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REVIEW ARTICLE

Return to Sport and Sports-Specific Outcomes Following Ulnar Collateral Ligament Reconstruction in Adolescent Athletes: A Systematic Review

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Abstract *Background:* The incidence of elbow injuries and ulnar collateral ligament (UCL) reconstruction in adolescent athletes is increasing. Knowledge and expectations of outcomes following this procedure are necessary for proper counseling and decision-making in this age group. *Questions/Purposes:* We sought to report patient-reported outcomes, rate of return to sport, and rate of complications and reoperation following UCL reconstruction in adolescent athletes. *Methods:* A systematic review was conducted for adolescent athletes undergoing UCL reconstruction. The primary outcome measure was patient-reported outcome scores, specifically the Conway Scale, the Andrews-Timmerman score, and the Kerlan-Jobe Orthopaedic Clinic (KJOC) score. Secondary outcome measures included return to sport, rate of subsequent procedures, and complication rate. A descriptive analysis was performed. *Results:* Seven studies met the inclusion criteria. The average patient-reported outcome scores ranged from 81 to 87% (Conway, "excellent"), 83.6 to 92.7 (Andrews-Timmerman), and 76 to 89.3 (KJOC). The average rates of return to sport were 84% to preinjury level or higher, 93% to any level, and 57% to a higher level. Complication rates ranged from 0.7 to 11%. Rate of subsequent elbow procedures ranged from 0 to 10%. *Conclusions:* This systematic review demonstrates favorable outcomes in adolescent athletes following UCL reconstruction. Patient-reported outcome scores and rates of return to sport were comparable with those reported in adult athletes. The procedure is not without risk of complications, and patients and parents should be counseled regarding this risk prior to surgery.

Keywords adolescent · baseball · pitching · ulnar collateral ligament reconstruction

Introduction

The medial ulnar collateral ligament (UCL) stabilizes the elbow against valgus stress and is most commonly injured in overhead-throwing athletes. Injury to the ligament is thought to be caused by an accumulation of microtrauma secondary to repetitive stress sustained during the overhead-throwing motion [21]. A tear of the ligament was career-ending for professional baseball pitchers, until the first UCL reconstruction was performed by orthopedic surgeon Frank Jobe in 1974. The procedure has since returned numerous professional players to their preinjury performance level, and its use has extended to a wider scope of athletes [10].

Since the 1990s, several studies have reported a rise in the number of UCL reconstructions performed on adolescent athletes [16, 19, 21]. In one major practice, the average age at the time of surgery dropped nearly a decade, decreasing from almost 30 years to less than 20 years of age over a 10-year time span [8]. As participation in organized youth sports increases, the number of injuries likewise increases. Five percent of baseball pitchers ages 9 to 14 years suffer elbow injuries serious enough to require surgery or retirement from baseball within 10 years [11]. Previous studies have associated these injuries with overuse, finding that pitchers with elbow injuries were more likely to have pitched more months per year, more games per year, and more innings per game [15, 19]. Despite efforts to increase awareness and implement injury-prevention programs, the number of UCL reconstructions performed on young athletes remains high, and the annual incidence of UCL

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reconstruction in the 15- to 19-year-old age group is projected to increase to 14.6 per 100,000 by 2025 [16, 23].

Previous reviews have demonstrated favorable outcomes and high rates of return to sport in athletes following UCL reconstruction, but relatively few studies have focused on adolescent players [5, 7]. As the incidence of elbow injuries continues to rise in this population, knowledge and expectations of outcomes following UCL reconstruction are increasingly necessary for proper counseling and decision-making in this age group.

We undertook a systematic review to synthesize the current evidence regarding UCL reconstruction in adolescent athletes and to answer the following: (1) What are the results of patient-reported outcome measures? (2) What is the rate of return to sport? and (3) What is the rate of complications and reoperation?

Material and Methods

A systematic review of the literature was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines regarding ulnar collateral ligament reconstruction in adolescent athletes. The PubMed (MEDLINE) and Cochrane Library databases were searched electronically using the following search term: "(Medial ulnar collateral ligament OR ulnar collateral ligament OR UCL) AND (Reconstruction OR Tommy John surgery) AND (outcomes OR return to sport OR return to play)." Articles from 1966 to 2018 were included in the search. Final search was performed on August 30, 2018. For each full-text article obtained, the reference section was reviewed for additional relevant articles not identified in the electronic search.

Studies were included if they were reported in English and evaluated outcomes or return to sport following UCL reconstruction in adolescent athletes at a minimum of 1-year follow-up. Patients ages 10 to 19 years and those described as "high school athletes" were considered adolescents. Studies reviewing results following repair of the ligament with or without "internal bracing" were excluded, as we were not specifically reviewing these techniques in this study. Studies were excluded if they were literature reviews, expert opinions, case reports, or studies that did not report outcomes or rates of return to sport. The initial search yielded 551 unique abstracts, of which 72 relevant full-text articles were assessed for inclusion. Of the 72 full-text articles, 65 were excluded because the study did not include a high school level cohort, the data regarding high school athletes was not easily extracted, or they were review articles. Therefore, seven studies were deemed eligible for inclusion in the final analysis. Study bias was assessed by two authors (G.G., A.C.A.) using the methodological index for non-randomized studies (MINORS) scoring system. Each study was assigned a score ranging from 0 (high bias) to 100% (low bias) according to this system. The abstracts selected for review were evaluated by two authors (G.G., A.C.A.). Questions regarding inclusion or exclusion were discussed with the senior author (B.M.G.) until consensus was achieved.

The following was extracted from each article: study design, level of evidence, patient demographics (number, age, gender), duration of clinical follow-up, surgical technique, rate of return to sport, patient-reported outcome measures, reoperations, and complications. The primary outcome measure was patient-reported outcome scores following ulnar collateral ligament reconstruction, specifically the Conway Scale (poor [worst], excellent [best]), Andrews-Timmerman score (0 [worst], 100 [best]), and Kerlan-Jobe Orthopedic Clinic (KJOC) score (0 [worst], 100 [best]). Secondary outcome measures included return to sport and rates of subsequent procedures and complications.

The pooling of results for meta-analysis was avoided secondary to the significant heterogeneity, methodological variability, low levels of evidence, and retrospective nature of the included studies. A descriptive analysis was instead performed, and outcomes that were reported in a minimum of 3 studies were summarized and included ranges, standard deviations, and weighted averages when possible (Table 1) [1].

Results

Seven studies with a total of 512 adolescent patients were analyzed in this systematic review (Fig. 1). The studies were all level IV evidence. The average MINORS score was 70%. The mean age at time of surgery ranged from 17 to 18 years. Mean duration of clinical follow-up ranged from 31 to 58 months (Table 1). Surgical technique varied: four studies used a modified Jobe technique, three used a docking technique, and one used the American Sports Medicine Institute technique (Table 2).

Patient-reported outcome scores were reported in five studies; the KJOC score was the most common, reported in four studies, with an average score that ranged from 76 to 89.3 (Table 3). Three studies reported the Andrews-Timmerman score, with an average score that ranged from 83.6 to 92.7. Three studies reported patient outcomes with the Conway scale, with "excellent" scores ranging from 81 to 87%, "good" scores ranging from 3 to 4%, "fair" scores ranging from 5 to 15%, and "poor" scores ranging from 3 to 4%.

The reporting of return to sport was variable. All seven studies reported rate of return to sport at the same level or higher, with a weighted average of 84% (Table 4). Four studies reported rate of return to sport at any level, with a weighted average of 93%. Four studies reported rate of progression to a higher level of sport (college or professional), with a weighted average of 57%. Mean time to return to sport was reported in four studies, ranging from 11 to 13.4 months. Complication rates were reported for adolescent cohorts in 3 studies, ranging from 0.7 to 11% (Table 2). The most common complication reported was transient ulnar neuropraxia. Rate of subsequent elbow procedures, reported in three studies, ranged from 0 to 10%. The most common subsequent procedure reported was open reduction internal fixation of a medial epicondyle fracture.

Table 1 Summary of included studies and patient demographics

First author	Year	LOE	MINORS (%)	No. adolescent patients	Age, (years)	Mean Follow-Up, (months)	Imaging findings	
							Plain radiograph	MRI
Cain [5]	2010	4	75	131	17.8 ± 2.1	Min. 24, mean NR for high school cohort	–	61% attenuated, 26% completely torn, 13% partially torn UCL
Erickson [8]	2016	4	72	69	NR for high school cohort	Min. 18, mean NR for high school cohort	–	Confirmed UCL tear in 100%
Jones [14]	2014	4	69	55	17.6 (15–18)	31 (24–37)	–	Confirmed UCL tear in 100%
O'Brien [18]	2015	4	54	19	16–19	Min. 24, mean NR for high school cohort	–	–
Osbahr [20]	2014	4	75	40	NR for high school cohort	Min. 120, mean NR for high school cohort	–	–
Petty [21]	2004	4	69	31	17.4 (15.9–19)	35 (18–75)	9/27 (33%) bony abnormalities within ligament (sublime tubercle/medial epicondylar avulsion fractures or ossicles)	26/27 (96%) showed disruption of ligament or bony avulsion
Saper [24]	2018	4	76	140	18 (13–19)	57.9 (32–115)	22/140 olecranon osteophytes (15.7%), 21/140 UCL calcification/ossicles (15%), 2/140 fracture/nonunion (1.4%), 2/140 other (1.4%)	Confirmed UCL tear in 100%

LOE level of evidence, *MINORS* methodological index for non-randomized studies, *NR* not recorded

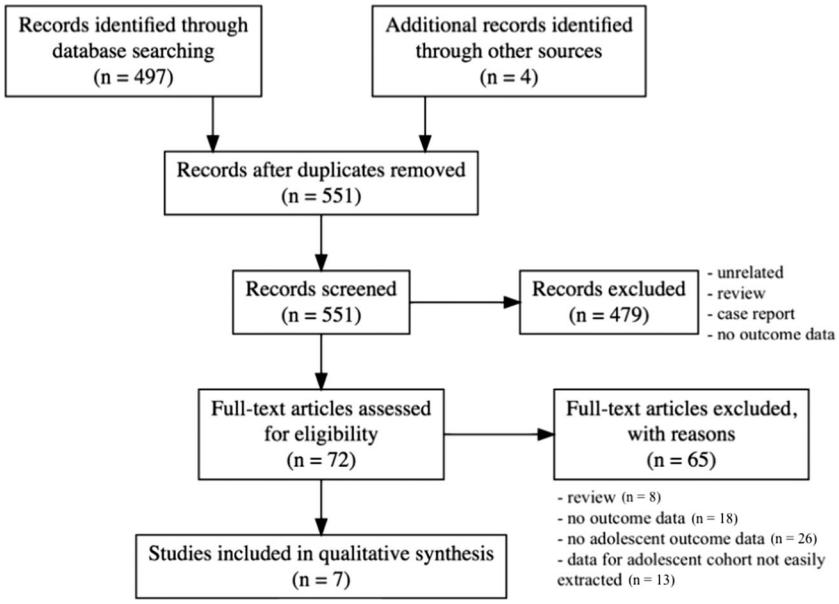

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart of included studies.

Discussion

Overall, our study demonstrated favorable outcomes in adolescent athletes following UCL reconstruction. Conway "excellent" scores ranged from 81 to 87%, and the Andrews-Timmerman and KJOC scores ranged from 84 to 97% and 76 to 89% of their maximum scores, respectively. These outcome scores were similar to those reported for older cohorts, such as the mean Conway "excellent" rating of 83% reported by Somerson et al. in a systematic review of 14 studies regarding UCL reconstruction [6, 20, 26]. Our analysis additionally demonstrated an 84% rate of return to preinjury level of play or higher, 93% rate of return to any level, and 57% rate of progression to a higher level. The preinjury rates were similar to the 86% rate of return to sport reported in a systematic review analyzing an older cohort by Erickson et al. [9].

This study had several limitations. Our review was limited by the heterogenicity of the data, inconsistency of outcome measures reported, risk of publication bias, and low levels of evidence. Additionally, we did not address UCL repair in adolescent athletes as there was a lack of sufficient studies to include for comparison. Savoie et al. investigated outcomes following UCL repair in a retrospective review of 60 patients with a mean age of 17.2 years [25]. The authors reported excellent outcomes similar to those reported for UCL reconstruction, along with a shorter mean time to return to sport, which averaged 6 months. These results contrast with previous studies comparing reconstruction and repair in older cohorts, which have demonstrated more favorable results with reconstruction [3, 6]. The study by Savoie et al. lacked a comparison group of patients who had undergone UCL reconstruction, but the authors reasoned that younger athletes have played sports for a shorter period and have sustained less overall damage to the UCL, and thus, their ligament is more amenable to repair. UCL repair is a less extensive procedure and avoids the added morbidity of harvesting a graft, so if the procedure could also promise excellent outcomes with low rates of failure, this option might be attractive to young athletes. Continued investigation into this topic would help to further define treatment recommendations in adolescent athletes with UCL insufficiency. The short-term nature of the results is also a limitation to the analysis. A majority of the studies had a minimum follow-up of 2 years or less. A longer follow-up would be necessary to determine if any long-term complications such as growth disturbances occurred.

An additional limitation to this analysis was the use of patient-reported outcome measures that have not been validated in the pediatric population. Recently, outcome measures such as the Pedi-ASES, Youth Throwing Score, and PROMIS Pediatric Upper Extremity have been validated for pediatric patients [2, 7, 13]. These outcome measures may not have been readily available to the authors of the reviewed studies at the time of data collection. The use of these measures would have strengthened the clinical applicability of the studies. Notably, the average age at the time of surgery was 17 years or older in a majority of the studies, which indicates that many participants were 18 years or older by the time of follow-up. In those cases, the adult patient-reported outcomes measures were appropriate.

Our review analyzed several studies that included patients of different skill levels at their particular sport. Differences in outcomes between patients of different levels were variable [5, 8, 18, 20]. Osbahr et al., in a retrospective study of 313 patients, reported that their collegiate cohort returned to sport at a significantly higher rate (92%) than their high school cohort (83%) [20]. When the authors evaluated the effect of other variables on rate of return to sport, such as graft choice, concomitant injury, transient post-operative

Table 2 Surgery and rehabilitation data

First author	Year	Surgical technique	Ulnar nerve transposition performed in all	Concomitant procedures	Complications	Subsequent procedures
Cain [5]	2010	Modified Jobe (described by Azar et al)	Yes	NR for high school cohort	NR for high school cohort	NR for high school cohort
Erickson [8]	2016	Standard docking or double docking technique	No	NR for high school cohort	NR for high school cohort	NR for high school cohort
Jones [14]	2014	Docking technique	–	2/55 (3.6%) transhumeral drilling for capitellar OCD lesions, 2/55 (3.6%) posteromedial olecranon osteophyte debridement	4/55 (7.3%) transient ulnar neuritis	0/55 (0%)
O'Brien [18]	2015	Docking technique or modified Jobe	No	NR for high school cohort	NR for high school cohort	NR for high school cohort
Osbahr [20]	2014	Modified Jobe (described by Azar et al)	Yes	14% concomitant elbow procedure	NR for high school cohort	10% post-operative elbow surgery, 13% post-operative shoulder surgery
Petty [21]	2004	Modified Jobe (described by Azar et al)	Yes	4/27 (15%) posteromedial olecranon osteophyte excision	3/27 (11%) 2 transient ulnar neuritis, 1 saphenous nerve sensory deficit secondary to graft harvesting injury	–
Saper [24]	2018	American Sports Medicine Institute (ASMI) technique	Yes	18/140 (12.9%) osteophyte excision, 13/140 (9.3%) excision of calcification/ossicles, 2/140 (1.4%) loose body removal, 9/140 (6.4%) other	1/140 (0.7%) intraoperative nerve injury	2/140 ORIF of medial epicondyle fracture, 1/140 lysis of adhesions, 1/140 excision of calcium deposit

NR not recorded, *OCD* osteochondral defect, *ORIF* open reduction internal fixation

Table 3 Patient-reported outcomes

	First author	Year	No. of patients	Score
Andrews-Timmerman score	Erickson [8]	2016	131	92.7 ± 6.1
	Jones [14]	2014	55	83.6 ± 7.2
	Saper [24]	2018	140	97.3 ± 6.1
Kerlan-Jobe Orthopaedic Clinic score	Erickson [8]	2016	131	89.3 ± 9.1
	Jones [14]	2014	55	88.0 ± 6.0
	O'Brien [18]	2015	40	76
	Saper [24]	2018	140	85.2 ± 14.6
Conway scale	Jones [14]	2014	55	87% excellent 4% good 5% fair 4% poor
	Osbahr [20]	2014	40	81% excellent 3% good 15% fair 3% poor
	Saper [24]	2018	140	86% excellent 4% good 6% fair 4% poor

neuropraxia, and history of previous elbow or shoulder surgery, the results were not statistically significant, suggesting that the level of sport played was a prominent factor in the outcome difference. Erickson et al., in a retrospective study of 187 patients, similarly found a higher rate of return to sport in their collegiate group, but found higher Andrews-Timmerman and KJOC scores in high school players [8]. The higher rates of return to sport in collegiate athletes despite more favorable outcome scores in high school athletes may have been due to an increased incentive for collegiate athletes to continue playing, such as retaining an athletic scholarship or holding more realistic aspirations of advancing to a professional career.

For younger athletes who may have the desire to obtain a college athletic scholarship or to ultimately play professionally, an important outcome measure following surgery is the ability to progress to a higher level of sport. Relatively, few high school baseball players advance to play at the college level, and even fewer progress to play professionally. According to the National Collegiate Athletic Association (NCAA), 7% of high school baseball players advance to play for the NCAA, and only 9.5% of those players make it to professional leagues [17]. Our review found a 57% rate of progression to the college or professional level. This finding suggests that players with the desire to pursue a prolonged baseball career following UCL reconstruction are still able to do so, although this relatively high rate of progression may also suggest that the patients included in these studies may have been relatively more competitive or ambitious than the average high school athlete.

Perhaps as a consequence of increased competitiveness or ambition, many players demonstrated multiple risk factors of elbow overuse. Petty et al. conducted a phone survey with their adolescent patients following UCL reconstruction, finding that the players had demonstrated an average of three risk factors prior to surgery, according to the recommendations made by the USA Baseball Medical and Safety Advisory Committee. Risk factors included year-round throwing with less than 2 months of rest, exceeding the recommended maximum number of pitches by age per game or per week, pitching breaking balls before age 14, inadequate warm-ups before pitching, and throwing fastballs at a velocity greater than 80 mph [21]. Presence of these factors supports the theory that overuse of the throwing arm is a possible cause of UCL injury in the adolescent population. Presence of these factors also highlights the continued importance of coach and parent education regarding injury prevention. Petty et al. noted that only 52% of players felt that their coaches were cautious about preventing injuries, suggesting that coaches may have ignored or not have been aware of national guidelines [21].

The procedure is not without risk of complications. In the studies that included a complication rate for their adolescent cohorts, the rate was ranged from 0.7 to 11%, with the majority of complications attributed to transient ulnar neuropraxia, all of which resolved within 8 weeks [14, 21, 24]. These complication rates are similar to previous reviews involving older cohorts, with both Somerson et al. and Erickson et al. reporting a rate of 10% [6, 20]. The rate of subsequent elbow procedures ranged from 0 to 10%. In the study spanning the longest period of clinical follow-up (minimum of 10 years), Osbahr et al. reported that only 10% of their high school cohort underwent post-operative elbow surgery in comparison with the 19% overall rate [20].

As the risk of complications and reoperation exists, nonoperative management is important to consider in young athletes. A trial of nonoperative treatment is appropriate in this population and recommended for partial tears [4]. In a study of 31 overhead-throwing athletes who underwent nonoperative treatment for UCL injury, Rettig et al. found that 42% were able to return to sport at their previous level of play at an average of 24.5 weeks following a rehabilitation program [22]. The program included a phase of rest and anti-inflammatory pain control followed by a phase of muscle strengthening and throwing. This study involved mainly collegiate and high school athletes, with an average age of 18 years. The results

Table 4 Return to sport

First author	Year	No. of patients	Same level or higher	Any level	Progressed to higher level	Time to return, (months)
Cain [5]	2010	131	108/131 (83%)	115/131 (88%)	65/131 (50%) to college, 8/131 (6%) to professional	–
Erickson [8]	2016	35	31/35 (89%)	–	–	–
Jones [14]	2014	55	48/55 (87%)	53/55 (96%)	–	11.5
O'Brien [18]	2015	19	16/19 (84%)	–	–	13.4
Osbahr [20]	2014	40	32/40 (80%)	39/40 (98%)	23/40 (58%)	–
Petty [21]	2004	27	20/27 (74%)	–	10/27 (37%) to college	11
Saper [24]	2018	140	121/140 (86%)	134/140 (98%)	70/138 (51%) to college, 16/138 (12%) to professional	11.6 (5–24)
Total		447	376/447 (84%)	341/366 (93%)	192/336 (57%)	

suggest that return to sport at the preinjury level of play is possible in young athletes following nonoperative treatment, but the outcome is less predictable than operative treatment. The extent of UCL injury was not reported in this study. In a study comparing operative and nonoperative treatment in professional baseball players, Ford et al. found that rates of return to sport at the same level of play were comparable for operative and nonoperative treatment in patients with incomplete tears (100% and 93%, respectively) [12]. Although this study involves a different patient population, its results suggest that an athlete can achieve good results following nonoperative treatment for partial tears, and a trial of nonoperative treatment is reasonable.

In conclusion, this systematic review demonstrates favorable outcomes in adolescent athletes following UCL reconstruction. Patient-reported outcome scores and rates of return to sport were comparable with those reported in adult athletes. The procedure is not without risk of complications, and patients and parents should be counseled regarding this risk prior to surgery.

Compliance with Ethical Standards

Conflict of Interest: Georgina Glogovac, MD, Rafael Kakazu, MD, Alexander Constantine Aretakis, BA, and Brian M. Grawe, MD, declare that they have no conflicts of interest.

Human/Animal Rights: N/A

Informed Consent: N/A

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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