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Seasonal and monthly trends in elbow ulnar collateral ligament injuries and surgeries: a national epidemiological study

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Background: Monthly incidence of elbow ulnar collateral ligament (UCL) injuries and surgeries is relatively unknown. Defining seasonal peaks of UCL injuries and surgeries may identify opportunities for injury-prevention strategies. The purpose of this study is to analyze seasonal and monthly variations in UCL injuries and surgeries across the United States with emphasis on the timing of baseball season.

Methods: The Truven Health MarketScan database (2013-2015) was queried for patients younger than 40 years with a diagnosis code of elbow UCL sprain and a procedural code for UCL repair or reconstruction. Differences in patient characteristics were evaluated using chi-square and Mann-Whitney U-tests. Negative binomial regression models were calculated for UCL injuries and surgeries to assess monthly trends.

Results: UCL injuries were sustained by 13,894 patients, with 1404 (10.1%) patients having undergone surgery. The median age at first diagnosis was 17 years, and the median age of patients requiring surgery decreased from 20 to 18 years from 2013 to 2015 ($P = .75$). Most UCL injuries (n = 3785) and surgeries (n = 438) occurred during the spring season (March 21-June 20), and spring injuries were most likely to result in surgical management (11.6%). During the baseball season (March to September), the number of UCL injuries peaked in April/May, then declined, except for a second peak in September/October (incidence rate ratio 0.97; confidence interval 0.95, 0.99; $P = .01$). The number of UCL surgeries steadily increased from March (n = 116) to June (n = 152), followed by a gradual decline (incidence rate ratio 1.00; confidence interval 0.96, 1.04; $P = .99$).

Conclusion: Athletes frequently experienced UCL injuries and surgeries in the early months (April-June) of the baseball season. More emphasis should be paid to rehabilitative strategies at the beginning of a baseball season to help mitigate injury risk.

The incidence of elbow ulnar collateral ligament (UCL) injuries in overhead athletes continues to rise at a dramatic rate at every level of competition.[2,6,9,12,16,20,21,24,27] Subsequently, more patients are undergoing surgical intervention with the goal of returning to high-level, competitive throwing.[12,16,21] The increasing rate of UCL injuries and surgeries has sparked an interest in UCL-related research, including epidemiology,[12,16,19] risk factors for injury,[5,8,25,28] modifications of operative techniques,[7,26] analysis of return to play,[1,15,22,23] and results after revision UCL reconstruction (UCL-R).[3,30,31] Understanding the epidemiology of UCL injuries is especially important for overhead athletes of all ages and their treating physicians as it may inform demand for surgical care and injury-prevention strategies.

The epidemiology of UCL injuries has been well described on both a local and national level throughout various levels of competition. Zaremski et al[32] analyzed UCL injuries in high school

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and collegiate athletes and found a 9-fold increased rate of nonsurgical cases of UCL injury between 2009 and 2016. Rothermich et al[27] analyzed the incidence of UCL injuries in 155 Division I collegiate baseball programs during the 2017 season and found that 2.5% of all eligible athletes underwent UCL-R. Nearly half (48.5%) were performed during the baseball season, and pitchers were nearly 6 times more likely to undergo UCL-R than nonpitching athletes. UCL injuries are similarly increasing in professional baseball players as 13% of all Major League Baseball (MLB) players have had UCL-R at some point in their career, while 25% of MLB pitchers and 15% of minor league pitchers have already undergone UCL-R.[6,19]

While annual trends in UCL injuries have been thoroughly studied, we are unaware of any epidemiological study specifically focusing on monthly variations in UCL injuries and surgeries. Such information may offer valuable insight into why certain risk factors may place an athlete at risk for UCL injury. Knowing when athletes are most at risk for UCL injury is a crucial step in risk factor modification through adequately timed injury-prevention strategies. Therefore, the present study analyzed seasonal and monthly variations in UCL injuries and surgeries across the United States using a national medical claims database. We hypothesized that there would be significant monthly variations in both UCL injuries and surgeries with a disproportionate amount of injuries occurring at the beginning (ie, March and April) and at the end (ie, August and September) of the baseball season.

Materials and methods

Study design and patient selection

Approval for this retrospective database study was obtained from the institutional review board of our institution (IRB# 2017-0169-CR4). The Truven Health MarketScan database (Copyright © 2017 Truven Health Analytics Inc. All Rights Reserved; access to the Truven data set was limited to employees of the Hospital for Special Surgery) was queried for patients with a diagnosis code for an elbow UCL sprain (*International Classification of Diseases* 9th revision code 841.1 or 10th revision code S53.44) from 2013 to 2015. The MarketScan database contains the largest convenience sample of privately insured patients in the United States with deidentified records for more than 230 million patients. It consists of longitudinal claims data including detailed demographic, diagnosis, and procedure information from both inpatient and outpatient visits. Patients who sustained a UCL injury and later underwent surgical management were identified based on Common Procedural Terminology codes 24345 (elbow UCL repair) and 24346 (elbow UCL-R).

Exclusion criteria included 1) age of patients over 40 years, as a UCL injury is less likely to occur during sports participation at this age, and we desired to investigate UCL injury and surgical patterns in a young, athletic cohort; and 2) patients with more than one UCL repair or reconstruction code to maintain a homogenous population of patients undergoing primary UCL surgery.

Statistical analysis

Patterns in both UCL injury and subsequent surgery were assessed by year, season (winter: December 21-March 20, spring: March 21-June 20, summer: June 21-September 20, fall: September 21-December 20), and calendar month. Additional variables of interest included patient age (categorized as <20 years, 20-30 years, and 30-40 years), gender, and laterality of surgery. Laterality of surgery was identified based on Common Procedural Terminology modifiers (right: RT, left: LT, or unknown if no modifier was reported).

Table I
Demographic characteristics and seasonal trends.

Characteristics	UCL injuries		Surgical cases		Injuries treated surgically
	N	%	N	%	%
Total	13,894	100.0	1404	100.0	10.1
Age, yr					
<20 yr	8971	64.6	932	66.4	10.4
20-30 yr	2847	20.5	406	28.9	14.3
30-40 yr	2076	14.9	66	4.7	3.2
Sex					
Male	10,030	72.2	1208	86.	12.0
Female	3864	27.8	196	14.	5.1
Laterality					
Right	-	-	627	44.6	-
Left	-	-	213	15.2	-
Unknown	-	-	564	40.2	-
Season					
Winter	3567	25.7	295	21.	8.3
Spring	3785	27.2	438	31.2	11.6
Summer	3308	23.8	355	25.3	10.7
Fall	3234	23.3	316	22.5	9.8

Descriptive summaries of all study variables were generated separately for UCL injury and UCL surgery, with categorical variables reported as frequencies (%). Annual patterns in the age and gender of the patient populations were assessed. In these analyses, age was treated as continuous and reported as median values with interquartile range (IQR). Differences in patient characteristics over time were evaluated using chi-square tests for categorical variables and Mann-Whitney U-tests for continuous variables.

Negative binomial regression models were run separately for UCL injuries and subsequent surgeries with calendar month as the sole predictor to assess for significant trends in the number of injuries and surgeries throughout the calendar year. Negative binomial models were used rather than traditional Poisson regression to account for overdispersion. Results are reported as incidence rate ratios (IRRs) and their corresponding 95% confidence intervals (CIs). Results with a P value $< .05$ were considered statistically significant. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 13,894 patients met inclusion criteria and were found to have a diagnosis of UCL injury. Most injuries (64.6%) occurred in patients aged <20 years, followed by patients aged 20-30 years (20.5%), and patients aged 30-40 years (14.9%). The median age at first diagnosis was 17 years (IQR 15-22 years), and this remained the same for each year of the study period despite minor fluctuations ($P < .01$). Male patients consistently comprised the majority of cases during the study period (72.4%; $P = .15$).

The total annual number of diagnosed UCL injuries varied over the 3-year period; however, the percentage of cases leading to surgical intervention with regard to the total annual case number remained markedly consistent (Table I). Among all patients with UCL injury, 1472 patients underwent a subsequent UCL surgery. Of these, 68 patients were excluded because they had multiple UCL procedure codes, resulting in a final surgical cohort of 1404 patients (10.1%). Most cases occurred in patients aged <20 years (66.4%), followed by those aged 20-30 years (28.9%), and those aged 30-40 years (4.1%). The median age of patients undergoing surgery decreased from 20 years (IQR 18-23) in 2013 to 18 years (IQR 17-20) in 2015, although this change did not reach significance ($P = .75$). Most surgical patients were male (82.9%; $P = .21$). Most of the cases

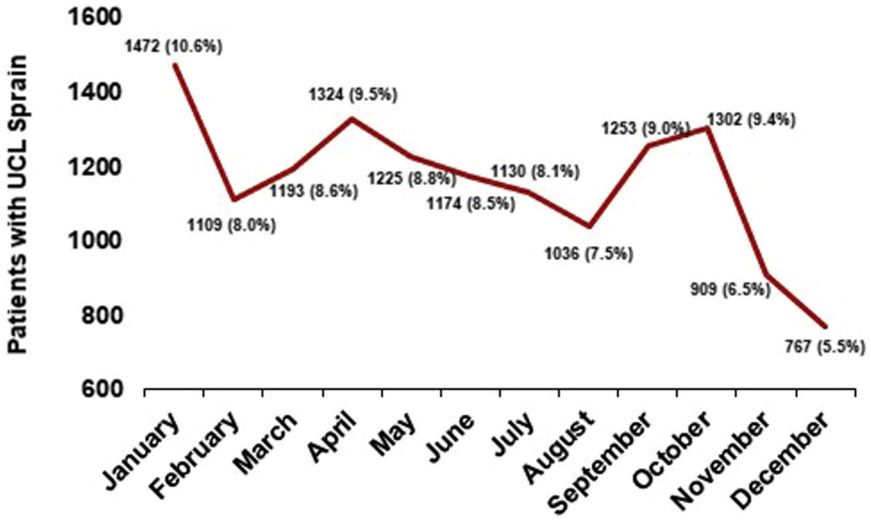

Figure 1 Number of patients per month diagnosed with UCL sprain (with percentage of total patients). *UCL*, ulnar collateral ligament.

occurred on the right extremity (44.7%), but many cases (40.2%) also did not include a laterality modifier (Table I).

Most UCL injuries (n = 3785; 27.2%) and surgeries (n = 438; 31.2%) occurred during the spring season. The winter season had the second most number of UCL injuries (n = 3567; 25.7%), followed by the summer (n = 3308; 23.8%) and fall (n = 3234; 23.3%). After the spring season, UCL surgeries were most commonly performed in the summer (n = 355; 25.3%), followed by the fall (n = 316; 22.5%) and the winter (n = 295; 21.0%). UCL injuries during the spring were most likely to result in operative management (11.6% of injuries), followed by injuries in the summer (10.7%) (Table I).

UCL injuries were most commonly reported in January (n = 1472), April (n = 1324), October (n = 1302 injuries), September (n = 1253 injuries), and May (n = 1225) (Fig. 1). To avoid variation due to the relatively small caseload of a single year, these 5 most common months for diagnosis were determined on average over the 3-year study period. The number of UCL injuries sustained decreased significantly throughout the calendar year (IRR 0.97; CI 0.95, 0.99; $P = .01$). During the typical baseball season (ie, March to September), the number of UCL injuries peaked in April and May and then declined until a second peak in September and October. The 2 peak periods of diagnosis for UCL injuries were consistent for each year in the study period (Fig. 2). The amount of UCL surgeries steadily increased in March (n = 116) and April (n = 140) and peaked in May (n = 149) and June (n = 152), followed by a steady decline for the rest of the months (Fig. 3). While there were fluctuations in the number of surgeries throughout the calendar year, there was no significant trend observed when considering the monthly averages for the entire study period (IRR 1.00; CI 0.96, 1.04; $P = .99$).

Discussion

In this study using nationwide claims data, the most important finding is that UCL injuries occurred most frequently at the start (ie, April and May) and end (ie, September and October) of a typical baseball season. In addition, UCL surgery is most frequently performed in the first half of the baseball season (April-June), followed by a declining trend throughout the rest of the year. UCL injuries and surgeries occurred most frequently in male athletes aged <20 years. The median age of patients undergoing UCL surgery decreased from 20 to 18 years during the study period; however, this trend did not reach statistical significance.

Regardless, it is a worrisome trend that UCL injuries and surgeries are affecting younger patients, and this finding is consistent with previous epidemiologic studies. For example, Erickson et al performed a national database study and reported that UCL-R is performed most frequently and at the fastest growing rate in patients aged 15-19 years.[12] Similarly, Hodgins et al[16] reported a yearly increase in the number of UCL-Rs in New York State between 2002 and 2011 with an overall surgical volume increase by 193% during the study period. The observed trend was significantly increased in patients between the ages of 17-20 years, suggesting that UCL injuries are especially prevalent in late adolescent athletes.

The currently reported epidemiologic trends are an important step in understanding seasonal risk factors for UCL injuries. Our results show that UCL injuries demonstrated a bimodal peak during the baseball season with the fewest injuries during the offseason months of November and December, which are the most common months for baseball players to refrain from throwing. Surprisingly, UCL injuries were diagnosed most commonly in the month of January, which is an important finding because this is when most overhead athletes start a throwing program to prepare for the upcoming spring season. January also had the least number of surgical cases, suggesting that these injuries are less likely to lead to operative management. Regardless, knowing that athletes are at potential increased risk for UCL injuries during this time is important for injury-prevention strategies because more gradual return to throwing programs may be merited, especially in youth athletes.

During a typical baseball season, UCL injuries revealed a bimodal peak at the beginning and the end of the season. The peak at the end of the season is likely explained by eventual breakdown after a full baseball season. This is especially true for youth athletes who play on multiple teams and ignore pitch count recommendations.[11,13,18] The peak of UCL injuries and the rise in UCL surgeries during the early spring months is an especially notable trend. In fact, UCL injuries reported during the spring months most frequently resulted in surgical management compared to injuries sustained during the other seasons. This is consistent with our anecdotal experience that most UCL surgeries occur during the early months of the baseball season before declining throughout the late summer and early fall months. There are multiple possible explanations for this early season surgical peak.

It is possible that some athletes sustained a UCL injury at the end of the previous season and were either misdiagnosed and/or

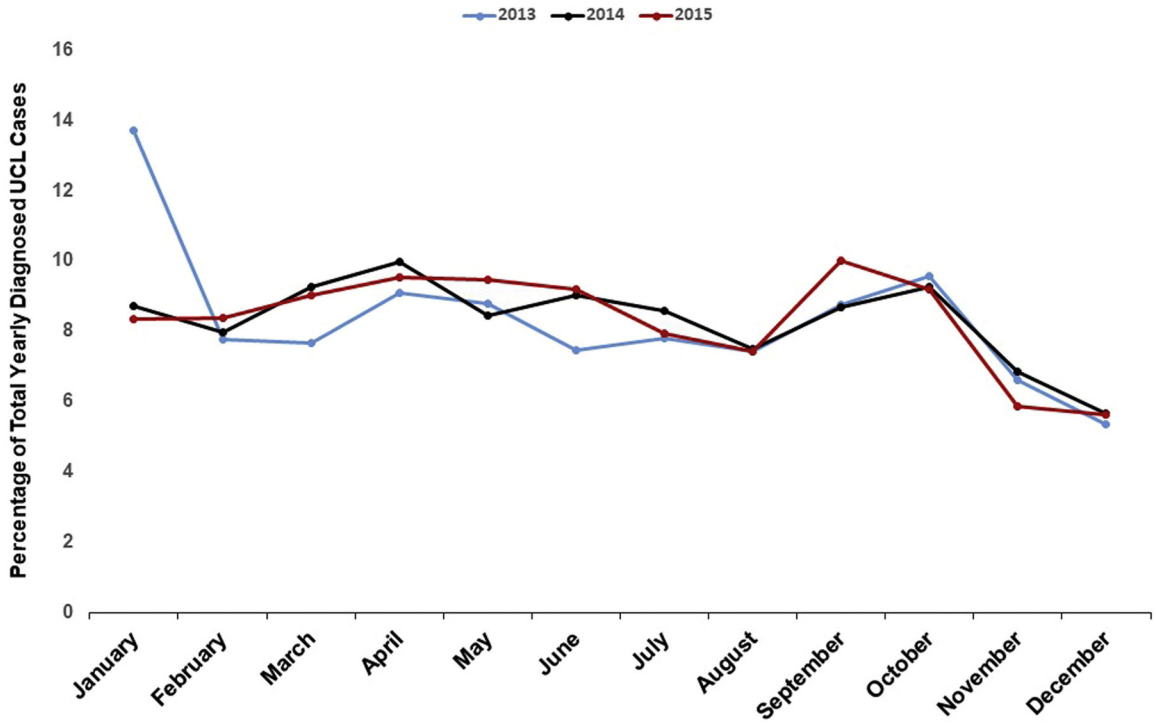

Figure 2 Percent of annual UCL diagnoses per month from 2013 to 2015.

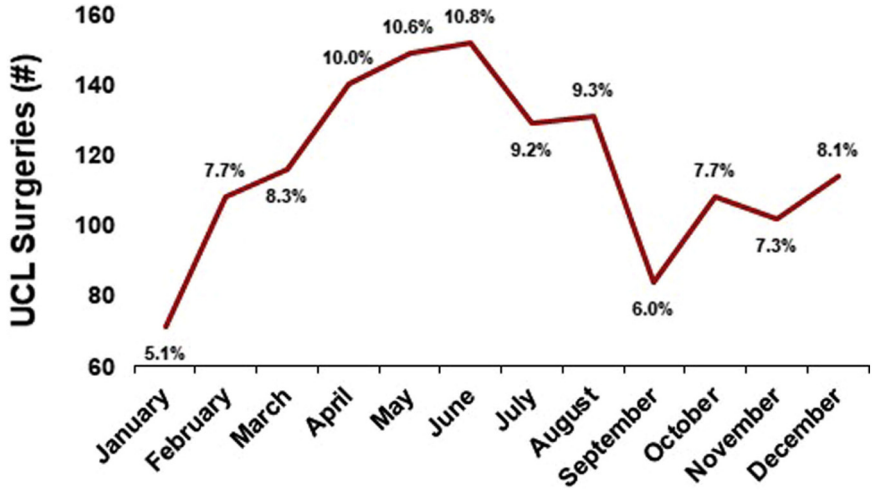

Figure 3 Average number of patients undergoing UCL-R per month (with percentage of total patients). *UCL-R*, ulnar collateral ligament reconstruction.

mismanaged during the offseason. A return to overhead throwing activities the following spring may result in continued medial elbow pain, eventually leading to surgical management of the UCL injury. Unfortunately, this is not an uncommon clinical vignette that we see in our practice, and it presents physicians with a learning opportunity to ensure that valuable rehabilitation time is not wasted during an offseason if a patient has a complete UCL tear or has already failed nonoperative management with a high-grade partial tear at the end of a baseball season. Alternatively, athletes may be less likely to seek medical attention for a UCL injury at the end of a baseball season because they have the luxury of resting during the offseason and missing time from competition is not at stake. Conversely, athletes may be more likely to seek medical care for a UCL injury in the spring than during other times because they do not have the luxury of an impending offseason while they remain unable to return to competition. It is also possible that UCL injuries occurring in the spring months are more severe as athletes are returning to high levels of throwing after the offseason.

Another possible explanation for the early season injury and surgical spike is that there may be unique risk factors for UCL injury during the spring season. For example, some throwing athletes may have increased risk for an elbow injury at the start of the season because they have not attained midseason levels of muscle strength and endurance, yet they are still throwing at increasing volume and intensity as they prepare for the upcoming season. In addition, multiple studies have confirmed decreased shoulder external rotation and total arc of motion in pitchers at the beginning of the season compared to the end of the season.[5,10,14] Decreased shoulder

range of motion in the form of glenohumeral rotation internal deficit and total arc of motion has been shown to be a risk factor for elbow injury.[4,17,29] Therefore, inadequate shoulder range of motion at the start of the season may contribute to the early season surgical spike.

We believe that early season decreased range of motion may be a strong contributor to the early season spike of UCL injuries and subsequent surgeries. Regardless, maintaining end-of-season range of motion values in the shoulder should be an important point of emphasis in the off-season and preseason training programs for overhead athletes, especially pitchers. We advocate that a pitcher should not progress to a full season's workload until any shoulder range of motion deficits developed in the offseason are appropriately resolved. Along these lines, adopting stricter pitch count regulations at the beginning of the season is another injury-prevention strategy that should be considered.

Strengths and limitations

There are a few notable strengths of the present study. The use of a national database allowed for a large study population comprised of patients located throughout the United States. This reduces possible selection and regional biases, which is especially important as UCL injuries and surgeries are less common than other sports injuries, such as anterior cruciate ligament tears or shoulder instability. Breaking down UCL injuries by months of the year is another key strength because this is the first known study to analyze this aspect of UCL injury and surgery epidemiology. Our findings provide unique insight into seasonal and monthly variations in UCL injuries, which can help establish the foundation for future studies attempting to investigate modifiable risk factors for injury with seasonal variations.

The present study also has multiple limitations that must be mentioned. First, similar to all database studies, the available data are reliant upon accurate coding. Then, the cause of the UCL sprain or reason for UCL surgery cannot be ascertained in the database. It is possible that some of the injuries or surgeries resulted from reasons other than injuries during overhead sports participation, such as trauma from a collision or contact sport or general trauma unrelated to a sport. However, UCL injury and surgery is a relatively unique entity for throwing athletes. Therefore, we would expect any subset of UCL injuries or UCL surgeries that were not from overhead throwing injuries to be very small. The level of play (ie, high school, collegiate, professional, or recreational) was not known, so specific patterns about a certain level of athletes cannot be ascertained. It is possible that seasonal and monthly variations are different across different levels of competition, and further research is needed to address this possibility. Finally, it is impossible to account for athletes who may have suffered a UCL injury but did not seek medical care, which would potentially alter the number of UCL injuries and possibly alter any observed trends.

Conclusion

The monthly incidences of UCL injuries revealed a bimodal peak in the early and late months of the baseball season. UCL injuries that occurred during the spring were most likely to result in surgical management, and the overall amount of UCL surgeries was highest during the spring months (ie, March through June). Our findings provide a foundation for future studies to investigate seasonal variations and modifiable risk factors for UCL injury and surgery. Offseason and preseason training programs should be evaluated and modified to account for this early season spike in UCL injuries and surgeries so athletes can participate in a full baseball season with minimal injury risk.

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