundation for the return to throwing movements. Gradually begin shoulder internal rotation exercises and incorporate compound multi-joint exercises to increase scapular stability and upper back strength. As the patient's function gradually improves, dynamic training is needed to increase movement speed, for instance, the Four-point Kneeling Position Toss 90/90 Wall Dibles, etc. Upper limb fitness training is also introduced to strengthen the explosive power and eccentric control ability of throwing-related muscles. The research shows that protocols for the Thrower's Ten Program began on average 7.2 weeks into the program, while Phases I and II of the Interval Throwing Program began on average 16.3 weeks (range: 14–21 weeks) and 22.6 weeks (range: 22–28 weeks), respectively [13]. During this stage, while incorporating rehabilitation training, elbow pain reactions still need to be closely monitored to ensure that all training is performed within the pain-free range, and that the load increase follows the principle of progressive overload.

3.2.3. Late phase

The core of rehabilitation in the late phase of UCL injury is the safe transition to systematic throwing training and ultimately back to the field. Before entering this stage, Ligament integrity should be assessed using a moving valgus stress test, as the moving valgus stress test is a superior examination technique for injuries to the UCL [14]. This ensures that there is no pain or instability in the elbow at different flexion angles, allowing training to be carried out smoothly. Warming up the athlete properly is crucial before beginning any throwing workout. We suggest a plyometric throwing warm-up following a normal full-body warm-up. In addition, the throwing program recommends a velocity-based progression model, gradually transitioning from low-intensity, short-distance throwing to high-intensity, competition-simulating training, while also incorporating core and lower-body strength training to maintain overall kinetic chain stability. Throughout this process,

training intensity and frequency must be adjusted by a professional based on individual progress to ensure performance recovery while avoiding reinjury.

3.3. Rehabilitation outcomes

For adolescents in the growth and development period, special attention should be paid to the use of progressive loading in injury rehabilitation, attention should be paid to the psychological fluctuations of adolescence to strengthen protection awareness, and plans should be formulated in combination with the characteristics of baseball to help them restore their best athletic condition and return to the field. A successful rehabilitation procedure incorporates the utilization of patient-reported outcomes, a sport-specific personalized treatment plan, kinetic chain strengthening, and an interval throwing programme [12]. During the rehabilitation phase, a systematic and individualized program should be implemented, focusing on strengthening muscle recovery, kinetic chain integration, and progressive throwing training. Rehabilitation success can be better ensured by relying on multidisciplinary collaboration (such as physical therapists and sports medicine physicians) and strictly adhering to the principle of painlessness.

4. Challenge and solutions for UCL injuries in adolescent baseball players

Adolescents are in the growth and development period, their skeletal epiphyses have not closed, and the strength and elasticity of soft tissues such as ligaments and tendons have not yet reached adult levels. When the UCL is repeatedly subjected to the eversion stress of pitching, it is easy to accumulate micro-injuries because "the soft tissue cannot keep up with the growth rate of the bone". In addition, the upper limb muscles (such as biceps and triceps) and core muscles are weak or unevenly developed, which will lead to decreased elbow stability during throwing, further increasing the load on the UCL. Nowadays, with the increasing number of youth baseball games and "over the pitch count" and "high-intensity training for multiple days in a row" in training, the UCL cannot be fully repaired, and micro-injuries gradually develop into tears.

Warm-up is often overlooked, but it is an important part of exercise - regardless of the type of sport, professional athletes usually spend 1-2 hours warming up to avoid injury. Following the recommendations of the Baseball Medical and Safety Advisory Board, adolescent baseball players must limit the number of throws they make. Power chain training is crucial in rehabilitation as it can reduce upper limb injuries in overhead athletes by developing lower limb strength, core strength, and stability. Physical training should also be an important means of reducing the proportion of UCL injuries. The rehabilitation process should be divided into stages based on the physiological phases of injury repair (inflammatory phase, proliferative phase, and remodeling phase) for different individuals. Clear goals should be set for each stage to prevent secondary injuries caused by premature weight-bearing or excessive activity. An interval throwing program, kinetic chain strengthening, and a sport-specific customized therapy plan are all components of a thorough rehabilitation regimen. The rehabilitation goal is not only the healing of the ligament, but also the restoration of the stability, strength, range of motion and sport-specific abilities (such as explosive power and coordination when throwing) of the elbow joint. Psychological rehabilitation is also an important part of recovery after injury.

Psychological considerations play a key role in RTP after UCL reconstruction. Loss of interest and fear of reinjury were the most often mentioned factors in the literature that was currently available. Psychological considerations accounted for 40.4% of the reasons why RTP was unsuccessful following UCL reconstruction. Given the dramatic increase in UCL reconstruction

procedures, particularly among younger patients, doctors should carefully assess their patients' psychological states before and after surgery to optimize RTP.

5. Conclusion

In conclusion, from the above-mentioned points, it is clear, UCL injury is an undoubtedly question that affects adolescent baseball players. The current findings add substantially to our understanding that the proportion of UCL injury among adolescent baseball players has been sharply increasing during the past few years. Face to the injury, the choices also cause a vital part; the patients should select treatment methods based on their specific injuries and the severity of the damage, and the evaluation of doctors is also essential. Through the two treatment methods described in the study, patients have a high probability of returning to play and resuming their same athletic performance level, or even higher. The rehabilitation after the treatment is important too, from the early, mid and late phases to help the patients get used to the “new” elbow, build up mechanisms preventing further injury and stabilizing the elbow, and get faster to return to play. Finally, a number of important limitations need to be considered. First, the data of the teenage baseball players are finite; second, individuals differ in their physical states; third, although the study is targeted at adolescents, significant physical changes occur during puberty; therefore, age is also a factor that needs to be taken into account. The research had thrown up many questions in need of further investigation, for instance, expanding the survey of teenage baseball players, a clear discussion of adolescent UCL injury, more treatment about the UCL injury, etc. Despite the substantial body of academic literature on UCL injuries, research on the attention and development of adolescent baseball players remains in the growth stage, presenting significant potential for academic advancement. I am confident that shortly, the significance of UCL injuries for adolescent baseball players will be more widely recognized among everyone, and preventive and treatment methods will become more specific and effective. This will enable adolescent baseball players to enjoy the pleasure of baseball and extend their sports careers.

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