2017

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Daniel R. Clifton

James A. Onate

Eric Schussler
Old Dominion University

Aristarque Djoko

Thomas P. Dompier

See next page for additional authors

Original Publication Citation

Clifton, D. R., Onate, J. A., Schussler, E., Djoko, A., Dompier, T. P., & Kerr, Z. Y. (2017). Epidemiology of knee sprains in youth, high school, and collegiate American football players. *J Athl Train, 52*(5), 464-473. doi:10.4085/1062-6050-52.3.09

Journal of Athletic Training 2017;52(5):464–473
doi: 10.4085/1062-6050-52.3.09

www.natajournals.org

original research

Epidemiology of Knee Sprains in Youth, High School, and Collegiate American Football Players

Daniel R. Clifton, MEd, ATC*; James A. Onate, PhD, ATC, FNATA*; Eric Schussler, PhD, PT, ATC†; Aristarque Djoko, MS‡; Thomas P. Dompier, PhD, ATC‡; Zachary Y. Kerr, PhD, MPH§

*School of Health and Rehabilitation Sciences, The Ohio State University, Columbus; †School of Physical Therapy and Athletic Training, Old Dominion University, Norfolk, VA; ‡The Datalys Center for Sports Injury Research and Prevention, Inc, Indianapolis, IN; §Department of Exercise and Sport Science, University of North Carolina at Chapel Hill

Context: Variations in knee-sprain incidence among competition levels are unclear but may help inform prevention strategies in American football players.

Objective: To describe the epidemiology of knee sprains in youth, high school, and collegiate football players.

Design: Descriptive epidemiology study.

Setting: Injury and athlete-exposure (AE) data were collected from 3 injury-surveillance programs at the youth, high school, and collegiate competition levels.

Patients or Other Participants: Data from 310 youth, 184 high school, and 71 collegiate football team-seasons were collected during the 2012 through 2014 seasons.

Main Outcome Measure(s): Knee-sprain rates and risks were calculated for each competition level. Injury rate ratios (IRRs) and risk ratios (RRs) compared knee-sprain rates by competition level. Injury proportion ratios (IPRs) compared differences in surgery needs, recurrence, injury mechanism, and injury activity by competition level.

Results: Knee-sprain rates in youth, high school, and collegiate football were 0.16/1000 AEs, 0.25/1000 AEs, and 0.69/1000 AEs, respectively. Knee-sprain rates increased as the competition level increased (high school versus youth: IRR = 1.60; 95% confidence interval [CI] = 1.12, 2.30; collegiate versus high school: IRR = 2.73; 95% CI = 2.38, 3.96). Knee-sprain risk was highest in collegiate (4.3%), followed by high school (2.0%) and youth (0.5%) athletes. Knee-sprain risk increased as the competition level increased (high school versus youth: RR = 3.73; 95% CI = 2.60, 5.34; collegiate versus high school: RR = 2.14; 95% CI = 1.83, 2.51). Collegiate football had the lowest proportion of knee sprains that were noncontact injuries (collegiate versus youth: IPR = 0.54; 95% CI = 0.31, 0.95; collegiate versus high school: IPR = 0.59; 95% CI = 0.44, 0.79) and the lowest proportion that occurred while being tackled (collegiate versus youth: IPR = 0.44; 95% CI = 0.26, 0.76; collegiate versus high school: IPR = 0.71; 95% CI = 0.51, 0.98).

Conclusions: Knee-sprain incidence was highest in collegiate football. However, level-specific variations in the distributions of knee sprains by injury activity may highlight the need to develop level-specific policies and prevention strategies that ensure safe sports play.

Key Words: knee injuries, injury surveillance, injury prevention

Key Points

- The risk of knee sprains increased as the competition level increased, with the highest risk occurring in collegiate football players.
- Total knee-sprain rates and the proportion due to being blocked were higher in collegiate than in youth or high school football athletes; however, a smaller proportion of collegiate knee sprains were due to tackling.
- Level-specific variations in the distributions of knee sprains by injury activity may highlight the need to develop policies and prevention strategies that ensure safe sports play.

Football is one of the most popular sports among US amateur athletes, with 14 154 National Federation of State High School Associations–sanctioned teams and 1 085 182 high school participants,[1] 670 National Collegiate Athletic Association (NCAA) teams and 72 788 collegiate participants,[2] and approximately 3 million youth football participants.[3] The sport of football has been highly scrutinized recently regarding sport-related concussion, yet the proportion of injuries to the knee remains high.[4] Knee injuries in American football players accounted for approximately 15% of all high school injuries in 1 study.[5] Knee injuries have also been reported to represent the second and third largest proportions of injuries in high school and collegiate football players, respectively.[6] Ankle injuries constituted the highest proportion of injuries in high school and collegiate football players.[6] Injuries to the head and face have been responsible for the fifth and sixth largest proportions of injuries in high school and collegiate football players, respectively.[6] In addition, knee injuries were identified in 54% of collegiate athletes attending a National Football League predraft combine.[7]

Knee injuries often result in pain and long-term instability, and, perhaps more importantly, an elevated long-term risk of osteoarthritis (OA).[8,9] Specifically, 50%

of individuals with an anterior cruciate ligament (ACL) rupture are likely to develop radiographic knee OA 10 to 15 years after the injury, regardless of whether the ACL was reconstructed initially.[9] This increased risk of knee OA may lead to reduced physical activity levels throughout a lifetime, which can contribute to the development of additional diseases that increase health care costs and reduce quality of life.[10,11] Despite the potential risks, participation in sports is important for maintaining regular physical activity and its associated physiological[12] and psychological benefits.[13,14]

Effectively reducing the risk of knee injury in football may require specific interventions at the competition level, but little is known about the epidemiology of knee injury by competition level, particularly in youth athletes. Therefore, the purpose of our study was to describe the epidemiology of knee injury in youth, high school, and collegiate football players (approximate age range, 5–23 years). Studying samples of football players across these levels of competition is unique because to date no other authors have used the same methods during the same time periods across all groups. An estimate of the incidence of knee injury during the 2012 through 2014 seasons was completed and data were compared among the 3 levels of football competition. We hypothesized that the rate of knee injury would increase incrementally with the level of competition, with a larger incidence of severe knee injuries (eg, ACL tears) occurring as physical maturation, along with intensity of practice and game competition, increased.

METHODS

Injury-Surveillance Programs

Data were collected from 3 larger injury surveillance programs: (1) the Youth Football Safety Study (YFSS); (2) the National Athletic Treatment, Injury and Outcomes Network (NATION); and (3) the NCAA Injury Surveillance Program (ISP). The YFSS and NATION were designed and implemented by the Datalys Center for Sports Injury Research and Prevention, Inc. The YFSS involves 5- to 14-year-old football players in 13 youth football leagues across 6 states; the NATION involves 27 sports from secondary schools[15]; and the NCAA-ISP has been ongoing since 1986 and involves 25 sports from each of the 3 competitive divisions.[16] All 3 programs use the same technology, methods, and common data elements, with slight variations for setting and level of competition.[16]

During the 2012 through 2014 seasons, the YFSS included more than 3000 individual athletes from 6 states, 13 youth football leagues, and 118 teams providing 310 team-seasons; the NATION program included 96 secondary school football programs providing 184 team-seasons; and the NCAA-ISP included 34 member institutions providing 71 team-seasons. The YFSS and NATION protocols were reviewed and approved by the Western Institutional Review Board (Puyallup, WA), and the NCAA-ISP protocol was reviewed and approved by the NCAA Research Review Board (Indianapolis, IN).

Injury-Documentation Applications

Deidentified injury and exposure information was reported by certified athletic trainers (ATs) using an export application that extracts common data elements identically coded from several injury-documentation applications, such as the Athletic Trainer System (Keffer Development, Grove City, PA).[16] Each injury-documentation application captures information about the injury type, severity, and mechanism; session type; and other factors. These frequencies are then aggregated into a single research database. To be included, an injury-documentation application had to undergo a certification process by which known values were correctly exported into a test database. The applications certified to participate included the Athletic Trainer System, Injury Surveillance Tool (Datalys Center for Sports Injury Research and Prevention, Inc, Indianapolis, IN), and Sports Injury Monitoring System (FlanTech, Iowa City, IA). Each application has its own proprietary data structure, but when injury data are exported from any system into the research database, they are coded the same. This approach allows ATs to document injuries as part of their normal clinical practice, thus eliminating the need to enter the same data multiple times.[16] The YFSS is limited to the Datalys Center Injury Surveillance Tool.

Data-Collection Procedures

At all 3 levels of competition, ATs attended each practice and game during the 2012 through 2014 seasons and reported injuries and athlete-exposures (AEs) via their preferred injury-documentation application. Data were reviewed through both automated and manual quality-control processes before inclusion in the research database.[16] Deidentified data were exported to the research database daily.

A reportable *injury* in all 3 surveillance programs was an injury, time loss (TL) or non–TL, that occurred as a result of participation in an organized practice or game and required attention from an AT or physician. Multiple injuries could be included as the result of 1 injury event. This study used all data collected on injuries identified as knee sprains.

When an injury occurred, the on-site AT provided a detailed injury report that included body site and diagnosis, as well as related circumstances such as activity, mechanism, and event type (ie, practice or competition). After initially entering injury data, the ATs could return to view and update the data as needed over the course of a season, such as when the student-athlete returned to sport participation or received a more definitive diagnosis through imaging or other means. In addition, the ATs were able to identify those injuries that required surgery or were a recurrence of an injury that occurred either earlier in the current academic year or prior.

Participation-restriction time was defined as the difference between the injury event date and the date on which the athlete returned to full sport participation. *Time-loss injuries* were those injuries that required at least 24 hours of participation restriction. *Severe injuries* required more than 21 days before return to participation and included those injuries that resulted in the student-athlete prematurely ending the season (ie, *season-ending injury*).[17]

Statistical Analyses

We analyzed the data to assess the rates and patterns of knee sprains in youth, high school, and collegiate football.

We first calculated knee-sprain rates, overall and by event. Injury rates were also calculated for TL injuries only and then severe injuries only. These rates were also calculated for each specific type of knee sprain (ie, ACL, posterior cruciate ligament, medial collateral ligament [MCL], lateral collateral ligament, capsular sprain). We then calculated pooled 1-year risks of overall knee sprains for each level of competition. Last, we examined distributions of knee sprains based on surgery needs, recurrence, injury mechanism, and injury activity.

Injury rate ratios (IRRs) compared knee-sprain rates by level of competition and by event type. Risk ratios (RRs) compared the risk of knee sprains by level of competition. Injury proportion ratios (IPRs) examined differences in the distributions of surgery needs, recurrence, injury mechanism, and injury activity by the level of competition.

The following is an example of an IRR comparing the overall knee-sprain rates between collegiate and high school football players:

$$\mathrm{IRR} = \frac{\left(\frac{\sum \text{collegiate knee-sprain events}}{\sum \text{collegiate athlete-exposures}}\right)}{\left(\frac{\sum \text{high school knee-sprain events}}{\sum \text{high school athlete-exposures}}\right)}$$

An *AE* was defined as 1 athlete's participation in 1 organized practice or game. The following is an example of an RR comparing the risk of incurring a knee sprain between collegiate and high school football players:

$$\mathrm{RR} = \frac{\left(\frac{\sum \text{collegiate athletes with a knee sprain}}{\sum \text{collegiate athlete-seasons}}\right)}{\left(\frac{\sum \text{high school athletes with a knee sprain}}{\sum \text{high school athlete-seasons}}\right)}$$

An *athlete-season* was defined as 1 athlete's participation in 1 season. Youth athlete-seasons were determined by the number of players on a preseason roster at the beginning of each season. High school athlete-seasons were derived from estimates of team size using National Federation of State High School Associations[1] participation data. Collegiate athlete-seasons were derived from estimates of team size using NCAA[2] participation data.

The following is an example of an IPR comparing the proportion of knee sprains that involved the MCL between collegiate and high school football players:

$$\mathrm{IPR} = \frac{\left(\frac{\sum \text{collegiate knee-sprain events involving the MCL}}{\sum \text{total collegiate knee-sprain events}}\right)}{\left(\frac{\sum \text{high school knee-sprain events involving the MCL}}{\sum \text{total high school knee-sprain events}}\right)}$$

Injury rate ratios, RRs, and IPRs with 95% confidence intervals (CIs) not including 1.00 were considered statistically significant. Data were analyzed using SAS Enterprise Guide software (version 4.3; SAS Institute Inc, Cary, NC).

RESULTS

Overall Frequencies

Knee-sprain rates for youth, high school, and collegiate football players are provided in Table 1. During the 2012 through 2014 seasons, a total of 33, 313, and 374 knee sprains were reported in youth, high school, and collegiate football, respectively. At all 3 levels, most knee sprains were TL injuries (youth: 51.5%; high school: 69.6%; collegiate: 73.5%). Also, the proportion of knee sprains that were severe in youth (12.1%) was lower than that in high school (32.9%; IPR = 0.37; 95% CI = 0.15, 0.94) and collegiate (36.9%; IPR = 0.33; 95% CI = 0.13, 0.83) players.

Knee-Sprain Rates

Knee-sprain rates in youth, high school, and collegiate football players were 0.16, 0.25, and 0.69/1000 AEs, respectively. Knee-sprain rates were greater during competition than during practice in collegiate (IRR = 14.30; 95% CI = 11.62, 17.59), high school (IRR = 5.11; 95% CI = 4.09, 6.47), and youth (IRR = 2.39; 95% CI = 1.19, 4.80) football players. The knee-sprain rate in collegiate football was greater than that in high school (IRR = 2.73; 95% CI = 2.35, 3.18) or youth (IRR = 4.38; 95% CI = 3.07, 6.26) football players. Also, the knee-sprain rate in high school football was greater than that in youth football (IRR = 1.60; 95% CI = 1.12, 2.30) players. For both TL injuries and severe injuries, knee-sprain rates were also greater in collegiate football compared with youth and high school football players.

Knee-Sprain Risks

Pooled 1-year risks of knee sprains in youth, high school, and collegiate football players are provided in Table 2. A total of 36, 281, and 323 athletes sustained knee sprains in youth, high school, and collegiate football, respectively. The risk of suffering a knee sprain in collegiate football (4.2%) was greater than that in high school (2.0%; RR = 2.14; 95% CI = 1.83, 2.51) or youth (0.5%; RR = 7.99; 95% CI = 5.59, 11.41) football players. Also, the risk of experiencing a knee sprain in high school football (2.0%) was greater than that in youth football (0.5%; RR = 3.73; 95% CI = 2.60, 5.34) players.

Specific Knee-Sprain Diagnoses

The distributions and rates of specific knee-sprain diagnoses in youth, high school, and collegiate football players are provided in Table 3. Medial collateral ligament injuries comprised 45.5%, 46.0%, and 61.5% of all knee sprains at the youth, high school, and collegiate level, respectively. Medial collateral ligament injury rates were 0.07, 0.12, and 0.43/1000 AEs for youth, high school, and collegiate football players, respectively. Anterior cruciate ligament injuries comprised 6.1%, 31.3%, and 22.2% of all knee sprains in youth, high school, and collegiate football players, respectively. Anterior cruciate ligament injury rates were 0.01, 0.08, and 0.15/1000 AEs for youth, high school, and collegiate football players, respectively.

Rate ratios by competition level for each specific diagnosis are depicted in the Figure. The MCL injury rate

Table 1. Knee-Sprain Rates by Event Type in Youth, High School, and Collegiate Football Players, 2012 Through 2014 Seasons

	Event Type								
	Game			Practice			Overall		
Level of Play	Injuries, No.	AEs	Injury Rate per 1000 AEs (95% CI)	Injuries, No.	AEs	Injury Rate per 1000 AEs (95% CI)	Injuries, No.	AEs	Injury Rate per 1000 AEs (95% CI)
Youth									
All injuries	13	44 583	0.29 (0.13, 0.45)	20	163 939	0.12 (0.07, 0.18)	33	208 523	0.16 (0.10, 0.21)
Time-loss injuries[a]	7	44 583	0.16 (0.04, –0.27)	10	163 939	0.06 (0.02, 0.10)	17	208 523	0.08 (0.04, 0.12)
Severe injuries[b]	4	44 583	0.09 (0.00, 0.18)	0	163 939	0.00	4	208 523	0.02 (0.00, 0.04)
High school									
All injuries	165	221 105	0.75 (0.63, 0.86)[c]	148	1 012 533	0.15 (0.12, 0.17)[c]	313	1 233 637	0.25 (0.23, 0.28)[c]
Time-loss injuries	125	221 105	0.57 (0.47, 0.66)[c]	93	1 012 533	0.09 (0.07, 0.11)[c]	218	1 233 637	0.18 (0.15, 0.20)[c]
Severe injuries	77	221 105	0.35 (0.27, 0.43)[c]	26	1 012 533	0.03 (0.02, 0.04)	103	1 233 637	0.08 (0.07, 0.10)[c]
Collegiate									
All injuries	226	52 014	4.34 (3.78, 4.91)[d,e]	148	487 109	0.30 (0.25, 0.35)[d,e]	374	539 124	0.69 (0.62, 0.76)[d,e]
Time-loss injuries	156	52 014	3.00 (2.53, 3.47)[d,e]	119	487 109	0.24 (0.20, 0.29)[d,e]	275	539 124	0.51 (0.45, 0.57)[d,e]
Severe injuries	80	52 014	1.54 (1.20, 1.88)[d,e]	58	487 109	0.12 (0.09, 0.15)[d,e]	138	539 124	0.26 (0.21, 0.30)[d,e]

Abbreviations: AE, athlete-exposure; CI, confidence interval.

[a] Defined as resulting in participation-restriction time of at least 24 hours.
[b] Defined as resulting in participation-restriction time of more than 21 days.
[c] High school estimate greater than youth estimate (injury rate ratio [IRR] > 1.00).
[d] Collegiate estimate greater than high school estimate (IRR > 1.00).
[e] Collegiate estimate greater than youth estimate (IRR > 1.00).

was greater in collegiate football than in high school (IRR = 3.65; 95% CI = 2.97, 4.50) or youth (IRR = 5.93; 95% CI = 3.52, 10.00) football players. The ACL injury rate was greater in collegiate football than in high school (IRR = 1.94; 95% CI = 1.45, 2.60) or youth (IRR = 16.05; 95% CI = 3.95, 65.26) football players. The ACL injury rate was also greater in high school football than in youth football (IRR = 8.28; 95% CI = 2.04, 33.59). Specifically, the noncontact ACL injury rate was greater in collegiate football than in high school football (IRR = 2.10; 95% CI = 1.31, 3.36) players.

The proportion of knee sprains that were classified as severe also differed among competition levels, with the smallest proportion occurring in youth football players (12.1%). In youth football, the 4 severe knee sprains consisted entirely of MCL (n = 3) and ACL (n = 1) sprains. In high school football, the 103 severe knee sprains consisted mostly of MCL (n = 41) and ACL (n = 55) sprains. In collegiate football, the 138 severe knee sprains consisted mostly of MCL (n = 48) and ACL (n = 71) sprains.

Injury Mechanisms

Knee-sprain distributions by injury mechanism are provided in Table 4. Player contact accounted for the largest proportion of knee sprains in youth (60.6%), high school (58.8%), and collegiate (72.5%) football players. Numerous knee sprains were also due to noncontact mechanisms (youth = 30.3%, high school = 27.5%, collegiate = 16.3%). Similar trends in injury-mechanism distributions also occurred for specific knee-sprain diagnoses. The proportion of knee sprains that resulted from player contact was higher in collegiate football than in high school football (IPR = 1.23; 95% CI = 1.10, 1.38) athletes. No differences were evident in the proportion of knee sprains due to player contact between collegiate and youth football (IPR = 1.20; 95% CI = 0.90, 1.59), or high school and youth football (IPR = 0.97; 95% CI = 0.73, 1.30) athletes. The proportion of knee sprains due to noncontact mechanisms was lower in collegiate football than in high school (IPR = 0.59; 95% CI = 0.44, 0.79) or youth (IPR = 0.54; 95% CI = 0.31, 0.95) football players. No differences were seen in the proportion of knee sprains due to

Table 2. Pooled 1-Year Risks of Knee Sprains in Youth, High School, and Collegiate Football Players, 2012 Through 2014 Seasons

Level of Play	Athletes With Knee Sprain, No.	Athlete-Seasons, No.[a]	1-Year Risk, % (95% Confidence Interval)
Youth	36	6200	0.53 (0.35, 0.71)
High school	281	14 168	1.98 (1.75, 2.21)[b]
Collegiate	323	7597	4.2 (3.80, 4.71)[c,d]

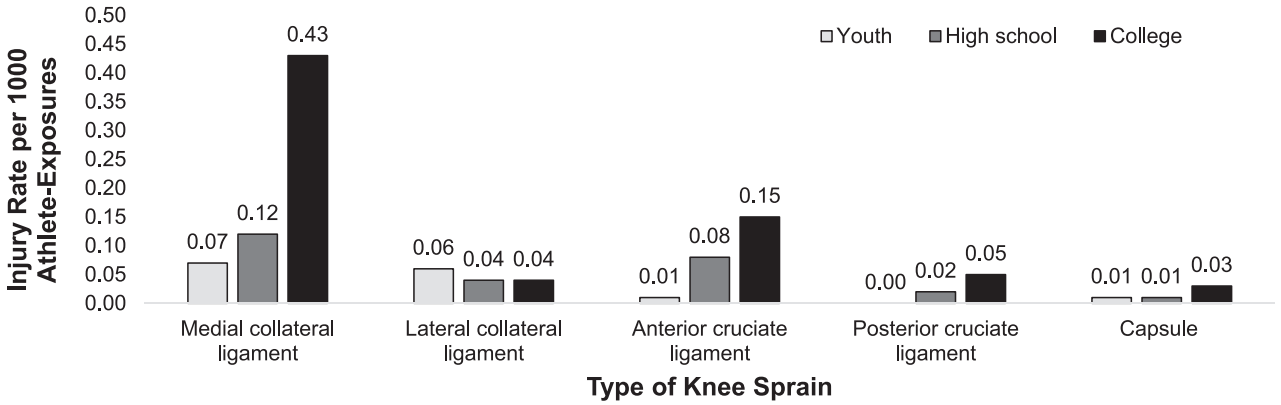
[a] *Athlete-season* defined as 1 athlete's participation in 1 season. Youth athlete-seasons determined by number of players on preseason roster at the beginning of each season; high school and collegiate athlete-seasons were determined by squad-size estimates of participation data from the National Federation of State High School Associations and the National Collegiate Athletic Association, respectively.
[b] High school estimate greater than youth estimate (risk ratio [RR] > 1.00).
[c] Collegiate estimate greater than high school estimate (RR > 1.00).
[d] Collegiate estimate greater than youth estimate (RR > 1.00).

Table 3. Knee-Sprain Counts and Rates by Specific Diagnosis in Youth, High School, and Collegiate Football Players, 2012 Through 2014 Seasons

Level of Play	Injuries, No. (%)	Injury Rate per 1000 Athlete-Exposures (95% Confidence Interval)			Injuries Requiring Surgery, %[c]	Recurrent Injuries, %[c]
		All Injuries	Time-Loss Injuries[a]	Severe Injuries[b]		
Youth						
MCL	15 (45.5)	0.07 (0.04, 0.11)	0.03 (0.01, 0.06)	0.01 (0.00, 0.03)	0.0	6.7
LCL	12 (36.4)	0.06 (0.02, 0.09)	0.03 (0.01, 0.05)	0.00	0.0	0.0
ACL	2 (6.1)	0.01 (0.00, 0.02)	<0.01 (0.00, 0.01)	<0.01 (0.00, 0.01)	—	—
PCL	1 (3.0)	<0.01 (0.00, 0.01)	<0.01 (0.00, 0.01)	0.00	—	—
Cap	3 (9.1)	0.01 (0.00, 0.03)	0.01 (0.00, 0.02)	0.00	—	—
Total	33 (100.0)	0.16 (0.10, 0.21)	0.08 (0.04, 0.12)	0.02 (0.00, 0.04)	3.0	3.0
High school						
MCL	144 (46.0)	0.12 (0.10, 0.14)	0.09 (0.07, 0.11)[d]	0.03 (0.02, 0.04)	3.5	3.5
LCL	45 (14.4)	0.04 (0.03, 0.05)	0.02 (0.01, 0.03)	<0.01 (0.00, 0.01)	4.4	8.9
ACL	98 (31.3)	0.08 (0.06, 0.10)[d]	0.05 (0.04, 0.06)[d]	0.04 (0.03, 0.06)[d]	33.7	4.1
PCL	19 (6.1)	0.02 (0.01, 0.02)	0.01 (0.00, 0.01)	0.00	5.3	0.0
Cap	7 (2.2)	0.01 (0.00, 0.01)	0.01 (0.00, 0.01)	0.00	0.0	14.3
Total	313 (100.0)	0.25 (0.23, 0.28)[d]	0.18 (0.15, 0.20)[d]	0.08 (0.07, 0.10)[d]	13.1	4.5
Collegiate						
MCL	230 (61.5)	0.43 (0.37, 0.48)[e,f]	0.27 (0.23, 0.32)[e,f]	0.09 (0.06, 0.11)[e,f]	4.8	8.3
LCL	21 (5.6)	0.04 (0.02, 0.06)	0.03 (0.02, 0.04)	0.01 (0.00, 0.02)	9.5	4.8
ACL	83 (22.2)	0.15 (0.12, 0.19)[e,f]	0.14 (0.11, 0.17)[e,f]	0.13 (0.10, 0.16)[e,f]	85.5[e]	7.2
PCL	26 (7.0)	0.05 (0.03, 0.07)[e,f]	0.04 (0.03, 0.06)[e,f]	0.02 (0.01, 0.03)[e]	7.7	11.5
Cap	14 (3.7)	0.03 (0.01, 0.04)[e]	0.02 (0.01, 0.03)[e]	<0.01 (0.00, 0.01)	7.1	0.0
Total	374 (100.0)	0.69 (0.62, 0.76)[e,f]	0.51 (0.45, 0.57)[e,f]	0.26 (0.21, 0.30)[e,f]	23.3[e,f]	7.8

Abbreviations: ACL, anterior cruciate ligament; Cap, capsular sprain; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

[a] Defined as resulting in participation-restriction time of at least 24 hours.
[b] Defined as resulting in participation-restriction time of more than 21 days.
[c] Not computed for counts <5.
[d] High school estimate greater than youth estimate (injury rate ratio [IRR] > 1.00 for rates, injury proportion ratio [IPR] > 1.00 for percentages).
[e] Collegiate estimate greater than high school estimate (IRR > 1.00 for rates, IPR > 1.00 for percentages).
[f] Collegiate estimate greater than youth estimate (IRR > 1.00 for rates, IPR > 1.00 for percentages).



Injury Rate Ratio (95% Confidence Interval)

Rate Comparison	Medial Collateral Ligament	Lateral Collateral Ligament	Anterior Cruciate Ligament	Posterior Cruciate Ligament	Capsule
College versus youth	5.93 (3.52, 10.00)	0.68 (0.33, 1.38)	16.05 (3.95, 65.26)	10.06 (1.36, 74.11)	1.80 (0.52, 6.28)
College versus high school	3.65 (2.97, 4.50)	1.07 (0.64, 1.79)	1.94 (1.45, 2.60)	3.13 (1.73, 5.66)	4.58 (1.85, 11.34)
High school versus youth	1.62 (0.95, 2.76)	0.63 (0.34, 1.20)	8.28 (2.04, 33.59)	3.21 (0.43, 23.99)	0.39 (0.10, 1.53)

Figure. Injury rates and rate ratios of knee sprains in youth, high school, and collegiate football players, 2012 through 2014 seasons.

Table 4. Knee-Sprain Injury Mechanisms by Specific Diagnosis in Youth, High School, and Collegiate Football Players, 2012 Through 2014 Seasons

	Injury Mechanism, No. (%)					
Level of Play	Player Contact	Surface Contact	Equipment Contact	Noncontact	Missing	Total
Youth						
MCL	9 (60.0)	1 (6.7)	0	5 (33.3)[a]	0	15 (100.0)
LCL	7 (58.3)	0	0	4 (33.3)	1 (8.3)	12 (100.0)
ACL	0	1 (50.0)[a,b]	0	1 (50.0)	0	2 (100.0)
PCL	1 (100.0)[a,b]	0	0	0	0	1 (100.0)
Cap	3 (100.0)	0	0	0	0	3 (100.0)
Total	20 (60.6)	2 (6.1)	0	10 (30.3)[a]	1 (3.0)	33 (100.0)
High school						
MCL	104 (72.2)[c]	6 (4.2)	2 (1.4)	29 (20.1)[d]	3 (2.1)	144 (100.0)
LCL	23 (51.1)	2 (4.4)	0	13 (28.9)	7 (15.6)	45 (100.0)
ACL	44 (44.9)	10 (10.2)	0	36 (36.7)	8 (8.2)	98 (100.0)
PCL	8 (42.1)	3 (15.8)	0	7 (36.8)	1 (5.3)	19 (100.0)
Cap	5 (71.4)	0	0	1 (14.3)	1 (14.3)	7 (100.0)
Total	184 (58.8)[c]	21 (6.7)	2 (0.6)	86 (27.5)[d]	20 (6.4)	313 (100.0)
Collegiate						
MCL	200 (87.0)	7 (3.0)	0	15 (6.5)	8 (3.5)	230 (100.0)
LCL	13 (61.9)	2 (9.5)	0	6 (28.6)	0	21 (100.0)
ACL	41 (49.4)	7 (8.4)	0	33 (39.8)	2 (2.4)	83 (100.0)
PCL	9 (34.6)	12 (46.2)	0	3 (11.5)	2 (7.7)	26 (100.0)
Cap	8 (57.1)	1 (7.1)	0	4 (28.6)	1 (7.1)	14 (100.0)
Total	271 (72.5)	29 (7.8)	0	61 (16.3)	13 (3.5)	374 (100.0)

Abbreviations: ACL, anterior cruciate ligament; Cap, capsular sprain; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

[a] Youth estimate greater than collegiate estimate (injury proportion ratio [IPR] > 1.00).
[b] Youth estimate greater than high school estimate (IPR > 1.00).
[c] Collegiate estimate greater than high school estimate (IPR > 1.00).
[d] High school estimate greater than collegiate estimate (IPR > 1.00).

noncontact mechanisms between high school and youth football (IPR = 0.91; 95% CI = 0.52, 1.57) players.

Injury Activities

Knee-sprain distributions by injury activity are provided in Table 5. Being tackled represented the largest proportion of knee sprains in youth (33.3%) and high school (20.8%) football players. General play was responsible for the largest proportion of knee sprains in collegiate football (24.1%). Tackling accounted for the second-largest proportion of knee sprains in youth football (15.2%), whereas blocking comprised the second-largest proportion in high school (17.9%) and collegiate (19.5%) football players. Similar trends in injury-mechanism distributions were also identified for specific knee-sprain diagnoses.

We found no differences in the proportion of knee sprains that occurred while blocking among the 3 levels of competition. However, differences were present in the proportion of knee sprains that occurred while being blocked, tackling, or being tackled. The proportion of knee sprains that occurred while being blocked was higher in collegiate football than in high school football (IPR = 1.55; 95% CI = 1.04, 2.30) players. No differences existed in the proportion of knee sprains that occurred while being blocked between high school and youth football (IPR = 3.48; 95% CI = 0.49, 24.62) or between collegiate and youth football (IPR = 5.38; 95% CI = 0.77, 37.59) players. The proportion of knee sprains that occurred while tackling was lower in collegiate football than in high school football (IPR = 0.54; 95% CI = 0.36, 0.80). No differences were evident in the proportion of knee sprains that occurred while tackling between high school and youth football (IPR = 1.12; 95% CI = 0.48, 2.60) or between collegiate and youth football (IPR = 0.60; 95% CI = 0.25, 1.43) players. The proportion of all knee sprains that occurred while being tackled was lower in collegiate football than in high school (IPR = 0.71; 95% CI = 0.51, 0.98) or youth (IPR = 0.44; 95% CI = 0.26, 0.76) football players. No differences were seen in the proportion of knee sprains that occurred while being tackled between high school and youth football (IPR = 0.62; 95% CI = 0.37, 1.06) players.

DISCUSSION

We used injury-surveillance data to describe the epidemiology of knee sprains among youth, high school, and collegiate American football players and found differences by competition level in the rates and distributions of knee sprains. Compared with youth and high school football, knee-sprain rates were higher in collegiate football players; however, a smaller proportion of knee sprains was due to tackling, whereas a larger proportion was due to being blocked. These findings may influence injury-prevention strategies by identifying potential needs that are unique to each competition level.

Overall Frequencies and Rates

Knee-sprain rates increased as the competition level increased, with collegiate football having the highest rate and youth football the lowest. Knee-sprain rates in

Table 5. Knee-Sprain Injury Activities by Specific Diagnosis in Youth, High School, and Collegiate Football Players, 2012 Through 2014 Seasons

Level of Play	Activity, No. (%)									
	Blocking	Being Blocked	Tackling	Being Tackled	Receiving Pass	Running	General Play	Conditioning	Other/Unknown	Total
Youth										
MCL	1 (6.7)	0	2 (13.3)	5 (33.3)[a]	2 (13.3)[a,b]	2 (13.3)	2 (13.3)	0	1 (6.7)	15 (100.0)
LCL	0	1 (8.3)	1 (8.3)	4 (33.3)	0	0	1 (8.3)	3 (25.0)	2 (16.7)	12 (100.0)
ACL	1 (50.0)	0	0	1 (50.0)	0	0	0	0	0	2 (100.0)
PCL	0	0	1 (100.0)[a,b]	0	0	0	0	0	0	1 (100.0)
Cap	0	0	1 (33.3)	1 (33.3)	0	0	0	0	1 (33.3)	3 (100.0)
Total	2 (6.1)	1 (3.0)	5 (15.2)	11 (33.3)[a]	2 (6.1)	2 (6.1)	3 (9.1)	3 (9.1)[a,b]	4 (12.1)	33 (100.0)
High school										
MCL	28 (19.4)	12 (8.3)	26 (18.1)[c]	37 (25.7)[c]	1 (0.7)	11 (7.6)	21 (14.6)[d]	1 (0.7)	7 (4.9)	144 (100.0)
LCL	9 (20.0)	5 (11.1)	7 (15.6)	6 (13.3)	3 (6.7)	6 (13.3)	5 (11.1)	1 (2.2)	3 (6.7)	45 (100.0)
ACL	15 (15.3)	9 (9.2)	15 (15.3)	16 (16.3)	0	17 (17.3)	19 (19.4)	0	7 (7.1)	98 (100.0)
PCL	3 (15.8)	5 (26.3)	5 (26.3)	4 (21.1)	0	2 (10.5)	0	0	0	19 (100.0)
Cap	1 (14.3)	2 (28.6)	0	2 (28.6)	0	1 (14.3)	1 (14.3)	0	0	7 (100.0)
Total	56 (17.9)	33 (10.5)	53 (16.9)[c]	65 (20.8)[c]	4 (1.3)	37 (11.8)	46 (14.7)[d]	2 (0.6)	17 (5.4)	313 (100.0)
Collegiate										
MCL	52 (22.6)	42 (18.3)[d]	24 (10.4)	31 (13.5)	5 (2.2)	12 (5.2)	55 (23.9)	0	9 (3.9)	230 (100.0)
LCL	5 (23.8)	3 (14.3)	2 (9.5)	4 (19.0)	3 (14.3)	3 (14.3)	1 (4.8)	0	0	21 (100.0)
ACL	12 (14.5)	13 (15.7)	5 (6)	14 (16.9)	4 (4.8)	13 (15.7)	18 (21.7)	2 (2.4)	2 (2.4)	83 (100.0)
PCL	1 (3.8)	3 (11.5)	1 (3.8)	4 (15.4)	2 (7.7)	1 (3.8)	11 (42.3)	0	3 (11.5)	26 (100.0)
Cap	3 (21.4)	0	2 (14.3)	2 (14.3)	0	2 (14.3)	5 (35.7)	0	0	14 (100.0)
Total	73 (19.5)	61 (16.3)[d]	34 (9.1)	55 (14.7)	14 (3.7)	31 (8.3)	90 (24.1)	2 (0.5)	14 (3.7)	374 (100.0)

Abbreviations: ACL, anterior cruciate ligament; Cap, capsular sprain; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

[a] Youth estimate greater than collegiate estimate (injury proportion ratio [IPR] > 1.00).
[b] Youth estimate greater than high school estimate (IPR > 1.00).
[c] High school estimate greater than collegiate estimate (IPR > 1.00).
[d] Collegiate estimate greater than high school estimate (IPR > 1.00).

collegiate football were 2.73 (95% CI = 2.35, 3.18) and 4.38 (95% CI = 3.07, 6.26) times as high as those in high school and youth football players, respectively. Additionally, the knee-sprain rate in high school football was 1.6 (95% CI = 1.12, 2.30) times as high as that in youth football players. These differences may be due to the larger sizes of players at higher skill levels who generate more force, potentially increasing the chance of injury. These findings are similar to those of previous researchers[18–20] who observed an increased risk of injury among more skilled athletes in various sports. However, earlier investigators also noted contradictory findings when competition was restricted to 1 level. For example, Chomiak et al[21] identified the risk of injury as twice as large for less skilled groups compared with more skilled groups. However, the ranges of ages (14–41 years) and competition levels (youth teams to adult professional teams) in the sample were wide.[21] In our study, we did not examine variations in knee-sprain rates by skill or experience level within each competition level. Thus, the role of skill level at each competition level remains unclear and warrants further examination.

Knee-sprain rates were also higher in competition than in practice at each competition level. This finding is consistent with the results of previous injury-surveillance studies that identified higher competition injury rates in high school athletics,[22] collegiate athletics,[23–25] professional football,[26] and professional soccer.[27,28] The observation highlights the increased intensity of game play that may occur within competitions versus practices. Athletes may be more willing to place themselves at risk of injury during games, and researchers[29] have suggested that individuals may be more willing to take risks if they feel the potential gain is meaningful enough. The perceived gain of winning may be meaningful enough for athletes to take greater risks compared with practices.

Injury Risk

Despite the intuitiveness of risk estimates, authors of epidemiologic studies have not often reported estimates of risk. The risk of sustaining a knee sprain increased as the competition level increased, with the greatest risk of injury occurring in collegiate football players. The risks of incurring a knee sprain in collegiate football were 2.14 (95% CI = 1.83, 2.51) and 7.99 (95% CI = 5.59, 11.41) times greater than in high school and youth football players, respectively. Additionally, the risk of experiencing a knee sprain in high school football was 3.73 (95% CI = 2.60, 5.34) times greater than in youth football. The increased likelihood of injury, which is similar to that found in previous research[18–20] on basketball and netball players, may result from an increased intensity of play associated with higher competition levels.

Specific Knee-Sprain Diagnoses

The MCL was the most commonly injured ligament at all 3 competition levels. Youth and high school MCL injury rates were similar to estimates reported by Roach et al[30] for

intercollegiate (0.11/1000 AEs) and intermural (0.07/1000 AEs) athletes. The second largest proportion of knee sprains for all 3 competition levels involved the ACL. High school and collegiate ACL injury rates were similar to those found in earlier investigations,[25,31–34] which demonstrated rates in a variety of sports between 0.09 and 0.34/1000 AEs. Although the youth ACL injury rate was lower than the rates for the other levels, this estimate may be imprecise because of the small number of ACL injuries that were reported (n = 2). Thus, additional prospective surveillance of ACL injuries in youth football players is needed to drive more precise rate estimates.

Similar to our finding that overall knee-sprain rates increased as the competition level increased, ACL and MCL injury rates also increased as the competition level increased. These findings are similar to those of previous authors,[35] who indicated the ACL injury rate in collegiate athletes was 2.38 times that of high school athletes after adjusting for sport and sex. It is interesting to note that the MCL injury rate was not different between youth and high school football players. Perhaps certain factors increase the MCL injury risk in collegiate football but not at lower competition levels. The possibility of risk factors that are specific to the competition level warrants further examination.

Injury Mechanisms

The largest proportion of knee sprains occurred from player contact. This finding supports previous results of Hootman et al,[25] who noted that the largest proportion of collegiate athletic injuries occurred from player contact (58.0% in games, 41.6% in practices). These observations may indicate a need for injury-prevention strategies, such as rule changes, that can reduce the risk of knee injury resulting from direct player contact. No differences were identified in the proportion of knee sprains that occurred from contact mechanisms between youth football (60.6%) and other competition levels. This finding may be a result of the relatively small number of knee sprains reported in youth football. The proportion of knee sprains resulting from noncontact mechanisms was lowest in collegiate football (16.3%) compared with other competition levels. As a result, injury-prevention programs that reduce the risk of noncontact injury[36–38] may be most valuable at lower competition levels.

Injury Activities

Because of the small number of knee sprains reported in youth football players, comparisons of proportions of knee sprains that resulted from various activities between youth football and other competition levels were limited. However, differences between high school and collegiate football players were identified. Collegiate football players had a lower proportion of knee sprains that resulted from tackling (9.1%) or being tackled (14.7%). One possible explanation for these findings is that the strength and coordination of collegiate football players may allow them to better absorb the impacts that occur during tackling activities. Through repetition and experience, players develop the motor skills of both tackling and being tackled in ways that may prepare them to initiate or absorb contact while minimizing the risk of injury. Additionally, more advanced players may develop strategies to minimize injury risk, such as avoiding contact to their legs or avoiding contact entirely.

FUTURE RESEARCH DIRECTIONS

Based on the findings of our study, future investigators should examine potential injury risk factors that are specific to competition levels in order to better understand injury risk based on skill level. Additionally, efforts should focus on developing injury-prevention strategies to target specific risk factors for knee injury by competition level. For example, strategies that teach youth athletes safe tackling and blocking techniques may reduce knee sprains. Developing such strategies may improve the effectiveness of injury-prevention programs by addressing risk factors specific to each competition level.

LIMITATIONS

The AEs that served as the denominator for knee-sprain rate estimates were recorded at the event level and not by time. Not all athletes participated for the same amount of time during a practice or game; those individuals who participated for longer durations of time may have been at greater risk for injury than those who participated less. However, AEs were not recorded at the time level to reduce the burden on the ATs collecting data. Another limitation is that our risk estimates may underestimate the true population injury risk because of the methods used to calculate athlete-seasons. Athlete-season calculations were based on preseason roster sizes and estimates of team sizes in high school and collegiate football. Because players may have left their teams throughout the course of a season, our athlete-season calculations may contribute to an underestimation of injury risk. We were also not able to obtain specific skill-level information within each competition level. Although we presumably examined skill level by comparing competition levels, it is possible that skill level is an important factor within competition levels as well. In addition, we were unable to account for other variations within competition levels, including the implementation of knee-sprain prevention strategies or the specific types of practice sessions used by each team. Furthermore, coverage differences among competition levels may have influenced injury rates. Collegiate football teams generally have more ATs devoted to medical coverage than high school and youth football teams, which may result in more reported injuries and subsequently a perceived greater risk of injury in collegiate football. Lastly, the relatively low number of injuries in youth football resulted in analytical limitations. Some comparisons between competition levels were not possible because of small sample sizes, especially analyses for specific diagnoses and injury activities.

CONCLUSIONS

Injury-surveillance data were used to describe the rates and patterns of knee injuries in youth, high school, and collegiate American football players. We found differences in rates, risks, and distributions of knee sprains by competition level. The risk of knee sprains increased as the competition level increased, with the highest risk occurring in collegiate football players. Total knee sprain

rates and the proportion due to being blocked were higher in collegiate than in youth or high school football players; however, a smaller proportion of knee sprains were due to tackling. Level-specific variations in the distributions of knee sprains by injury activity may highlight the need to develop policies and prevention strategies that ensure safe sports play. It is important to acknowledge, however, that the low incidence of ACL injury in our sample of youth football players made it difficult to understand differences in rates and patterns of ACL injury between youth football and other competition levels.

ACKNOWLEDGMENTS

Funding for this study was provided by USA Football; the National Athletic Trainers' Association Research & Education Foundation; BioCrossroads, in partnership with the Central Indiana Corporate Partnership Foundation; and the NCAA. The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the programs' sponsors. We thank the many athletic trainers who volunteered their time and efforts to submit data to the NCAA-ISP, NATION, and YFSS programs. Their efforts are greatly appreciated and have had a tremendously positive effect on the safety of athletes.

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Address correspondence to Daniel R. Clifton, MEd, ATC, School of Health and Rehabilitation Sciences, The Ohio State University, 2050 Kenny Road, Columbus, OH 43221. Address e-mail to clifton.95@osu.edu.