Journal of Women's Sports Medicine

Sex-Specific Differences In Elbow Ulnar Collateral Ligament Injuries: A Retrospective Analysis

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BACKGROUND: The incidence of UCL injuries has increased considerably and is well documented in male-focused literature. Although women are not immune to UCL injuries, limited work has explored potential sex-specific differences in UCL mechanism of injury, clinical presentation, care pathway, or return to play. The purpose of the present study was to evaluate patterns of elbow UCL injury in male and female athletes via MRI review.
METHODS: Retrospective chart review of diagnosed elbow UCL injuries at a single sports medicine institution from January 2015- January 2022 was performed. Inclusion criteria were as follows: (1) patients 15-35 years of age, (2) diagnosis of an elbow UCL injury, (3) athlete, (4) MRI of elbow at the time of injury, (5) patient documentation records with demographic information. Male and female groups were compared for differences in injury patterns and the presence of concurrent injuries. A secondary analysis assessed demographic differences between the two cohorts. To determine if there were statistically significant differences between males and females, t-tests or Mann-Whitney U tests were used for numerical variables based on distribution, while chi-square or Fisher's exact tests were used for categorical variables.
RESULTS: Of 1,068 patients diagnosed with a UCL injury during the study window, 168 patients met inclusion criteria (113 (67%) males and 55 (33%) females). The average age in both groups was 17.9 ± 2 years. No statistically significant differences were observed with regard to handedness, injury year, or injury month. When comparing injury-related clinical factors between male and female patients, statistically significant differences were discovered for injury onset, UCL grade, and tear location (all $p<0.001$). Males had a higher rate of bony edema (63% vs. 26%; $p<0.001$). No significant differences were found with other associated injuries.
CONCLUSION: This present study demonstrates that sex-specific differences exist in UCL injury patterns – including onset of UCL injury, grade, and tear location. We also found that MRI findings, symptom duration, and management strategies differed between male and female athletes. Female athletes more commonly presented with chronic UCL injuries, many of which displayed no significant findings on MRI imaging. The results of this study suggest that sex-specific differences in UCL injury occurrence and presentation exist. Further research is needed to better inform the care and treatment of UCL injuries in both male and female athletes.

INTRODUCTION

The ulnar collateral ligament (UCL) in the elbow provides stabilization during high angular velocity and valgus stress movements, such as throwing and other overhead arm movements.[1–4] Injury to the UCL can be debilitating, and resultantly many patients elect to undergo UCL reconstruction or repair.[1–4] In recent years, the incidence of UCL injuries has increased considerably and is well documented in male-focused literature.[5–8] Although women are not immune to UCL injuries, very little literature explores potential sex-specific differences in UCL mechanism of injury, clinical presentation, care pathway, or return to play.[9,10] Like many other sports medicine injuries, our understanding of sex-specific differences in UCL injuries remains sparse.

The understanding of women's anterior cruciate ligament (ACL) injuries has increased in the last two decades.[11,12] ACL injuries are 4 to 8 times more common in women and are often the result of minimal to non-

DOI: 10.53646/jwsm.v3ii.33
Published online: April 15, 2023

contact injuries.[13–15] Men and women have been observed to utilize different patterns of knee movement, resulting in gender-related changes in whole-body musculoskeletal dynamics, such as knee valgus stress.[13] The female ACL has been shown to have decreased collagen, less elasticity, and to fail at a lower load compared to the male ACL.[11,12,16,17] Furthermore, the female athlete has different levels of elastin, as well as varying levels of estrogen during the menstrual cycle, which also may play a role in ACL injury.[13,18,19] Though research concerning the female ACL is important, it is not the only ligamentous pathology that requires further sex-specific investigation. For example, no such work comparing morphological or biomechanical properties of the male and female UCL is currently available.

Very little information exists regarding sex-specific differences in incidence or mechanism of UCL injury. Argo et al. published the largest study (n=19) examining treatment of UCL injury in female athletes.[10] The results of this investigation suggest that female athletes appear to be able to consistently return to a high level of function after repair or reconstruction for medial elbow instability.[10] UCL injuries amongst female athletes have been observed during gymnastics, softball, calf roping, cheerleading, javelin, tennis, baton twirling, judo, swimming, equestrian, alpine skiing, and handball.[10,20,21] Although female participation in UCL injury-related sports is high, the nature of UCL injuries in female athletes has received little attention in the current literature.

Magnetic resonance imaging (MRI) of the elbow is widely used to assess UCL integrity.[22–24] No study has investigated sex-specific differences in patterns of elbow UCL injuries using MRI. The primary objective of the present study was to evaluate patterns of elbow UCL injury in male and female athletes via MRI review. A secondary objective was to review sex-specific differences between patient demographics, including age, weight, and sport. We hypothesized that there would be significant differences in injury patterns between male and female patients with UCL injuries.

MATERIALS AND METHODS

Study Design

Study approval was obtained from the Institutional Review Board after which, retrospective chart review of diagnosed elbow UCL injuries at a single sports medicine institution from January 2015- January 2022 was performed. The present study sought to explore male and female athletes who had sustained a UCL injury. Inclusion criteria were as follows: (1) patients 15-35 years of age, (2) diagnosis of an elbow UCL injury, (3) athlete, (4) MRI of elbow at the time of injury, (5) patient documentation records containing demographic information. Patients were excluded from the study if they possessed any of the following: (1) previous UCL surgery, (2) ages <15 or >35 years old, (3) no elbow MRI at the time of injury, (4) non-athletic injury, (5) infection, (6) skeletal immaturity due to open physes (Figure 1).

Demographic Data Collection

A sports medicine physician assistant (PA-C) performed chart review for all included patients to obtain the following demographic data: age (years), weight (kg), year of injury, month of injury, sport, position, handedness (right or left), injury acuity (acute versus chronic), duration of symptoms (weeks), associated ulnar nerve symptoms, time to return to play (months), and treatment method (platelet rich plasma (PRP), physical therapy (PT), nonsteroidal anti-inflammatories (NSAIDs), UCL repair with internal brace, or UCL reconstruction). Per chart review, "acute injury" was defined as athletes who described feeling a pop, snap, or immediate pain during one specific incident, tenderness over the anterior band of the UCL, positive milking maneuver and moving valgus stress test on physical examination, as well as indicative MRI findings.[25,26] "Chronic injury" was defined as athletes admitting to a past history of medial elbow pain, tenderness over the anterior band of the UCL, positive milking maneuver and moving valgus stress test on physical examination, as well as thickened or no significant MRI findings.[27]

Imaging Studies

MRI analyses were performed utilizing 1.5 T with arthrogram or 3 T non-contrast with surface coil (Siemens Medical Solutions USA, Inc., Malvern, PA, USA, and GE Healthcare, Chicago, IL, USA). All MRI imaging reports were produced by a musculoskeletal fellowship-trained radiologist from the respective institution at the time of MRI. Each musculoskeletal radiologist at the institution had over 10 years of experience.

MRI Review

MRI report from time of injury for each athlete was utilized for the current study. UCL injuries were categorized into three grades: Grade 1 – low-grade sprain/partial tear, Grade 2 – moderate to high-grade partial tear, and Grade 3 – full thickness or undersurface tear. Sprain/low-grade partial tears were defined as abnormal thickening (> 7mm) without a fluid gap or attenuation and T2 hyperintense signal to normal ligament involving less than 50% of ligament fibers. High-grade partial tears were defined as discontinuity of tendon and fluid signal gap between tendon fibers involving 50 to <100% of ligament fibers. Compete full-

DOI: 10.53646/jwsm.v3ii.33
Published online: April 15, 2023

thickness tears were defined as tears through entirety of the ligament. Location of ligament injury was also documented (proximal, mid-substance, distal, or thickened (chronic) entire ligament calcification (Figure 2). This described process was also applied to associated lateral collateral ligament (LCL) injury reporting.

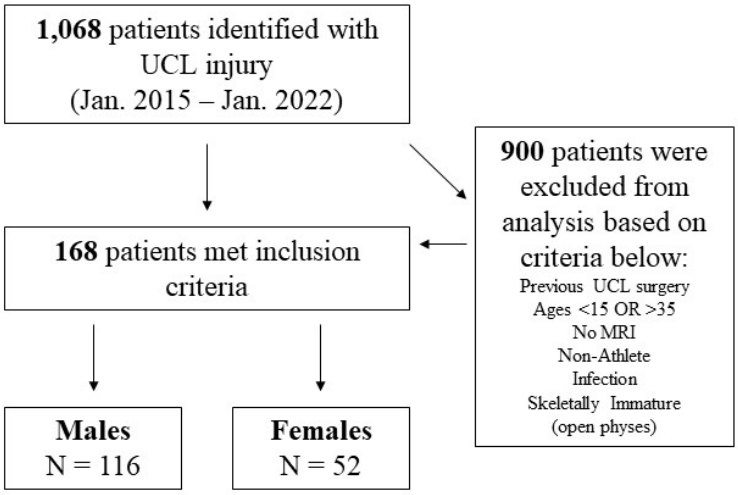

Figure 1. Flow chart of data collection for UCL sex differences retrospective study.

Figure 2. Coronal images demonstrating differences in UCL tear location. A) T2-weighted coronal view of the elbow demonstrates a low-grade partial mid-substance tear (Grade 1) (arrow); B) T2-weighted coronal view of the elbow shows a high-grade partial distal tear (Grade 2) (arrow).

The biceps, triceps, common flexor and extensor tendons, and cartilage were defined as "injured" if there was a fluid signal intensity gap in the normal structure. Edema was defined by increased T2 signal on fluid-sensitive sequences with a corresponding decrease in T1 signal observed at either the medial epicondyle of the humerus or sublime tubercle of the ulna. Fracture was defined by cortical discontinuity or subchondral linear low T1 signal with surrounding increased T2 signal. If there were any discrepancies in MRI analysis (based on vocabulary used in radiologist report to determine grade of UCL tear), the senior author (fellowship-

DOI: 10.53646/jwsm.v3ii.33
Published online: April 15, 2023

trained sports medicine surgeon) reconciled the radiologist's interpretations.

Statistical Analysis

Patient demographics, sport-related characteristics, and injury-related characteristics were summarized overall and stratified by male and female sex. Means and standard deviations were used to summarize continuous variables that closely followed a normal distribution and medians and 25th and 75th percentiles were used to summarize skewed variables. All categorical variables were summarized with counts and percentages. To determine if there were statistically significant differences between male and female athletes, t-tests or Mann-Whitney U tests were used for numerical variables based on distribution while chi-square or Fisher's exact tests were used for categorical variables. Ordinal variables including injury year, UCL tear grade, and other associated injuries were also compared using Mann-Whitney U tests. For variables that were considered injury outcomes and that were significantly different between males and females in the unadjusted analysis (symptom duration and return to play), an adjusted analysis was also used. The adjusted analysis utilized generalized linear models with a negative binomial distribution and log link function and controlled for key demographic factors (age and weight) as well as injury-related factors that were significantly different between sex (injury onset, tear location, and bony edema). The purpose of the adjusted analysis was to determine if the sex differences found in the unadjusted analysis were truly related to sex, or if the differences were driven by other demographic or injury-related differences between the groups. All analysis was performed using SAS 9.4 (SAS Institute; Cary, NC). Statistical significance was determined at $p < 0.05$.

RESULTS

Review yielded 1,068 patients diagnosed with a UCL injury at a single sports medicine institution between 2015-2022. One hundred and sixty-eight patients met inclusion criteria and were included in analysis, 113 (67%) males and 55 (33%) females. The average age in both groups was 17.9 ± 2 years and ranged from 15-24 years (Table 1). There was a significant difference in weight as average male weight was 87 kg while average female weight was 72 kg ($p<0.001$). No statistically significant differences were observed with regard to handedness, injury year, or injury month. Due to the wide range of sports and positions, formal statistical tests were not run to compare sport across sex. Most injuries in males occurred playing high school (48%) or college (40%) baseball, while most injuries in females occurred playing high school (33%) or college (33%) softball.

When comparing injury-related clinical factors, statistically significant differences were discovered for injury onset, UCL grade, and tear location (all $p<0.001$) (Table 2). Nearly all male injuries were acute (94%), Grade 1 (43%), and were proximal (43%) or distal (41%) in location. The majority of females had chronic injuries (71%) and intact UCLs (71%). Males had a higher rate of bony edema (63% vs. 26%; $p<0.001$). None of the participants had associated LCL tears or triceps tendon injuries. No significant differences were found with other associated injuries.

When looking at treatment patterns, just over half (51%) of females were treated with physical therapy (PT), while 14% of females were treated with either UCL reconstruction or repair. PT was also the most common treatment for males (41%), with the second most common treatment for males being UCL repair (27%) followed by UCL reconstruction (15%). Despite the differences in the order of most frequent treatments, no statistically significant associations between treatment and sex were observed. During unadjusted variable analysis, symptom duration was found to be significantly longer for females (20 weeks compared to 2 weeks for men), but once this analysis was adjusted for other key factors (age, weight, injury onset, tear location, and bony edema) the differences based on sex were no longer significant ($p=0.312$) (Table 3). Similarly, the unadjusted analysis for return to play resulted in males demonstrating a significantly longer duration (median of 4 months compared to 3 months for females) ($p=0.021$), but the adjusted analysis resulted in no significant difference ($p=0.133$).

Sex was no longer significant for symptom duration and return to play after performing analysis that adjusted for age, weight, onset of injury, tear location, and bony edema ($p=0.312$ and $p=0.133$, respectively).

DISCUSSION

The main findings of this study were that sex differences exist in onset of UCL injury, grade of injury, and tear location. Nearly all male injuries were acute, resulting in a Grade 1 tear in either the proximal or distal location. Most females had chronic injuries and presented with intact UCLs. Interestingly, of the 39 female athletes with chronic UCL injuries, 29 presented with no significant finds on MRI imaging.

Furthermore, female athletes were observed to have increased symptom duration (~10 times longer) compared to their male counterparts. These findings are interesting and suggest that further work exploring potential differences in the mechanical and biological properties of the male and female UCL is warranted.

DOI: 10.53646/jwsm.v3ii.33
Published online: April 15, 2023

Table 1. Participant demographic and sport-related characteristics.

Characteristic	*All (n=168)*	*Male (n=113)*	*Female (n=55)*	*p-value*
Age (years)				0.084
mean ± std	17.9 ± 2.0	17.9 ± 2.0	17.8 ± 2.1	
min - max	15 - 24	15 - 24	15 - 23	
Weight (kg)				<0.001
mean ± std	82.0 ± 16.5	87.0 ± 15.2	71.6 ± 14.3	
min - max	40.2 - 152.4	63 - 152.4	40.2 - 119.3	
Handedness				0.955
Right	150 (89.3%)	101 (89.4%)	49 (89.1%)	
Left	18 (10.7%)	12 (10.6%)	6 (10.9%)	
Injury Year				0.177
2015	8 (4.8%)	5 (4.4%)	3 (5.5%)	
2016	16 (9.5%)	8 (7.1%)	8 (14.5%)	
2017	15 (8.9%)	9 (8%)	6 (10.9%)	
2018	22 (13.1%)	16 (14.2%)	6 (10.9%)	
2019	27 (16.1%)	16 (14.2%)	11 (20%)	
2020	23 (13.7%)	19 (16.8%)	4 (7.3%)	
2021	31 (18.5%)	22 (19.5%)	9 (16.4%)	
2022	26 (15.5%)	18 (15.9%)	8 (14.5%)	
Injury Month				0.155
January	16 (9.5%)	12 (10.6%)	4 (7.3%)	
February	17 (10.1%)	13 (11.5%)	4 (7.3%)	
March	30 (17.9%)	21 (18.6%)	9 (16.4%)	
April	12 (7.1%)	6 (5.3%)	6 (10.9%)	
May	10 (6%)	7 (6.2%)	3 (5.5%)	
June	13 (7.7%)	11 (9.7%)	2 (3.6%)	
July	9 (5.4%)	4 (3.5%)	5 (9.1%)	
August	13 (7.7%)	10 (8.8%)	3 (5.5%)	
September	11 (6.5%)	8 (7.1%)	3 (5.5%)	
October	18 (10.7%)	14 (12.4%)	4 (7.3%)	
November	8 (4.8%)	3 (2.7%)	5 (9.1%)	
December	11 (6.5%)	4 (3.5%)	7 (12.7%)	
Sport				N/A
College Baseball	45 (26.8%)	44 (38.9%)	1 (1.8%)	
High School Baseball	56 (33.3%)	54 (47.8%)	2 (3.6%)	
College Football	2 (1.2%)	2 (1.8%)	0 (0%)	
High School Football	10 (6%)	10 (8.8%)	0 (0%)	
College Softball	18 (10.7%)	0 (0%)	18 (32.7%)	
High School Softball	19 (11.3%)	1 (0.9%)	18 (32.7%)	
College Tennis	1 (0.6%)	1 (0.9%)	0 (0%)	

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Track and Field	2 (1.2%)	1 (0.9%)	1 (1.8%)	
Acrobatics and Tumbling	10 (6%)	0 (0%)	10 (18.2%)	
Volleyball	4 (2.4%)	0 (0%)	4 (7.3%)	
Basketball	1 (0.6%)	0 (0%)	1 (1.8%)	
Position				N/A
Baseball Pitcher	92 (54.8%)	89 (78.8%)	0 (0%)	
Football Offensive Guard	1 (0.6%)	1 (0.9%)	0 (0%)	
Softball Catcher	13 (7.7%)	0 (0%)	13 (23.6%)	
Football Wide Receiver	9 (5.4%)	9 (8%)	0 (0%)	
Softball Pitcher	3 (1.8%)	0 (0%)	6 (11%)	
Softball Infielder	7 (4.2%)	0 (0%)	7 (12.7%)	
Softball Outfielder	13 (7.7%)	0 (0%)	13 (23.6%)	
Baseball Catcher	6 (3.6%)	6 (5.3%)	0 (0%)	
Tennis server	1 (0.6%)	1 (0.9%)	0 (0%)	
Javelin thrower	2 (1.2%)	1 (0.9%)	1 (1.8%)	
Tumbling	10 (6%)	0 (0%)	10 (18.2%)	
Volleyball Server	4 (2.4%)	0 (0%)	4 (7.3%)	
Quarterback	3 (1.8%)	3 (2.7%)	0 (0%)	
Baseball Outfielder	2 (1.2%)	2 (1.8%)	0 (0%)	
Basketball Center	1 (0.6%)	0 (0%)	1 (1.8%)	
Baseball Infielder	1 (0.6%)	1 (0.9%)	0 (0%)	

To date, there are no published works comparing the biomechanical properties of the female UCL to the male UCL. Nonetheless, it is reasonable to think that there may be similarly important sex-specific differences as has been observed in ACL research regarding elasticity, collagen content, and loads to failure.[11,12,16,17] Further, there are known anatomic differences between the male and female upper torso and arms.[28] For example, females typically possess less torso and arm muscle mass and strength, resulting in less muscle torque and less power.[29] Females are also known to have a greater carrying angle at the elbow and more ligamentous laxity.[9] Gardner et al. suggest that injuries to the UCL of female athletes most commonly occur due to chronic microtrauma.[9] In agreement with this work, the present study observed that the majority (71%) of female UCL injuries were chronic in nature. Of note, 74.4% (n=29) of chronic UCL injuries experienced by female athletes presented with no significant MRI findings. It is reasonable to assume that increased ligamentous laxity in the female elbow may be a possible causative factor in UCL incompetence without suggestive MRI imaging. Nonetheless, the reason for UCL injury symptomology without traditional MRI findings is beyond the scope of this study and deserves further attention. The detection of female athletes with UCL injury symptomology but non-significant MRI presentation is important, as clinicians may be missing these injuries due to this lack of traditional MRI presentation, resulting in delayed or undiagnosed female athlete UCL injuries.

The nonoperative management of UCL injuries in female athletes is not well understood. Nicolette and Gravlee observed five Division I collegiate gymnasts who sustained acute UCL injuries resulting from valgus overload to the elbow.[30] Four of these five athletes were able to return to sport 1.5-12 weeks post-injury with nonoperative treatment.[30]

Though this work was limited by a small sample size, it suggests that non-throwing female athletes may respond well to nonoperative management after acute UCL injury. Podesta et al. explored the use of platelet rich plasma (PRP) injections in young athletes with partial UCL tears (28 males and 6 females consisting of 27 baseball players, 3 softball players, 2 tennis players, and 2 volleyball players).[31] After a single PRP injection and rehabilitation, 88% of participating athletes were able to return to play within 12 weeks following their injury. The authors did not report the specific number of female athletes that were able to return to play post PRP injection.[31] Currently, limited data regarding the

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Published online: April 15, 2023

Table 2. Injury characteristics related to onset, imaging, treatment, and outcomes.

Characteristics	*All (n=168)*	*Male (n=113)*	*Female (n=55)*	*p-value*
Injury Onset				<0.001
Acute	122 (72.6%)	106 (93.8%)	16 (29.1%)	
Chronic	46 (27.4%)	7 (6.2%)	39 (70.9%)	
MRI Imaging				<0.001
Grade 1 – low-grade sprain/partial tear	56 (33.3%)	48 (42.5%)	8 (14.5%)	
Grade 2 – moderate/high-grade partial tear	37 (22%)	33 (29.2%)	4 (7.3%)	
Grade 3 – full thickness or undersurface tear	31 (18.5%)	27 (23.9%)	4 (7.3%)	
Intact UCL	44 (26.2%)	5 (4.4%)	39 (70.9%)	
UCL tear location				<0.001
Proximal	64 (38.1%)	48 (42.5%)	6 (9.2%)	
Midsubstance	15 (8.9%)	12 (10.6%)	3 (5.5%)	
Distal	53 (31.5%)	46 (40.7%)	7 (12.7%)	
Thickened (chronic) entire ligament calcified	16 (9.5%)	6 (5.3%)	10 (18.2%)	
No significant findings	30 (17.9%)	1 (< 1%)	29 (52.7%)	
LCL tear				N/A
No associated injury	168 (100%)	113 (100%)	55 (100%)	
Triceps tendon				N/A
No triceps injury	168 (100%)	113 (100%)	55 (100%)	
Biceps tendon				0.250
Any injury (i.e., swelling, edema, etc.)	3 (1.8%)	1 (0.9%)	2 (3.6%)	
No biceps injury	165 (98.2%)	112 (99.1%)	53 (96.4%)	
Common flexor tendon				0.054
Partial	39 (23.2%)	31 (27.4%)	8 (14.5%)	
Complete	1 (0.6%)	1 (0.9%)	0 (0%)	
Any injury (i.e., swelling, edema, etc.)	128 (76.2%)	81 (71.7%)	47 (85.5%)	
No flexor injury				
Common extensor tendon				0.552
Partial	3 (1.8%)	3 (2.7%)	0 (0%)	
No common extensor injury	165 (98.2%)	110 (97.3%)	55 (100%)	
Subchondral fractures				0.086
Partial	2 (1.2%)	2 (1.8%)	0 (0%)	
Complete	4 (2.4%)	4 (3.5%)	0 (0%)	
No subchondral fractures injury	162 (96.4%)	107 (94.7%)	55 (100%)	
Cartilage injury	1 (0.6%)	1 (0.9%)	0 (0%)	
Bony edema	85 (50.6%)	71 (62.8%)	14 (25.5%)	<0.001
Treatment				0.244
Platelet Rich Plasma (PRP)	27 (16.1%)	16 (14.2%)	11 (20%)	
Physical Therapy (PT)	74 (44%)	46 (40.7%)	28 (50.9%)	
NSAIDs	5 (3%)	3 (2.7%)	2 (3.6%)	

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UCL Repair	42 (25%)	31 (27.4%)	11 (20%)	
UCL Reconstruction	20 (11.9%)	17 (15%)	3 (5.5%)	
Symptom Duration (weeks)				<0.001*
Median (Q1, Q3)	3 (1, 8)	2 (1, 4)	20 (4, 52)	
min - max	1 - 104	1 - 50	1 - 104	
Ulnar nerve symptoms	40 (23.8%)	24 (21.2%)	16 (29.1%)	0.262
Return to Play (months)				0.021*
Median (Q1, Q3)	4 (3, 6)	4 (3, 6)	3 (2, 6)	
min - max	2 - 16	2 - 16	2 - 12	

operative management of UCL injuries in female athletes exists. A case report by Grumet et al. detailed a 16 year old female high school gymnast who suffered a bony avulsion of the medial UCL band and was treated with a successful open repair.[21] In a case series, Jones et al. discussed the use of UCL reconstruction via docking technique in 55 adolescent, 4 of which were female athletes.[32] Of all participating athletes, 87% had excellent results using the Conway scale. However, 2 of the 3 female gymnasts had poor outcomes.[32] In a retrospective cohort study, Argo et al. reported on 19 female athletes with UCL insufficiency, of which 42% (n = 8) were softball players, 21% (n = 4) were gymnasts, and 10.5% (n = 2) were tennis players. Following failure of nonoperative treatment for a mean duration of approximately 5 months, operative intervention was performed. Ligament repair versus reconstruction was decided intraoperatively, with 18 of 19 female patients undergoing repair. This preference for UCL repair in female athletes is in stark contrast to the treatment selection for male athletes, for whom surgical intervention most commonly involves UCL reconstruction.[33,34] The present study revealed that close to half of all male athletes were treated with surgical management, whereas only about 14% of female athletes received surgical intervention. Nonetheless, patient outcome data (return to sport, symptom recurrence, etc.) was not collected, so it is difficult to determine whether this sex-specific difference in selected management strategy (operative versus nonoperative) reflects the true percent of successful treatment of male and female UCL injuries.

Historically, UCL injuries have been discussed as a male-specific pathology. The vast majority of current sports performance and clinical literature related to this pathology focuses on overhead throwing athletes, specifically baseball pitchers.[7,35–38] A recent text by Gardner and Bedi reports that only 79 of 1902 (4.2%) patients in UCL studies to date are female, and some studies lacked formal sex comparisons.[9] As such, male-dominated literature may be incorrectly guiding the diagnosis and treatment of female UCL injuries. UCL injuries amongst female athletes have been observed to occur while participating in gymnastics, softball, calf roping, cheerleading, javelin, tennis, baton twirling, judo, swimming, equestrian, alpine skiing, and handball.[10,20,21] The present study demonstrates that UCL injuries are commonly experienced by female athletes and differ in clinical and morphological presentation compared to those in male athletes. Here, we demonstrate that sex-specific differences exist in UCL injury patterns, with female athletes more commonly presenting with UCL injuries resulting from a chronic mechanism compared to the more common acute presentation in male athletes. Female athletes exhibiting UCL injury symptomology were also much more likely to present with non-indicative MRI findings compared to males (males; n = 1, females; n = 29). Furthermore, female athletes were observed to have increased symptom duration (~10 times longer) compared to their male counterparts, possibly indicating that these injuries had been missed or diagnosed in a delayed fashion (median symptom duration; males = 2 weeks, females = 20 weeks). These findings suggest that further exploration of this topic may better inform the care and treatment of both male and female athletes with UCL injuries.

The results of the present study should only be interpreted within the context of the following potential limitations. This was a retrospective study with limited sample size, lacked direct physical examination, and did not observe patient outcomes after management. The exact anatomical location of bony edema was not reported, which may have provided greater insight into specific onset of injury. Pertaining to onset of injury, the research team was unable to account for 'acute on chronic' injuries. Finally, this study lacked a formal review of 1.5 T with arthrogram and 3 T non-contrast with surface coil MRI studies by radiologists. Instead, the research team collected data from preexisting radiologist reports and clinical/surgical notes.

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Table 3. Generalized linear model results for return to play and duration of symptoms.

	Duration of Symptoms		*Return to Play*	
	Relative Risk of increased time (95% CI)	*p*-value	Relative Risk of increased time (95% CI)	*p*-value
Male vs. Female	0.80 (0.53, 1.23)	0.312	1.24 (0.94, 1.63)	0.133
Age	1.07 (1.00, 1.14)	**0.046**	1.06 (1.02, 1.10)	**0.007**
Weight	0.99 (0.98, 1.00)	**0.004**	1.00 (0.99, 1.01)	0.986
Acute vs. Chronic Injury	7.57 (5.18, 11.08)	**<0.001**	1.07 (0.82, 1.42)	0.608
Tear Location (all vs. no tear)	1.00 (0.86, 1.17)	0.984		
Proximal	0.96 (0.55, 1.69)	0.893	1.30 (0.95, 1.79)	0.099
Midsubstance	0.8 (0.42, 1.54)	0.505	1.94 (1.36, 2.76)	**<0.001**
Distal	0.99 (0.56, 1.76)	0.980	1.38 (1.01, 1.90)	**0.045**
Thickened entire ligament calcified	1.15 (0.72, 1.82)	0.561	2.42 (1.79, 3.28)	**<0.001**
Bony Edema (yes vs no)	1.05 (0.80, 1.39)	0.717	1.05 (0.88, 1.25)	0.588

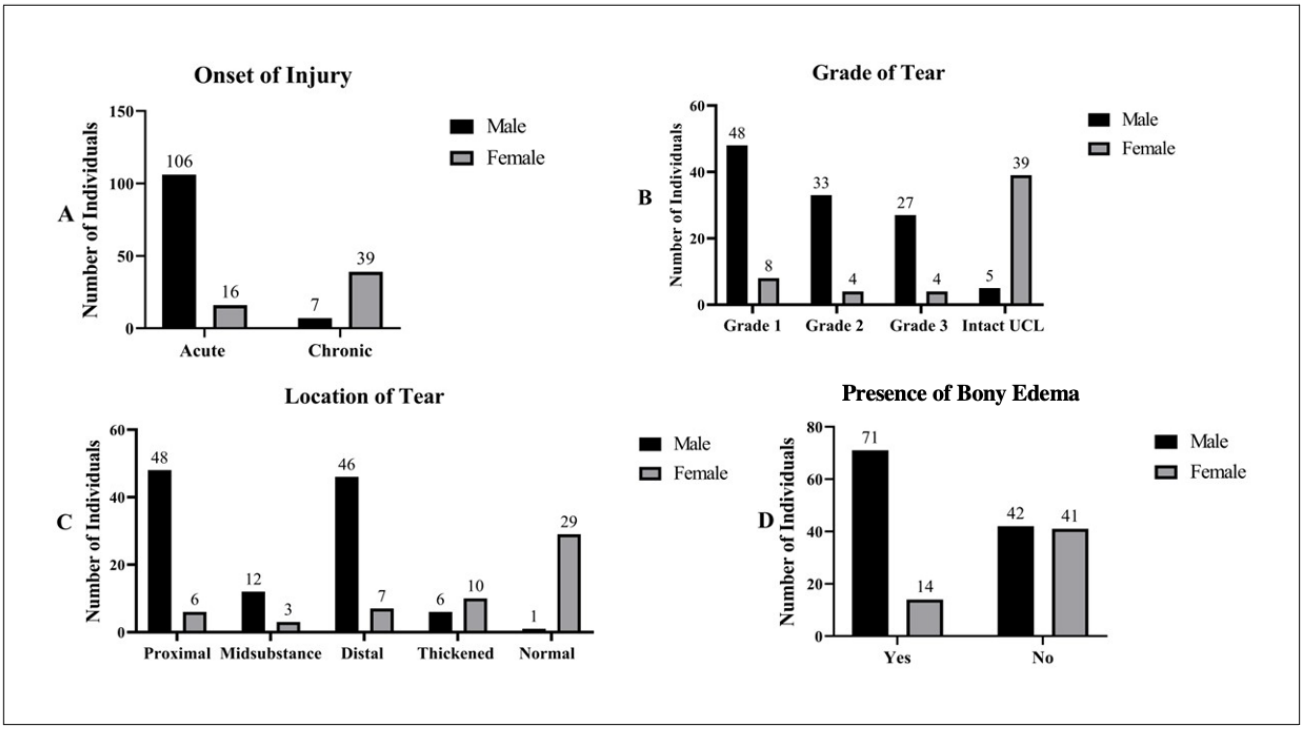

Figure 2. Distribution of A) onset of UCL injury, B) grade of UCL tear, C) location of UCL tear, and D) presence or absence of bony edema.

DOI: 10.53646/jwsm. v3ii.33
Published online: April 15, 2023

CONCLUSION

The present study demonstrates that sex-specific differences exist in UCL injury patterns, such as onset of UCL injury, injury grade, and tear location. We also found that MRI findings, symptom duration, and management strategies differed between male and female athletes. Female athletes more commonly presented with chronic UCL injuries, many of which displayed no significant findings on MRI imaging. The results of this study suggest that sex-specific differences in UCL injury occurrence and presentation exist. Further research is needed to better inform the care and treatment of UCL injuries in both male and female athletes.

Conflict of Interest Statement

The authors report no conflict of interest with the contents of this manuscript.

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DOI: 10.53646/jwsm.v3i1.33
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DOI: 10.53646/jwsm.v3i1.33
Published online: April 15, 2023