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Descriptive Epidemiology of Injuries in Professional Ultimate Frisbee Athletes

Matthew C. Hess, MD*; David I. Swedler, PhD, MPH†; Christine S. Collins, MEd*; Brent A. Ponce, MD*; Eugene W. Brabston, MD*

*School of Medicine, Department of Orthopaedic Surgery, University of Alabama at Birmingham; †Pacific Institute for Research and Evaluation, Calverton, MD

Context: Injuries in professional ultimate Frisbee (ultimate) athletes have never been described.

Objective: To determine injury rates, profiles, and associated factors using the first injury-surveillance program for professional ultimate.

Design: Descriptive epidemiology study.

Setting: American Ultimate Disc League professional ultimate teams during the 2017 season.

Patients or Other Participants: Sixteen all-male teams.

Main Outcome Measure(s): Injury incidence rates (IRs) were calculated as injuries per 1000 athlete-exposures (AEs). Incidence rate ratios were determined to compare IRs with 95% confidence intervals, which were used to calculate differences.

Results: We observed 299 injuries over 8963 AEs for a total IR of 33.36 per 1000 AEs. Most injuries affected the lower extremity (72%). The most common injuries were thigh-muscle strains (12.7%) and ankle-ligament sprains (11.4%). Running was the most frequent injury mechanism (32%). Twenty-nine percent of injuries involved collisions; however, the concussion rate was low (IR = 0.22 per 1000 AEs). Injuries were more likely to occur during competition and in the second half of games. An artificial turf playing surface did not affect overall injury rates (Mantel-Haenszel incidence rate ratio = 1.28; 95% confidence interval = 0.99, 1.67).

Conclusions: To our knowledge, this is the first epidemiologic study of professional ultimate injuries. Injury rates were comparable with those of similar collegiate- and professional-level sports.

Key Words: injury surveillance, American Ultimate Disc League, flying disc, AUDL-ISP, athletic injuries

Key Points

- The American Ultimate Disc League Injury Surveillance Program is the first multiseason injury-surveillance program in ultimate.
- Using the American Ultimate Disc League Injury Surveillance Program, we established injury rates for professional ultimate athletes.
- Relatively minor lower extremity injuries, such as muscle strains and ankle sprains, were the most common injuries, but nearly half of all injuries resulted in time loss from participation.
- The epidemiologic data from this study can serve as baseline data for future injury interventions, training procedures, and potential rule changes by teams or the league.

Ultimate Frisbee, which is also known as *ultimate*, has grown since its founding in New Jersey in 1968 to gaining full recognition by the International Olympic Committee in 2015.[1,2] Already a popular medal event at the World Games for nearly 2 decades, ultimate is played around the world by an estimated 7 million men and women of all ages.[2] In the United States, male and female athletes compete at organized youth, collegiate, and club levels.[3] Since 2012, athletes have been competing on the professional level as part of the American Ultimate Disc League (AUDL), which comprises 24 teams across the United States and Canada.[1]

Designated to be a noncontact or limited-contact sport, ultimate involves a full range of athletic motions in a blend of endurance sprinting, cutting, pivoting, jumping, throwing, and even diving headfirst to catch with an outstretched hand (layout).[2,4] Athletes often jump in groups, layout side by side, and unintentionally collide with one another. All contact that is not incidental to game play is considered a *foul*. The sport, with 7-player teams competing on a field roughly the size of an American football field, is commonly likened to a cross among football, basketball, and soccer.

Whereas ultimate is a popular sport that shares athletic motions with other common sports and, thus, also shares many potential risk factors for injury, research[5] concerning its injury patterns and characteristics is limited. Yen et al[6] tracked injuries at the 2007 Ultimate Players Association College Championships and showed that more than 50% of men's injuries were due to interathlete contact and more than 50% of all injuries affected the lower extremity. In a retrospective, longitudinal study of a single collegiate club sport program, Akinbola et al[7] found that ultimate accounted for one-third of injuries across all sports, with injury trends similar to those reported in many National Collegiate Athletic Association (NCAA) sports. Swedler et al[8] conducted the most comprehensive injury-surveillance study of ultimate, tracking more than 100 men's and women's collegiate teams throughout a season, and were the first to determine injury rates in the sport. These studies have shown the relatively high injury rate of ultimate athletes but have lacked the continuous injury surveillance that is needed to develop robust data. A professional ultimate league offers the potential for increased infrastructure for injury surveillance.

From 2012 to 2015, professional ultimate did not have a systematic, continuous injury-tracking system similar to the systems used by NCAA sports and professional leagues[9] despite the potential benefits of injury databases, including allowing researchers to determine injury patterns, influence potential rule changes, and study methods to decrease injuries.[10–12] To realize these same benefits for ultimate, we partnered with the AUDL to establish an injury-surveillance program (AUDL-ISP) in 2016. Therefore, the purpose of our study was to use the AUDL-ISP to establish injury rates for professional ultimate athletes; characterize those injuries by mechanism, location, and type; and identify possible risk factors for injury. We report 1 complete season of prospectively captured injury data among professional ultimate players.

METHODS

The AUDL-ISP was founded as a partnership between the AUDL and the University of Alabama at Birmingham. It is based on the system used during the previous investigation of injuries in collegiate ultimate and incorporates definitions and methods from the NCAA Injury Surveillance Program (NCAA-ISP).[8,13] A pilot study of 7 teams was conducted during the 2016 season. Lessons learned during the pilot study (eg, inconsistent times for data entry, incomplete understanding of injury definitions, loss to follow up) and participant feedback informed the procedures for the AUDL-ISP during the 2017 season. In this study, we report in detail on the injuries that occurred throughout the 2017 AUDL season, referencing major comparable results from the 2016 season when relevant.

Data Collection

The AUDL teams and volunteers were recruited to serve as the representatives responsible for communicating with the research team and recording injury data. The league encouraged but did not require all AUDL teams to participate in the AUDL-ISP. Given that all AUDL teams are required to have an athletic trainer (AT) present at competitions but not all practices, the AT was recruited to be the team representative when possible. Regardless of their previous medical knowledge, team representatives during the preseason were trained and tested on the AUDL-ISP, including injury definitions and diagnoses. Sixty-three percent (n = 10) of team representatives were ATs or medically trained. The other 37% (n = 6) were either team staff or athletes.

Throughout the preseason, regular season, and postseason, a weekly e-mail was sent on Sunday nights to all team representatives with a link to a secure, Web-based survey created using the REDCap (Research Electronic Data Capture, Nashville, TN) electronic data-capture tool hosted at the senior author's academic institution.[14] All data were housed and analyzed external to the league to minimize potential interference. Preseason data were captured but removed from the final analysis due to inconsistent entries across teams. To ensure completeness of the data and minimize recall bias, reminders were e-mailed to team representatives if data entry was not completed within 48 hours.

The electronic survey tool captured each team's competition and practice information, number of participating athletes, and injury information from the previous week. Data collected on each injury included (1) whether an injury occurred during a competition or practice, (2) the mechanism of injury, (3) the anatomic location of the injury, (4) the injury determination, (5) the injury type, and (6) other associated factors. We used *injury determination* rather than *injury diagnosis*, as discussed in a previous study.[8] The electronic format of the survey tool provided for completeness of data while the research team monitored weekly data entry and remained in contact with team representatives throughout the season to answer questions. Injury data were not associated with any identified athlete. The University of Alabama at Birmingham Institutional Review Board deemed analysis of this database exempt from review.

Definitions

Injury. A reportable *injury* in the AUDL-ISP was defined as physical harm that happened while the player was participating in an AUDL competition or practice and caused the player to miss part of a competition or practice.[8] We collected additional injury data used by the NCAA-ISP,[13] including (1) *time loss* (ie, whether the injury restricted an athlete's participation for 1 or more days beyond the day of injury) and (2) whether medical attention was required onsite. If a day off from competition or practice followed the injury event, the AT or trained staff was instructed to determine whether the injured athlete would have been able to participate. The need for medical attention was a binary variable and determined by the athlete who sustained the injury. If he saw the AT or other available medical personnel for care of the injury at any point, the injury was recorded as requiring medical attention.

Athlete-Exposure. One *athlete-exposure* (AE) was defined as 1 athlete participating in 1 competition (played at least 1 point) or 1 practice, regardless of the time associated with participation.

Athlete Position. *Athlete position* was defined as the position at which an athlete was playing when the injury occurred during official gameplay for a competition or scrimmaging during practice. The categories were *offense-cutter*, *offense-handler*, *defense-handler coverage*, *defense-cutter coverage*, and *nongame-play situation*. We included nongame-play situation as a category because competitions and practices include time for warming up, conditioning, or practicing drills in which athletes are susceptible to injury but not participating in well-defined positions. For example, if an athlete was injured while his team was on offense and he was playing in the cutter role, offense and cutter were selected. If an athlete was injured while making a sharp cut in a warmup drill, the injury was classified as a nongame-play situation. An athlete acting as a handler primarily throws the disc and makes smaller cuts in the backfield. An athlete acting as a cutter primarily receives the disc and makes longer cuts downfield away from the disc. Each team typically has 2 to 3 handlers and 4 to 5 cutters per point.

Injury Type. Team representatives identified whether an injury was a first injury, reinjury (recurrence), exacerbation, or of unsure origin. Based on the literature, no simple solutions existed to categorize injuries that happened at the same location as a previous injury. Using the injury definitions from recent epidemiologic literature,[15–18] the definitions were as follows.

A *first injury* was defined as an injury meeting any of the following criteria: (1) first time an injury occurred at a given location, regardless of the mechanism of injury and determination; (2) first time a given injury was determined at the involved location; or (3) an injury occurred at this location previously, but the present injury had a completely novel mechanism.

A *reinjury (recurrence)* was defined as an acute onset or overuse injury at the location of a previous injury when either (1) six or more weeks had elapsed since the previous injury or (2) the athlete stated he had fully recovered from the previous injury and no evidence of lingering injury existed.

An *exacerbation* was defined as an acute-onset or overuse injury at the location of a previous injury when either (1) less than 6 weeks had elapsed since the previous injury or (2) the athlete stated he had not fully recovered from the previous injury or evidence of lingering injury existed.

Team representatives were instructed to respond *unsure of injury origin* if they were not confident that a given injury fit neatly into 1 of the other categories.

Statistical Analysis

Data were exported and downloaded from the REDCap database, cleaned, ordered, and analyzed in Microsoft Excel for Mac 2011 (version 14.7.2; Microsoft Corp, Redmond, WA). Some statistical analysis was performed in Stata/SE (version 15.0; Stata Corp, College Station, TX). Injury incidence rates (IRs) were calculated as the number of injuries per 1000 AEs.[9,13] Our main IR calculation used the broad definition of injury. Additional IRs were calculated for overall injuries, injuries in competition, and injuries in practice. For overall injuries examined by mechanism, location, and determination, we calculated the percentage of total injuries to demonstrate the overall distribution of injury patterns. Incidence rate ratios (IRRs) were used to compare IRs across risk factors. We used the Mantel-Haenszel stratification for playing surface. We set the α level at .05 and calculated 95% confidence intervals (CIs); ranges that did not include a value of 1 were considered different.

RESULTS

All 24 AUDL teams in the 2017 season were contacted, and 19 teams expressed interest in participating. Of those teams, 2 were lost to follow up, and 1 was excluded due to inconsistent weekly participation. The 16 all-male teams included in the analysis were geographically distributed across the United States and Canada, with 6 in the East Division, 4 in the South Division, 3 in the Midwest Division, and 3 in the West Division. They participated in 239 games and 207 practices. Three teams did not record practice information. The average weekly survey-completion rate across the 16 teams was 97%.

Injury Rates

Using our definition of injury, we observed a total of 299 injuries across 8963 AEs for an IR of 33.36 per 1000 AEs (Table 1). Injuries were more than twice as likely to occur during competitions as during practices (IRR = 2.25; 95% CI = 1.95, 2.58). The 2017 IR and increased rate during competition were both similar to pilot findings from the 2016 season (26.47 [95% CI = 21.81, 32.12] and 6.43 [95% CI = 3.53, 11.71], respectively). Most injuries required the services of an AT (n = 238; 79.6%), and about half (n = 144; 48.2%) resulted in an athlete missing 1 or more days of participation. The majority of all injuries captured (n = 205; 68.6%) were first-time injuries (IRR for first versus all other occurrence = 2.18; 95% CI = 1.89, 2.50). Injury recurrences and exacerbations composed 13.4% (n = 40) and 17.1% (n = 51) of injury types, respectively. For each injury, team representatives were also instructed to answer *yes* or *no* to the question: "Was this injury evaluated by a physician offsite/is it planned to be? (eg, see a physician later, get imaging or further workup)." They answered *no* for most injuries (78.6%, n = 235).

Mechanism of Injury

Running was the most common mechanism of injury (n = 97; 32%), and the rates of running injuries during competitions and practices were similar (Table 2). Layout-related injuries composed 20% (n = 60) of all injuries and occurred nearly 4 times as often during competitions as during practices (IRR = 3.92; 95% CI = 2.89, 5.19). Almost one-third of injuries involved interathlete collisions (29%); collision injuries occurred more than 4 times as frequently during competitions as during practices (IRR = 4.21; 95% CI = 3.25, 5.35). The 2016 season showed a similar trend: running injuries were the most common collision injuries, accounting for a relatively large portion of injuries.

Injury Location

Most injuries involved the lower extremity (72%), consistent with the pilot data (Figure 1). The most often injured locations were the ankle (19%, n = 58), thigh (17%, n = 50), and knee (14%, n = 42). Among all injuries, those affecting the right side (50%, n = 149) did not occur more often than those affecting the left side (40%, n = 121; IRR = 1.23; 95% CI = 0.97, 1.56). However, among upper extremity injuries, those affecting the right side were more frequent than those affecting the left side (IRR = 2.13; 95% CI = 1.17, 3.85).

Injury Determinations

The most common injury determinations were muscle/tendon strains (n = 86; 29%) and ligament sprains (n = 58; 19%; Tables 3 and 4). In particular, the most typical injuries overall were thigh-muscle strains (n = 38; 12.7% of overall injuries) and ankle-ligament sprains (n = 34; 11.4% of overall injuries). These were also the most common injuries observed during the 2016 season. Team representatives reported only 2 (0.7%) concussions, resulting in an ultimate

Table 1. Injury Rates for Various Injury Definitions and Types Over the 2017 Professional Ultimate Season

Injury Definition and Type	Injury, No.	Athlete-Exposures, No.	Injury Rate per 1000 Athlete-Exposures (95% CI)	Injury Rate Ratio (95% CI)
All injuries				
Competition	215	4770	45.07 (39.55, 51.36)[c]	2.25 (1.95, 2.58)[c,d]
Practice[a]	84	4193	20.03 (16.21, 24.76)[c]	NA
Overall	299	8963	33.36 (29.84, 37.29)[c]	NA
Required attention by athletic trainer[b]				
Competition	172	4770	36.06 (31.13, 41.75)[c]	2.29 (1.96, 2.67)[c,d]
Practice	66	4193	15.74 (12.39, 20.00)[c]	NA
Overall	238	8963	26.65 (23.43, 30.10)[c]	NA
Time loss $\geq$1 d				
Competition	93	4770	19.50 (15.94, 23.84)[c]	1.60 (1.29, 1.97)[c,d]
Practice	51	4193	12.16 (9.26, 15.98)[c]	NA
Overall	144	8963	16.07 (13.66, 18.90)[c]	NA
Medical attention and time loss				
Competition	85	4770	17.82 (14.43, 22.00)[c]	1.87 (1.49, 2.31)[c,d]
Practice	40	4193	9.54 (7.01, 12.99)[c]	NA
Overall	125	8963	13.94 (11.72, 16.60)[c]	NA
Injury type for all injuries (overall)				
First injury	205	8963	22.87 (19.98, 26.19)[c]	2.18 (1.89, 2.50)[e]
Reinjury (recurrence)	40	8963	4.46 (3.28, 6.08)[c]	
Exacerbation	51	8963	5.69 (4.33, 7.48)[c]	
Unsure of injury origin	3	8963	0.33 (0.11, 1.04)	

Abbreviations: CI, confidence interval; NA, not applicable.

[a] Three teams recorded no athlete-exposures during practice.
[b] *No trainer available* was selected for 6 practice injuries but zero competition injuries.
[c] Difference determined by the 95% CI.
[d] Injury rate ratio for competition versus practice injuries.
[e] Injury rate ratio for first injury versus any other type of injury.

overall rate of 2.23 per 10 000 AEs, and 10 (3.3%) knee-ligament sprains, for an overall rate of 1.12 per 1000 AEs.

Other Factors Associated with Injuries

The number of injuries increased throughout a competition (Figure 2). More than twice as many injuries occurred in the second half (n = 172) as in the first half (n = 72). Most injuries that occurred during practice happened during scrimmaging (63%, n = 49) followed by drills with running/cutting (14%, n = 11), warmup (8%, n = 6), other (8%, n = 6), conditioning (5%, n = 4), and stationary throwing (3%, n = 2); 6 injuries were missing data.

Athletes in the offense-cutter position were injured most often, whereas those in the defense-handler coverage position sustained the least number of injuries (Figure 3). Generally, cutters sustained more injuries than handlers, and offensive players sustained more injuries than defensive players.

Table 2. Mechanisms of All Injuries Over the 2017 Professional Ultimate Season

Activity	Overall (N = 299) Injury, No.	Overall %	Competition (n = 215) Injury, No.	Competition Injury Rate per 1000 Athlete-Exposures (95% CI)	Practice (n = 84) Injury, No.	Practice Injury Rate per 1000 Athlete-Exposures (95% CI)	Injury Rate Ratio (95% CI)[a]
Running	97	32	57	11.95 (9.23, 15.47)[c]	40	9.54 (7.01, 12.99)[c]	1.25 (0.94, 1.63)
Solo layout	45	15	36	7.55 (5.45, 10.45)[c]	9	2.15 (1.12, 4.12)[c]	3.52 (2.46, 4.87)[c]
Running collision	42	14	32	6.71 (4.75, 9.48)[c]	10	2.38 (1.28, 4.43)[c]	2.81 (1.92, 3.98)[c]
Jumping	25	8	21	4.40 (2.87, 6.75)[c]	4	0.95 (0.36, 2.54)	4.61 (2.85, 7.06)[c]
Jumping collision	24	8	22	4.61 (3.04, 7.00)[c]	2	0.48 (0.12, 1.91)	9.67 (6.05, 14.66)[c]
Overuse/accumulation	24	8	20	4.19 (2.71, 6.49)[c]	4	0.95 (0.36, 2.54)	4.39 (2.68, 6.80)[c]
Layout collision	15	5	13	2.73 (1.58, 4.69)[c]	2	0.48 (0.12, 1.91)	5.71 (3.04, 9.78)[c]
Throwing[b]	10	4	5	1.05 (0.44, 2.52)	5	1.19 (0.50, 2.86)	0.88 (0.29, 2.05)
Twisting	10	3	5	1.05 (0.44, 2.52)	5	1.19 (0.50, 2.86)	0.88 (0.29, 2.05)
Other	5	2	3	0.63 (0.20, 1.95)	2	0.48 (0.12, 1.91)	NA
Struck-by-disc collision	2	1	1	0.21 (0.03, 1.49)	1	0.24 (0.03, 1.69)	NA

Abbreviations: CI, confidence interval; NA, not applicable.

[a] Injury rate ratio for competition versus practice injuries.
[b] The throwing category comprised thrower motion (overall = 2 [1%], competition = 1 [0.5%], and practice = 1 [1%]), collision while throwing (overall = 3 [1%], competition = 3 [1%], and practice = 0 [0%]), and no collision while throwing (overall = 5 [2%], competition = 1 [0.5%], and practice = 4 [5%]).
[c] Difference determined by the 95% CI.

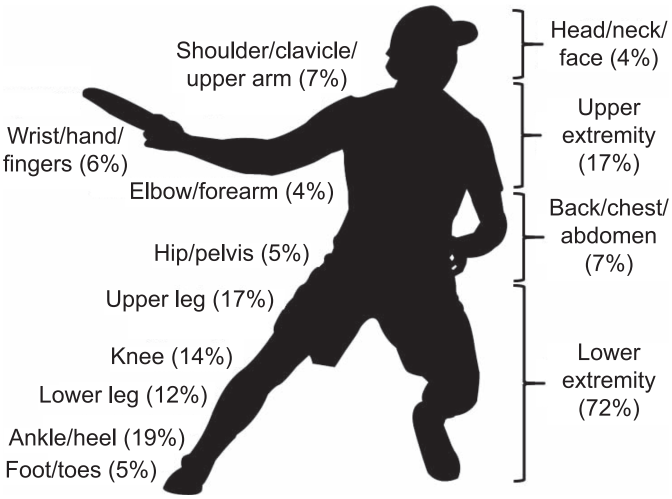

Figure 1. Injury locations for all injuries over the 2017 professional ultimate season (N = 299).

Using a bivariate analysis of injuries by playing surface, we found that 34% more injuries occurred on turf than on grass, which was a significant difference (Table 5). However, when playing-surface injury rates were stratified by competition and practice settings, the injury rate was only 28% greater, with a CI that just barely included 1.0 (Mantel-Haenszel IRR = 1.28; 95% CI = 0.99, 1.67). Injuries occurred 47% more often on wet or slick playing surfaces, a difference that approached significance. The location of competition had no effect on injury rates. We observed no difference in injury rates when athletes competed in a game on back-to-back days versus when they played 2 games in 1 day (doubleheader) and when they played 1 game each week (IRR = 0.94; 95% CI = 0.70, 1.27).

DISCUSSION

To our knowledge, this is the first study of injury rates, characteristics, and associated factors in professional ultimate. It is only the second study in which injuries

Table 3. Injury Determinations for All Injuries Over the 2017 Professional Ultimate Season

	Overall (N = 299)		Competition (n = 215)		Practice (n = 84)		
Determination	Injury, No.	%	Injury, No.	Injury Rate per 1000 Athlete-Exposures (95% CI)	Injury, No.	Injury Rate per 1000 Athlete-Exposures (95% CI)	Injury Rate Ratio (95% CI)[a]
Muscle/tendon strain	86	29	56	11.74 (9.05, 15.23)[b]	30	7.15 (5.01, 10.22)[b]	1.64 (1.24, 2.13)[b]
Ligament sprain	58	19	42	8.81 (6.52, 11.90)[b]	16	3.82 (2.34, 6.22)[b]	2.31 (1.66, 3.12)[b]
Bruise/hematoma	46	15	36	7.55 (5.45, 10.45)[b]	10	2.38 (1.28, 4.43)[b]	3.16 (2.21, 4.39)[b]
Muscle cramping	29	10	26	5.45 (3.72, 8.00)[b]	3	0.72 (0.23, 2.22)	7.62 (4.97, 11.18)[b]
Pain: no diagnosis	24	8	15	3.14 (1.90, 5.21)[b]	9	2.15 (1.12, 4.12)[b]	1.47 (0.82, 2.42)
Other	18	6	12	2.52 (1.43, 4.43)[b]	6	1.43 (0.64, 3.18)	NA
Abrasion/laceration	11	4	11	2.31 (1.28, 4.16)[b]	0	0.00	NA
Tendinitis	11	4	7	1.47 (0.70, 3.08)	4	0.95 (0.36, 2.54)	1.54 (0.68, 3.17)
Fracture	6	2	4	0.84 (0.31, 2.23)	2	0.48 (0.12, 1.91)	1.76 (0.48, 4.50)
Bursitis	4	1	1	0.21 (0.03, 1.49)	3	0.72 (0.23, 2.22)	0.29 (0.01, 1.63)
Dislocation/subluxation	4	1	3	0.63 (0.20, 1.95)	1	0.24 (0.03, 1.69)	2.64 (0.54, 7.71)
Concussion	2	1	2	0.42 (0.10, 1.68)	0	0.00	NA

Abbreviations: CI, confidence interval; NA, not applicable.

[a] Injury rate ratio for competition versus practice injuries.

[b] Difference determined by the 95% CI.

Table 4. Injury Location by Determination for Overall Injuries Over the 2017 Professional Ultimate Season (N = 299 Unique Injuries)[a]

	Injury Determination, n (%)							
Anatomic Location	Muscle/Tendon Strain	Ligament Sprain	Bruise/ Hematoma	Muscle Cramping	Pain: No Diagnosis	Abrasion/ Laceration	Tendinitis	Fracture
Head[b]/face/neck	1 (0.3)	0 (0.0)	3 (1.0)	0 (0.0)	3 (1.0)	0 (0.0)	0 (0.0)	1 (0.3)
Shoulder/clavicle/arm[c]	4 (1.3)	4 (1.3)	2 (0.7)	0 (0.0)	3 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)
Elbow/forearm	2 (0.7)	0 (0.0)	3 (1.0)	0 (0.0)	0 (0.0)	5 (1.7)	0 (0.0)	1 (0.3)
Wrist/hand/fingers	5 (1.7)	7 (2.3)	3 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.7)
Back/chest/abdomen	6 (2.0)	0 (0.0)	1 (0.3)	3 (1.0)	6 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)
Hip/pelvis[d]	7 (2.3)	0 (0.0)	2 (0.7)	1 (0.3)	1 (0.3)	0 (0.0)	1 (0.3)	0 (0.0)
Thigh	38 (12.7)	0 (0.0)	5 (1.7)	6 (2.0)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
Knee[d]	6 (2.0)	10 (3.3)	11 (3.7)	0 (0.0)	4 (1.3)	3 (1.0)	6 (2.0)	0 (0.0)
Leg[d]	7 (2.3)	1 (0.3)	4 (1.3)	18 (6.0)	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)
Ankle[d]/heel	8 (2.7)	34 (11.4)	5 (1.7)	1 (0.3)	4 (1.3)	1 (0.3)	3 (1.0)	1 (0.3)
Foot/toes	2 (0.7)	2 (0.7)	7 (2.3)	0 (0.0)	1 (0.3)	1 (0.3)	0 (0.0)	0 (0.0)

[a] We combined some rows and removed some columns to simplify viewing.

[b] The 2 (0.7%) concussions involved the head.

[c] All 4 (1.3%) dislocations/subluxations affected the shoulder/clavicle/arm.

[d] For bursitis, 1 (0.3%) case each occurred in the hip/pelvis, knee, leg, and ankle.

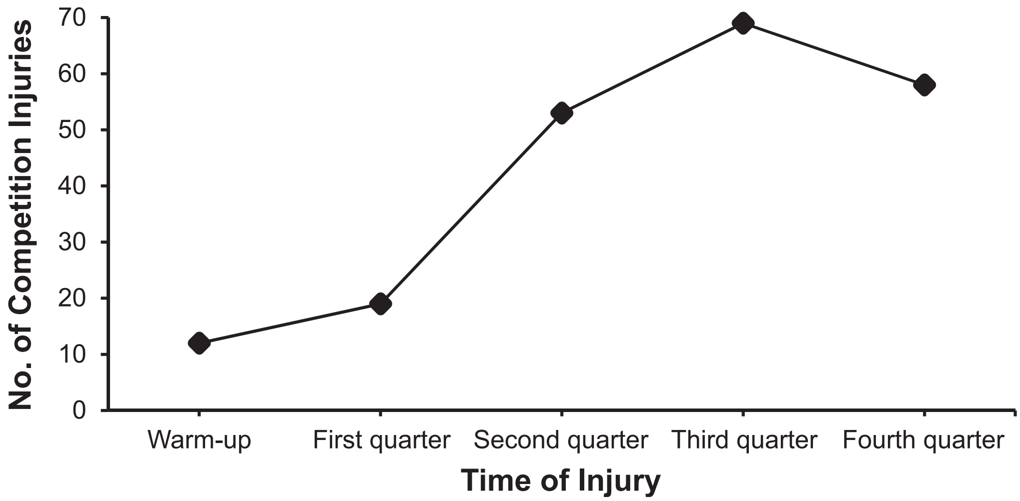

Figure 2. Time of injury during competitions over the 2017 professional ultimate season. The 4 competition injuries that occurred during overtime are not shown; however, only 11 of 239 games were played into overtime.

among competitive ultimate athletes have been tracked prospectively. We demonstrated the viability of a new ISP built on the lessons learned from previous collegiate surveillance and 2 seasons working with the AUDL.[8] Whereas we focused only on the professional level of ultimate, the injury trends were largely consistent with the patterns observed at other levels of ultimate competition.[5,6,8]

Our analysis identified injury rates that were much higher than in collegiate athletes.[8] We calculated AEs as the denominator using exactly the same procedure as in the collegiate study; however, it is difficult to compare injury rates in professional ultimate with those in other forms of ultimate because 1 AE at the professional level is not equivalent to 1 AE at another level. Specifically, AUDL games take twice as long and consist of double the number of points played in collegiate-level or club-level competitions. This means that an AUDL competition exposes athletes to twice the at-risk time while recording the same exposure. This is consistent with findings in other sports regarding the variations in exposure across different levels of the same sport.[19]

Given that context, the overall injury rate in men's collegiate ultimate was 12.63 per 1000 AEs, and using the same injury definition, the professional level had an injury rate that was almost 3 times higher (IR = 33.36).[8] The observed difference in IRs may also be due to underreporting at the collegiate level. Whereas Swedler et al[8] incorporated training materials similar to those used in the AUDL-ISP, they neither requested that teams use data-entry volunteers with athletic training or medical experience nor sought to ascertain the training level of the volunteers. The difference may also reflect the limitations of using the AE metric in the denominator. For example, in a study of Dutch soccer players, van Beijsterveldt et al[20] reported that professional athletes experienced more playing time during the equivalent exposure of amateur players. Whereas we may eventually find a higher risk of injury in professional ultimate, the similarities in the injury patterns observed in both professional and collegiate

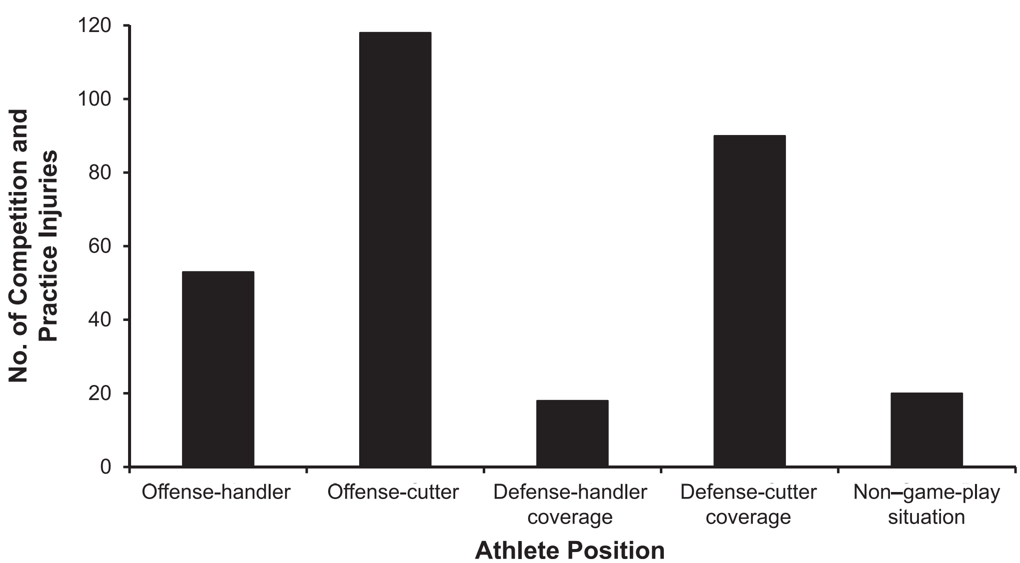

Figure 3. Injuries by athlete position over the 2017 professional ultimate season. Given the difficulty in accurately measuring within-competition and -practice exposures, we did not calculate incidence rates for athlete position.

Table 5. Factors Associated With Injuries Over the 2017 Professional Ultimate Season

Factor	Injury, No.	Athlete-Exposures	Injury Rate per 1000 Athlete-Exposures (95% CI)	Injury Rate Ratio (95% CI)
Playing surface type				
Overall				
Turf	224	6112	36.65 (32.22, 41.17)[e]	1.34 (1.17, 1.53)[e]
Grass	74	2702	27.39 (21.88, 34.29)[e]	
Competition[a]				
Turf	161	3419	47.09 (40.50, 54.75)[e]	1.20 (1.02, 1.41)[e]
Grass[b]	53	1351	39.23 (30.13, 51.08)[e]	
Practice				
Turf	63	2693	23.39 (18.33, 29.86)[e]	1.51 (1.15, 1.93)[e]
Grass[b]	21	1351	15.54 (10.17, 23.76)[e]	
Playing surface condition				
Dry surface	30	634	47.32 (33.37, 67.10)[e]	1.47 (0.98, 2.11)
Wet/slick surface	269	8329	32.30 (28.71, 36.33)[e]	
Competition location[c]				
Home	108	2293	47.10 (39.18, 56.62)[e]	1.12 (0.91, 1.35)
Away	102	2417	42.20 (34.90, 51.03)[e]	
Competition status[d]				
Back-to-back days or doubleheader	66	1524	43.31 (34.20, 54.83)[e]	0.94 (0.70, 1.27)
Single competition in 1 week	149	3246	45.90 (39.24, 53.70)[e]	

Abbreviation: CI, confidence interval.

[a] The total of competition injuries is 214 because 1 injury was listed as occurring indoors/hard surface floor.

[b] Two teams had zero grass athlete-exposures for competitions and practices.

[c] The 5 injuries that occurred at neutral field locations are not shown.

[d] Represents total injuries and athlete-exposures occurring over a full weekend of competition when games were played on back-to-back days or back to back on a single day (double header).

[e] Difference determined by the 95% CI.

ultimate likely indicate good generalizability for our results.

Our definition of injury was highly sensitive, aiming to capture the maximum number of injuries occurring over the season in order to match the previous ultimate literature.[6,8] However, the AUDL-ISP included additional definitions for each injury to permit some comparisons with the NCAA-ISP. We observed a rate of 17.82 injuries per 1000 AEs for competition injuries that required medical attention and resulted in time loss from participation for at least 1 day beyond the injury (Table 1). Compared with the average competition injury rates for men's NCAA sports from 1988 to 2004, men's professional ultimate ranked below football (IR = 35.9), wrestling (IR = 26.4), and soccer (IR = 18.8) but just above hockey (IR = 16.3), lacrosse (IR = 12.6), and basketball (IR = 9.9).[10] The overall NCAA trend across all sports was a more than threefold increase in competition over practice injuries (IRR = 3.46),[10] and we also observed an increase in competition injuries (IRR = 2.25; 95% CI 1.95, 2.58). Comparing our results with men's NCAA sports data from 2009 to 2014 that included only injuries requiring medical attention but that did not necessarily restrict play for 1 or more days, we demonstrated a rate of 36.06 competition injuries per 1000 AEs (Table 1).[21] Thus, men's professional ultimate ranked well above the average (IR = 15.1) but below football (IR = 39.9) and wrestling (IR = 38.5) and above hockey (IR = 26.3) and soccer (IR = 17.9).[21] Further study of why injury rates in the AUDL are greater than in common NCAA sports and collegiate ultimate is warranted.

Given that ultimate is a running- and cutting-intensive sport, it is unsurprising that running was the most common mechanism of injury (32%) and that most injuries (72%) affected the lower extremity. This high percentage of injuries caused by running offers targets for intervention.[22] Thigh-muscle strains were the most frequent injuries observed (12.7%), followed by ankle-ligament sprains (11.4%), which were the most common injuries across most NCAA sports.[10] We also observed a relatively high proportion of knee injuries (14% by location). The current system does not differentiate either the thigh muscles injured or the specific knee ligaments affected. In a retrospective, self-reported survey of 135 ultimate players, 55% of athletes experienced hamstrings strains and 36% experienced quadriceps strains,[5] indicating that hamstrings strains were possibly more common than quadriceps strains. We anticipate that future versions of the AUDL-ISP will better delineate injury diagnoses and severity. Preventing muscle strains, as well as ankle- and knee-ligament injuries, is challenging, but focusing on strength and flexibility training, proprioceptive training, and prophylactic use of ankle braces has shown some efficacy in similar sports.[23–25] Sport-specific injury-prevention efforts should address these most common injuries.

Whereas ultimate at all levels is categorized as a noncontact sport, a high proportion of injuries were due to interathlete collisions (29%).[2,4] A similarly high proportion has also been reported in collegiate play (31%–36%).[6,8] In both professional and collegiate play, collision injuries occurred more often during competitions than during practices, presumably reflecting the increased intensity level of interteam competition. This same trend has been observed in men's collegiate soccer, in which interathlete contact was reported as the primary cause of competition injuries.[22] The high occurrence of collision injuries is concerning and, with further and more specific data collection, may be targeted with potential rule changes to limit athlete collisions. For example, a 2006 rule introduced to remove male soccer players from a game for intentional elbow-to-head contact decreased head injuries by 29%.[26]

Although slightly fewer layout-related injuries (20%) occurred in the AUDL than in collegiate play (26%), we expected to find even fewer of these injuries in the elite-level athletes who have likely already learned proper, safe layout form. Professional athletes also experienced fewer overuse injuries (8%) than collegiate athletes (18%), and injuries were more than twice as likely to be first-time injuries than reinjuries or exacerbations of previous injuries.[8] This may suggest that (1) professional athletes have better resources available through an organized league; (2) professional athletes are more educated and experienced in rehabilitation and injury prevention; or (3) professional, organized team warmups and conditioning are helping to decrease persistent injuries.

The injury pattern we noted may be related to athlete fatigue over the course of a competition (Figure 2). In soccer, fatigue increases in the initial phase of the second half and toward the end of the game.[27] Athletes are likely to be tired after the first quarter, leading to increased injuries in later parts of the game. As was true in soccer, we observed more injuries in the third quarter (after half time). Coaches and medical staff can potentially decrease injury rates by incorporating low-intensity activity during half-time and more frequent substitutions throughout game play.[28]

Investigators studying ultimate have not assessed the effect of a player's position on injury rates. We learned that offensive players experienced greater than 50% more injuries than defensive players (171 versus 108) and that cutters were injured almost 3 times more often than handlers (208 versus 71; Figure 3). We were unable to evaluate injury rates by position, and it is possible that we found more injuries in cutters because more players are in the cutting position at any given moment in game play. However, approximately 50% of athletes are on offense and 50% are on defense during game play. Therefore, the numbers of these exposures ought to be more similar, and we are more likely to be seeing a true difference. Athletes and coaches should be aware of the differential risk of injury for athletes in different roles on the team and target injury-prevention and return-to-play strategies accordingly. More research is needed to determine the effect of player position on the likelihood of injury.

Based on the AE data we collected, in the AUDL, teams compete and practice on artificial turf most of the time. Whereas turf playing surfaces are perceived to be associated with greater injury rates than grass, Meyers[29] reported that, in men's collegiate soccer competitions, turf had lower injury rates than grass. Turf offers a more consistent playing surface than grass and is designed to drain water more efficiently, potentially helping to mitigate the increased rate of injury we observed on wet or slick surfaces. In our pilot study, more than twice as many injuries occurred when athletes competed on turf as on grass (IRR = 2.21; 95% CI = 1.36, 3.58); however, the IRR for practices was not different (IRR = 1.61; 95% CI = 0.43, 6.05). Over the 2017 season, our results were similar. Although the unadjusted IRR was different (Table 5), exposure to turf was confounded by competition versus practice status. Using the Mantel-Haenszel stratification by competition versus practice status produced an IRR with a 95% CI that included 1.0, although just barely. We interpreted this to mean that turf presented a slightly increased risk for injury during practices or games; however, a blanket analysis of turf versus grass injury rates without accounting for competition status is incomplete because the increased injury rate in games superseded the effect of turf exposure.

We did not note a difference between professional players competing on back-to-back days or twice on the same day and professional players competing in games separated by about 1 week. However, the relative increase in overuse injuries during collegiate play may be partly explained by the fact that athletes often compete in multiple games per day over 2-day tournaments. Given the difficulties in accurately comparing injury rates between our study and the collegiate study of Swedler et al,[8] we are unable to prove our hypothesis that the single-game-per-week format of the AUDL decreased injury rates; still, the percentage of overuse injuries in the professional cohort did seem to be lower.

LIMITATIONS AND STRENGTHS

Because designated team representatives collected injury data and injuries were recorded without athlete identification, we were unable to validate a sample of injury entries or ensure adherence to our precise definitions of injury. Most team representatives conducting data entry (63%) were ATs or medically trained staff, and we attempted to train all representatives regardless of medical knowledge. Yet other researchers[30] demonstrated large differences in surveillance data reporting between ATs and team staff, such as coaches. In our study, a preliminary analysis of teams with or without ATs reporting data suggested that teams with ATs may have been reporting more injuries than those without ATs. However, it is difficult to determine whether those injury rates represented natural differences between teams or true increased reporting by ATs versus underreporting by non-ATs. We hope to rely on only AT reporters for each team in future studies to improve the consistency and reliability of our surveillance data.

In contrast to competitions, ATs were not required to attend all practices. This may decrease the validity of practice data compared with competition data and is a recognized limitation of many ISPs.[21] We also used AEs in the denominator to calculate our injury rates. Given that ultimate often involves numerous substitutions between points, with some athletes playing more points than others in any given competition, our study may have underestimated injury rates for teams with a large number of participating players but a small cohort of highly active players.

Whereas we expected to and did observe different injury rates among participating teams, it is impossible to determine whether the difference was due to overreporting or underreporting by team representatives or represents true variations in injury rates by team that could be due to a host of differences not captured in this study. For the 3 teams without recorded practice AEs or injuries, we suspect that 2 did not hold practices but are uncertain why the third team did not record any practice exposures or injuries. We were also limited in the level of detail we could obtain for each injury determination because we were limited to determinations made on the field by ATs. To better compare ultimate injury rates and patterns with the NCAA-ISP, accurate International Classification of Diseases diagnoses would be beneficial.[13] Our current surveillance system also lacks the ability to monitor the outcome of injuries sustained in the season, especially the 21% of injuries that required evaluation at an outside medical facility. The current AUDL-ISP tracks injury information anonymously to protect athletes' health privacy. This also limited us to tracking time loss from participation as a binary variable. We seek to expand the system to track injuries on the individual level so that we can follow all injuries for more precise diagnoses and quantify the amount of time loss from participation due to specific injuries. Unlike other researchers, we were unable to assess injury patterns or rates for women, male athletes outside of approximately 18 to 30 years of age, or other levels of the sport, such as recreational, youth, collegiate, or club.[7,8]

CONCLUSIONS

The AUDL-ISP is the first multiseason ISP in the sport of ultimate. Using its data, we established injury rates for professional ultimate athletes. Minor lower extremity injuries, such as muscle strains and ankle sprains, were most common; however, nearly half of all injuries resulted in time loss from participation. The epidemiologic data from this study can serve as baseline data for potential future injury interventions, training procedures, and rule changes that teams or the league may implement.[31] The success of the AUDL-ISP over its first 2 seasons has led to its continued use and expansion within the AUDL.

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Address correspondence to Matthew C. Hess, MD, School of Medicine, Department of Orthopaedic Surgery, University of Alabama at Birmingham, Orthopaedic Specialties Building, 1313 13th Street South, Birmingham, AL, 35205. Address e-mail to mattcharleshess@gmail.com.