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original research

Epidemiology of National Collegiate Athletic Association Women's Gymnastics Injuries, 2009–2010 Through 2013–2014

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Context: Recent injury-surveillance data for collegiate-level women's gymnastics are limited. In addition, researchers have not captured non–time-loss injuries (ie, injuries resulting in restriction of participation <1 day).

Objective: To describe the epidemiology of National Collegiate Athletic Association (NCAA) women's gymnastics injuries during the 2009–2010 through 2013–2014 academic years.

Design: Descriptive epidemiology study.

Setting: Aggregate injury and exposure data collected from 11 women's gymnastics programs providing 28 seasons of data.

Patients or Other Participants: Collegiate student-athletes participating in women's gymnastics during the 2009–2010 through 2013–2014 academic years.

Intervention(s): Women's gymnastics data from the NCAA Injury Surveillance Program (ISP) during the 2009–2010 through 2013–2014 academic years were analyzed.

Main Outcome Measure(s): Injury rates; injury rate ratios; injury proportions by body site, diagnosis, and apparatus; and injury proportion ratios were reported with 95% confidence intervals (CIs).

Results: The ISP captured 418 women's gymnastics injuries, a rate of 9.22/1000 athlete-exposures (AEs; 95% CI = 8.33, 10.10). The competition injury rate (14.49/1000 AEs) was 1.67 times the practice injury rate (8.69/1000 AEs; 95% CI = 1.27, 2.19). When considering time-loss injuries only, the injury rate during this study period (3.62/1000 AEs) was lower than rates reported in earlier NCAA ISP surveillance data. Commonly injured body sites were the ankle (17.9%, n = 75), lower leg/Achilles tendon (13.6%, n = 57), trunk (13.4%, n = 56), and foot (12.4%, n = 52). Common diagnoses were ligament sprain (20.3%, n = 85) and muscle/tendon strain (18.7%, n = 78). Overall, 12.4% (n = 52) of injuries resulted in time loss of more than 3 weeks. Of the 291 injuries reported while a student-athlete used an apparatus (69.6%), most occurred during the floor exercise (41.9%, n = 122) and on the uneven bars (28.2%, n = 82).

Conclusions: We observed a lower time-loss injury rate for women's gymnastics than shown in earlier NCAA ISP surveillance data. Safety initiatives in women's gymnastics, such as "sting mats," padded equipment, and a redesigned vault table, may have contributed to minimizing the frequency and severity of injury.

Key Words: incidence, sports, injury surveillance

Key Points

- The time-loss injury rate for women's gymnastics was lower than that demonstrated in earlier National Collegiate Athletic Association Injury Surveillance Program surveillance data.
- Lower extremity injuries composed the largest proportion of injuries.
- Injury distributions varied by apparatus, with the floor exercise accounting for the largest proportion of injuries.
- Researchers should monitor and evaluate the use of injury-prevention strategies.

When the National Collegiate Athletic Association (NCAA) conducted its first national championship in women's gymnastics during the 1981–1982 academic year, 179 teams and 2063 athletes participated.[1] However, over the past 30 years, participation has decreased. In the 2012–2013 academic year, 82 teams and 1488 athletes participated, but the average squad size per team increased from 11.5 in 1981–1982 to 18.1.[1] Despite the decrease in the overall number of student-athletes participating annually, collegiate women's gymnastics programs continue to recruit student-athletes who began specialized training at an early age. Early specialization, coupled with high-impact upper and lower extremity movements, may place student-athletes at increased risk of injury in college, particularly if they ignore signs of overuse.[2,3] Therefore, examining the incidence of injuries sustained during women's gymnastics will help drive the development of targeted injury-prevention interventions.

Numerous researchers have examined the epidemiology of women's gymnastics at multiple levels, including club sports,[4,5] high school,[6] college,[7,8] and elite.[9,10] Investigators[4–12] have predominantly reported that lower extremity injuries, sprains, strains, and overuse injuries composed the largest proportions of injuries that female gymnasts sustained. In addition, researchers[7] have highlighted the lower back as an area of concern for female gymnasts. Most injuries were reported to have occurred during the floor

exercise and on the uneven bars.[4–7] Varying apparatus-specific mechanisms of injury occur.[7,13]

Such findings have contributed to the implementation of equipment modifications, such as using a "sting mat" to soften landings and absorb landing impacts[14]; adding padding to balance beams; and using a new vaulting table, which features a larger and cushioned push-off surface. However, few researchers have examined women's gymnastics-related injuries over the past decade. Samples from recent research have been small[13] or have focused on younger gymnasts, whose injuries may differ from those of collegiate-level student-athletes who have fully developed physically.[4,11] From 2009–2010 through 2013–2014, the NCAA Injury Surveillance Program (ISP) has monitored all injuries occurring in a sample of women's gymnastics varsity teams. Unlike past research[7] examining NCAA women's gymnastics, this study captured non–time-loss (NTL) injuries (ie, injuries resulting in restriction of participation <1 day) to optimally summarize the types of injuries that athletic trainers (ATs) manage and treat. Therefore, the purpose of our study was to use data from the NCAA ISP to describe the epidemiology of women's gymnastics injuries occurring within the NCAA competition level during the 2009–2010 through 2013–2014 academic years.

METHODS

Data were obtained from the NCAA ISP, which is managed by the Datalys Center for Sports Injury Research and Prevention, Inc, an independent, nonprofit research organization.[15] The ISP depends on a convenience sample of amateur varsity sport teams with ATs reporting injury data. More in-depth information about the methods of the NCAA ISP during the 2009–2010 through 2013–2014 academic years is available in a previous publication[15,*] but is also summarized in this section.

Data Collection

The ATs from participating programs reported injuries in real time through their electronic health record applications throughout the academic year. They also had the option to use the Datalys Center's in-house Injury Surveillance Tool (Datalys Center, Indianapolis, IN) to provide data. Common data elements that included injury and exposure information from the electronic health record applications and the Injury Surveillance Tool were deidentified, recoded, and exported to an aggregate database. In addition to unintentional injuries, the surveillance system captured other sport-related adverse health (ie, illness) events, such as heat-related conditions, general medical conditions, and skin infections. Only varsity-level practice and competition events were included in the ISP data sets. Junior varsity programs and any individual weight-training and conditioning sessions were excluded.

For each event, the ATs completed a detailed report on the injury or condition (eg, site, diagnosis) and the circumstances (eg, activity, mechanism, event type [ie, competition or practice]). They could view and update previously submitted information as needed during the course of a season. When an athlete was able to return to participation, ATs provided the date of return, which generated the number of days of time loss (calculated as the difference between the return date and the injury date). For injuries that restricted participation beyond the end of the season, ATs used the date on which athletes were able to safely return to sport-specific activity as the date of return. They also provided the number of student-athletes participating in each practice and competition.

Before arriving at the Datalys Center, the data were stripped of any identifiers and personally identifiable information (eg, name, date of birth, insurance information) and retained only relevant variables and values.[15] Exported data passed through an automated verification process that conducted a series or range of consistency checks. Data were reviewed and flagged for invalid values. The automated verification process would notify the ATs and data quality-control staff, who would help the ATs resolve the concern. Data that passed the verification process were placed into sport-specific aggregate data sets used for analysis. Data provided to the researchers for this study used the women's gymnastics aggregate data set.

Definitions

A *reportable injury* in the ISP was defined as an injury that (1) occurred as a result of participation in an organized intercollegiate practice or competition and (2) required attention from an AT or physician. Multiple injuries occurring from 1 injury event could be included. As opposed to the previous 25 years of NCAA-reported data that reported only time-loss (TL) injuries, this 5-year data set was uniquely different because NTL injuries were included.

A *reportable athlete-exposure* (AE) was defined as 1 student-athlete participating in 1 NCAA-sanctioned practice or competition in which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation. Only student-athletes with actual playing time in a competition were included in competition exposures.

Statistical Analysis

Data were analyzed to assess rates and patterns of collegiate women's gymnastics injuries. Body parts were categorized as *head/face*, *neck*, *shoulder/clavicle*, *arm/elbow*, *hand/wrist, trunk* (including chest, abdomen, upper back, and lower back), *hip/thigh/upper leg*, *knee*, *lower leg/Achilles tendon*, *ankle*, *foot*, and *other*. No injuries were recorded for the upper leg. Diagnoses were categorized as *ligament sprain*, *muscle/tendon strain*, *inflammation* (including bursitis and tendinitis), *entrapment/impingement*, *contusion/abrasion*, *concussion*, *fracture*, *stress fracture*, *dislocation/subluxation*, and *other*. In addition, *knee internal derangement* included any isolated or combined anterior cruciate ligament, posterior cruciate ligament, collateral ligament (medial or lateral, not differentiated), or meniscus (medial or lateral, not differentiated) injury. The number of days that injuries restricted participation was categorized as *NTL injuries*, resulting in restricted

* Portions of the Methods section are reprinted with permission. Kerr ZY, Dompier TP, Snook EM, et al. National Collegiate Athletic Association Injury Surveillance System: review of methods for 2004–2005 through 2013–2014 data collection. *J Athl Train*. 2014;49(4):552–560.

Table 1. Injury Rates and 95% Confidence Intervals by Time in Season and Type of Athlete-Exposure in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Injuries	Practice			Competition			Total		
	Injuries in Sample, No.	Athlete-Exposures	Rate (95% Confidence Interval) per 1000 Athlete-Exposures	Injuries in Sample, No.	Athlete-Exposures	Rate (95% Confidence Interval) per 1000 Athlete-Exposures	Injuries in Sample, No.	Athlete-Exposures	Rate (95% Confidence Interval) per 1000 Athlete-Exposures
All									
Preseason	257	25 014	10.27 (9.02, 11.53)	0	0	Not applicable	257	25 014	10.27 (9.02, 11.53)
Regular season	88	12 917	6.81 (5.39, 8.24)	55	3627	15.16 (11.16, 19.17)	143	16 544	8.64 (7.23, 10.06)
Postseason	13	3278	3.97 (1.81, 6.12)	5	515	9.71 (1.20, 18.22)	18	3793	4.75 (2.55, 6.94)
Total	358	41 209	8.69 (7.79, 9.59)	60	4142	14.49 (10.82, 18.15)	418	45 351	9.22 (8.33, 10.10)
All time loss									
Preseason	91	25 014	3.64 (2.89, 4.39)	0	0	Not applicable	91	25 014	3.64 (2.89, 4.39)
Regular season	37	12 917	2.86 (1.94, 3.79)	29	3627	8.00 (5.09, 10.91)	66	16 544	3.99 (3.03, 4.95)
Postseason	4	3278	1.22 (0.02, 2.42)	3	515	5.83 (0.00, 12.42)	7	3793	1.85 (0.48, 3.21)
Total	132	41 209	3.20 (2.66, 3.75)	32	4142	7.73 (5.05, 10.40)	164	45 351	3.62 (3.06, 4.17)
All severe[b]									
Preseason	36	25 014	1.44 (0.97, 1.91)	0	0	Not applicable	36	25 014	1.44 (0.97, 1.91)
Regular season	8	12 917	0.62 (0.19, 1.05)	6	3627	1.65 (0.33, 2.98)	14	16 544	0.85 (0.40, 1.29)
Postseason	1	3278	0.31 (0.00, 0.90)	1	515	1.94 (0.00, 5.75)	2	3793	0.53 (0.00, 1.26)
Total	45	41 209	1.09 (0.77, 1.41)	7	4142	1.69 (0.44, 2.94)	52	45 351	1.15 (0.83, 1.46)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014.
[b] Includes injuries that resulted in time loss >3 weeks or the student-athlete prematurely ending his or her season.

participation for less than 1 day; *injuries*, resulting in time loss of 1 to 21 days; and *severe injuries*, resulting in a time loss of more than 3 weeks.

Data were analyzed using SAS Enterprise Guide software (version 4.3; SAS Institute Inc, Cary, NC). Statistical analyses included calculation of rate ratios (RRs), injury proportion ratios (IPRs), and χ^2 tests. The overall injury rate was calculated as the ratio of injuries per 1000 total AEs. Injury rates were also calculated as the ratio of practice injuries per 1000 practice exposures and the ratio of competition injuries per 1000 competition exposures. Injury rates were also calculated per NCAA division. The following is an example of an RR comparing competition and practice injury rates:

$$\mathrm{RR} = \frac{\text{number of competition injuries}}{\text{number of competition AEs}} \Bigg/ \frac{\text{number of practice injuries}}{\text{number of practice AEs}}$$

The following is an example of an IPR comparing the proportion of shoulder injuries sustained on the uneven bars apparatus and all other apparatuses:

$$\mathrm{IPR} = \frac{\text{number of shoulder injuries on the uneven bars}}{\text{number of total injuries on the uneven bars}} \Bigg/ \frac{\text{number of shoulder injuries on all other apparatuses}}{\text{number of total injuries on all other apparatuses}}$$

All 95% confidence intervals (CIs) not containing 1.0 were considered different. This study was approved by the Research Review Board of the NCAA.

RESULTS

Overall Frequencies and Rates

During the 2009–2010 through 2013–2014 academic years, ATs reported 418 college women's gymnastics injuries across 28 team seasons from 11 programs. A total of 358 injuries (85.6%) occurred during practice, and 60 (14.4%) occurred during competition. Most injuries (61.5%, n = 257) occurred in the preseason, 34.2% (n = 143) in the regular season, and 4.3% (n = 18) in the postseason. Overall, 12.4% (n = 52) of injuries resulted in time loss of more than 3 weeks. Of these severe injuries, 46.2% (n = 24) returned to sport participation after 3 weeks, and 53.8% (n = 28) resulted in student-athletes prematurely ending their seasons. Of all injuries, 6.7% (n = 28) required surgery, and 16.3% (n = 68) were recurrent injuries.

These 418 injuries occurred during 45 351 AEs, for an injury rate of 9.22/1000 AEs (95% CI = 8.33, 10.10; Table 1). However, when considering only injuries resulting in time loss of at least 1 day (39.2%, n = 164), the injury rate was reduced to 3.62/1000 AEs (95% CI = 3.06, 4.17). During the 5-year period, the injury rate remained steady, with the highest and lowest rates occurring in the 2009–2010 (9.81/1000 AEs) and 2013–2014 (8.22/1000 AEs) academic years (Figure).

The competition injury rate (14.49/1000 AEs) was 1.67 times the practice injury rate (8.69/1000 AEs; 95% CI = 1.27, 2.19). However, injury rates for competition (11.94/1000 AEs) and practice (11.45/1000 AEs) did not differ

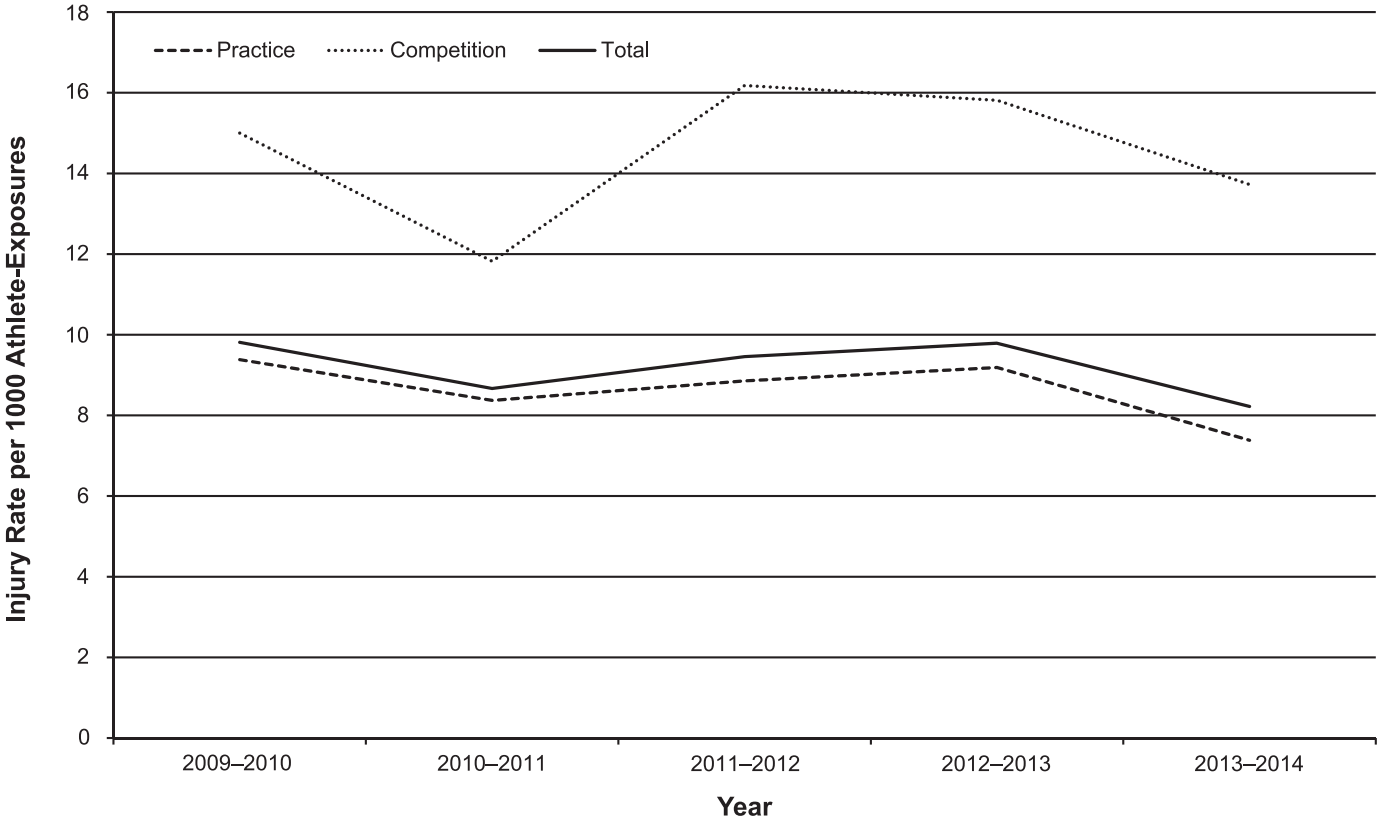

Figure. Injury rates per 1000 athlete-exposures by competition, practice, and academic year for women's gymnastics from 2009–2010 through 2013–2014. Note that all injuries, regardless of the time restriction from participation, are included.

within Division I (RR = 1.04; 95% CI = 0.70, 1.56). In addition, the injury rate was higher in Division I (11.50/1000 AEs) than in Divisions II and III (7.10/1000 AEs; RR = 1.62; 95% CI = 1.33, 1.97). Among practices, the preseason injury rate (10.27/1000 AEs) was 1.65 times the rate of injury during the regular season and postseason combined (6.24/1000 AEs; 95% CI = 1.31, 2.07). However, this RR was not different when considering only TL injuries (RR = 1.44; 95% CI = 1.00, 2.07).

Body Sites Injured and Diagnoses

Commonly injured body sites included the ankle (17.9%, n = 75), lower leg/Achilles tendon (13.6%, n = 57), trunk (13.4%, n = 56), and foot (12.4%, n = 52; Table 2). Among body parts, the knee had the largest proportion of severe injuries (30.2%, n = 13) and injuries requiring surgery (20.9%, n = 9). The severe knee injuries requiring surgery were mostly tears to the anterior cruciate ligament. Among body parts, the shoulder (29.6%, n = 8), ankle (26.7%, n =

Table 2. Distribution of Body Parts Injured in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Body Part	Injuries in Sample, No. (%)	Rate (95% Confidence Interval) per 1000 Athlete-Exposures	Non–Time-Loss Injuries, No. (%)	Severe Injuries, No. (%)[b]	Requiring Surgery, No. (%)	Recurrent Injuries, No. (%)
Head/face	20 (4.8)	0.44 (0.25, 0.63)	5 (25.0)	3 (15.0)	1 (5.0)	0 (0.0)
Neck	3 (0.7)	0.07 (0.00, 0.14)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)
Shoulder/clavicle	27 (6.5)	0.60 (0.37, 0.82)	16 (59.3)	2 (7.4)	2 (7.4)	8 (29.6)
Arm/elbow	35 (8.4)	0.77 (0.52, 1.03)	20 (57.1)	10 (28.6)	2 (5.7)	5 (14.3)
Hand/wrist	14 (3.4)	0.31 (0.15, 0.47)	10 (71.4)	0 (0.0)	2 (14.3)	2 (14.3)
Trunk	56 (13.4)	1.23 (0.91, 1.56)	33 (58.9)	7 (12.5)	3 (5.4)	8 (14.3)
Hip/thigh/upper leg	29 (6.9)	0.64 (0.41, 0.87)	23 (79.3)	1 (3.5)	0 (0.0)	2 (6.9)
Knee	43 (10.3)	0.95 (0.66, 1.23)	21 (48.8)	13 (30.2)	9 (20.9)	4 (9.3)
Lower leg/Achilles tendon	57 (13.6)	1.26 (0.93, 1.58)	43 (75.4)	4 (7.0)	3 (5.3)	12 (21.1)
Ankle	75 (17.9)	1.65 (1.28, 2.03)	41 (54.6)	5 (6.7)	2 (2.7)	20 (26.7)
Foot	52 (12.4)	1.15 (0.83, 1.46)	31 (59.6)	7 (13.5)	2 (3.9)	6 (11.5)
Other	7 (1.7)	0.15 (0.04, 0.27)	5 (71.4)	0 (0.0)	0 (0.0)	1 (14.3)
Total	418 (100.0)	9.22 (8.33, 10.10)	249 (59.6)	52 (12.4)	26 (6.2)	68 (16.3)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.

[b] Includes injuries that resulted in time loss >3 weeks or the student-athlete prematurely ending his or her season.

Table 3. Distribution of Injury Diagnoses in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Injury Diagnosis	Injuries in Sample, No. (%)	Rate (95% Confidence Interval) per 1000 Athlete-Exposures	Non–Time-Loss Injuries, No. (%)	Severe Injuries, No. (%)[b]	Requiring Surgery, No. (%)	Recurrent Injuries, No. (%)
Ligament sprain	85 (20.3)	1.87 (1.48, 2.27)	33 (38.8)	14 (16.5)	5 (5.9)	8 (9.4)
Muscle/tendon strain	78 (18.7)	1.72 (1.34, 2.10)	52 (66.7)	5 (6.4)	6 (7.7)	8 (10.3)
Inflammation[c]	47 (11.2)	1.04 (0.74, 1.33)	41 (87.2)	0 (0.0)	0 (0.0)	8 (17.0)
Entrapment/impingement	13 (3.1)	0.29 (0.13, 0.44)	10 (76.9)	0 (0.0)	0 (0.0)	4 (30.8)
Contusion/abrasion	32 (7.7)	0.71 (0.46, 0.95)	25 (78.1)	1 (3.1)	0 (0.0)	3 (9.4)
Concussion	12 (2.9)	0.26 (0.11, 0.41)	1 (8.3)	3 (25.0)	0 (0.0)	0 (0.0)
Fracture	15 (3.6)	0.33 (0.16, 0.50)	4 (26.7)	9 (60.0)	5 (33.3)	3 (20.0)
Stress fracture	16 (3.8)	0.35 (0.18, 0.53)	9 (56.3)	2 (12.5)	1 (6.3)	3 (18.8)
Dislocation/subluxation	14 (3.4)	0.31 (0.15, 0.47)	2 (14.3)	9 (64.3)	3 (21.4)	3 (21.4)
Other[d]	106 (25.4)	2.34 (1.89, 2.78)	72 (67.9)	9 (8.5)	6 (5.7)	28 (26.4)
Total	418 (100.0)	9.22 (8.33, 10.10)	249 (59.6)	52 (12.4)	26 (6.2)	68 (16.3)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.
[b] Includes injuries that resulted in time loss >3 weeks or the student-athlete prematurely ending his or her season.
[c] Includes bursitis and tendinitis.
[d] Includes injuries with counts <10. Injuries in this category with multiple reports included spasms (n = 6), synovitis (n = 4), chondromalacia (n = 3), nosebleed (n = 3), hyperextension (n = 3), capsulitis (n = 3), tendinosis (n = 2), bone spur (n = 2), spinal stenosis (n = 2), and disc injury (n = 2). In addition, injuries included those coded for diagnosis as *miscellaneous*.

20), and lower leg/Achilles tendon (21.1%, n = 12) had the largest proportion of recurrent injuries.

Common diagnoses included ligament sprain (20.3%, n = 85) and muscle/tendon strain (18.7%, n = 78; Table 3). Diagnoses with the largest proportions of severe injuries were dislocations/subluxations (64.3%, n = 9) and fractures (60.0%, n = 9). In addition, dislocations/subluxations and fractures had the greatest proportions of surgeries (21.4%, n = 3, and 33.3%, n = 5, respectively). Entrapments/impingements (30.8%, n = 4) and dislocations (21.4%, n = 3) had the largest proportions of recurrent injuries.

The most common injuries were ankle sprains (11.2%). These 47 ankle sprains included 31 lateral ligament complex sprains and 12 medial (deltoid) ligament sprains. Other common injuries included hip/thigh/upper leg strains (4.8%, n = 20), lower leg/Achilles tendon inflammations (4.3%, n = 18), and internal knee derangements (4.1%, n = 17). In addition, 6 lower back strains were reported, but 4 resulted in time loss of less than 1 day. The competition injury rate of internal knee derangements (1.45/1000 AEs) was 5.43 times that of practice (0.27/1000 AEs; 95% CI = 2.01, 14.67). In addition, the competition injury rate of medial (deltoid) ligament sprains (1.45/1000 AEs) was 9.95 times that of practice (0.15/1000 AEs; 95% CI = 3.21, 30.85). Internal knee derangements also composed the largest proportion of severe injuries (47.1%, n = 8) and injuries requiring surgery (41.2%, n = 7).

Mechanism of Injury and Apparatuses

Of the 383 (91.6%) injuries with a known mechanism, most were sustained from contact with the surface (33.7%, n = 129) or overuse (29.8%, n = 114; Table 4). Few overuse injuries were severe (2.6%, n = 3), and none required surgery. However, 20.9% (n = 27) and 7.8% (n = 10) of injuries due to contact with the surface were severe and required surgery, respectively.

Of the 291 (69.6%) injuries reported during an apparatus event, most occurred during the floor exercise (41.9%, n = 122) and on the uneven bars (28.2%, n = 82). Differences existed among apparatuses by body site, diagnosis, and

Table 4. Distribution of Mechanisms of Injury in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a,b]

Mechanism of Injury	Injuries in Sample, No. (%)	Rate (95% Confidence Interval) per 1000 Athlete-Exposures	Non–Time-Loss Injuries, No. (%)	Severe Injuries, No. (%)[c]	Requiring Surgery, No. (%)	Recurrent Injuries, No. (%)
Contact with another person	6 (1.6)	0.13 (0.03, 0.24)	1 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)
Contact with surface (ie, mat)	129 (33.7)	2.84 (2.35, 3.34)	58 (45.0)	27 (20.9)	10 (7.8)	19 (14.7)
Contact with apparatus	63 (16.5)	1.39 (1.05, 1.73)	34 (54.0)	10 (15.9)	4 (6.4)	7 (11.1)
Contact with out-of-bounds object	2 (0.5)	0.04 (0.00, 0.11)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)
No apparent contact[d]	62 (16.2)	1.37 (1.03, 1.71)	35 (56.5)	7 (11.4)	7 (11.3)	11 (17.7)
Overuse/gradual	114 (29.8)	2.51 (2.05, 2.98)	95 (83.3)	3 (2.6)	0 (0.0)	22 (19.3)
Illness/infection	7 (1.8)	0.15 (0.04, 0.27)	5 (71.4)	0 (0.0)	0 (0.0)	0 (0.0)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.
[b] Includes the 383 injuries with a known mechanism of injury (91.6% of all injuries).
[c] Includes injuries that resulted in time loss >3 weeks or the student-athlete prematurely ending his or her season.
[d] Includes injuries that were not caused by contact but not considered overuse/gradual or illness/infection, such as sustaining an ankle sprain while running or a lower leg strain while decelerating.

Table 5. Body Part Injured, Diagnosis, Severity of Injury, and Surgery Needs by Apparatus in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Variable	Apparatus[b]			
	Balance Beam, No./48 (%)	Floor Exercise, No./122 (%)	Uneven Bars, No./82 (%)	Vault, No./39 (%)
Body part				
Head/face	3 (6.3)	5 (4.1)	6 (7.3)	0 (0.0)
Neck	0 (0.0)	0 (0.0)	2 (2.4)	1 (2.6)
Shoulder/clavicle	0 (0.0)	2 (1.6)	15 (18.3)	0 (0.0)
Arm/elbow	4 (8.3)	2 (1.6)	14 (17.1)	6 (15.4)
Hand/wrist	2 (4.2)	0 (0.0)	9 (11.0)	1 (2.6)
Trunk	5 (10.4)	8 (6.6)	11 (13.4)	5 (12.8)
Hip/thigh/upper leg	5 (10.4)	5 (4.1)	5 (6.1)	3 (7.7)
Knee	5 (10.4)	22 (18.0)	5 (6.1)	4 (10.3)
Lower leg/Achilles tendon	1 (2.1)	34 (27.8)	1 (1.2)	6 (15.4)
Ankle	10 (20.8)	33 (27.1)	3 (3.7)	10 (25.6)
Foot	13 (27.1)	11 (9.0)	11 (13.4)	3 (7.7)
Other	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Diagnosis				
Ligament sprain	15 (31.3)	32 (26.2)	12 (14.6)	8 (20.5)
Muscle/tendon strain	5 (10.4)	19 (15.6)	18 (22.0)	11 (28.2)
Inflammation[c]	1 (2.1)	15 (12.3)	5 (6.1)	5 (12.8)
Entrapment/impingement	0 (0.0)	5 (4.1)	4 (4.9)	1 (2.6)
Contusion/abrasion	11 (22.9)	7 (5.7)	10 (12.2)	2 (5.1)
Concussion	2 (4.2)	4 (3.3)	4 (4.9)	0 (0.0)
Fracture	2 (4.2)	2 (1.6)	6 (7.3)	0 (0.0)
Stress fracture	0 (0.0)	6 (4.9)	0 (0.0)	2 (5.1)
Dislocation/subluxation	2 (4.2)	2 (1.6)	7 (8.5)	1 (2.6)
Other	10 (20.8)	30 (24.6)	16 (19.5)	9 (23.1)
Injury severity and surgery needs[d]				
Non–time-loss injuries	26 (54.2)	70 (57.4)	42 (51.2)	27 (69.2)
Severe injuries[e]	5 (10.4)	19 (15.6)	15 (18.3)	4 (10.3)
Requiring surgery	2 (4.2)	9 (7.4)	9 (11.0)	1 (2.6)
Recurrent injuries	5 (10.4)	21 (17.2)	7 (8.5)	7 (17.9)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.
[b] Does not include 20 general conditioning injuries, and 7 competition and 100 practice injuries with unknown or missing apparatus data.
[c] Includes bursitis and tendinitis.
[d] Does not include injuries with unknown or missing mechanism injury. Percentages are calculated from only those injuries with a known injury mechanism.
[e] Includes injuries that resulted in time loss >3 weeks or the student-athlete prematurely ending his or her season.

mechanism of injury (Tables 5 and 6). Shoulder injuries composed a larger proportion of injuries on the uneven bars (18.3%, n = 15) than on other apparatuses (1.0%, n = 2; IPR = 19.1; 95% CI = 4.5, 81.74). Lower leg/Achilles tendon injuries were responsible for a larger proportion of injuries in the floor exercise (27.8%, n = 34) than on other apparatuses (4.7%, n = 8; IPR = 5.89; 95% CI = 2.83, 12.28). In addition, contusions accounted for a larger

Table 6. Mechanism of Injury by Apparatus in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Mechanism of Injury[b]	Apparatus[c]			
	Balance Beam, No./44 (%)	Floor Exercise, No./111 (%)	Uneven Bars, No./77 (%)	Vault, No./38 (%)
Contact with another person	0 (0.0)	0 (0.0)	1 (1.3)	1 (2.6)
Contact with surface (ie, mat)	8 (18.2)	54 (48.7)	32 (41.6)	16 (42.1)
Contact with apparatus	27 (61.4)	1 (0.9)	26 (33.8)	6 (15.8)
Contact with out-of-bounds object	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
No apparent contact[d]	5 (11.4)	19 (17.1)	10 (13.0)	1 (2.6)
Overuse/gradual	4 (9.1)	37 (33.3)	8 (10.4)	14 (36.8)
Illness/infection	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.
[b] Does not include injuries with unknown or missing mechanism of injury.
[c] Does not include 20 general conditioning injuries and 7 competition and 100 practice injuries with unknown or missing apparatus data.
[d] Includes injuries that were not caused by contact but not considered overuse/gradual or illness/infection, such as sustaining an ankle sprain while running or a lower leg strain while decelerating.

Table 7. Most Common Injuries Associated With an Apparatus in National Collegiate Athletic Association Women's Gymnastics, 2009–2010 Through 2013–2014[a]

Apparatus	Most Common Injury	Injuries Associated With Apparatus, No. %	Most Frequent Mechanism of Apparatus Injury (No.)
Balance beam (n = 48)	Ankle sprain	8 (16.7)	Contact with surface (ie, mat) (5)
	Hip/thigh/upper leg contusion	4 (8.3)	Contact with balance beam (2)
	Foot sprain	4 (8.3)	Contact with balance beam (4)
Floor exercise (n = 122)	Ankle sprain	20 (16.4)	Contact with surface (ie, mat) (16)
	Lower leg inflammation	11 (9.0)	Overuse (11)
	Knee internal derangement	11 (9.0)	Contact with surface (ie, mat) (7)
Uneven bars (n = 82)	Concussion	4 (4.9)	Contact with surface (ie, mat) (3)
	Shoulder muscle/tendon strain	4 (4.9)	No apparent contact (2)
	Hand/wrist sprain	4 (4.9)	Contact with uneven bars (3)
Vault (n = 39)	Ankle sprain	5 (12.8)	Contact with surface (ie, mat) (3)
	Arm/elbow muscle/tendon strain	3 (7.7)	Overuse (2)
	Lower leg/Achilles tendon inflammation	3 (7.7)	Overuse (3)

[a] Data originated from the Datalys Center for Sports Injury Research and Prevention Injury Surveillance Program, 2009–2010 through 2013–2014. Data include multiple injuries that may have occurred at 1 injury event.

proportion of injuries on the balance beam (22.9%, n = 11) than on other apparatuses (7.8%, n = 19; IPR = 2.93; 95% CI = 1.49, 5.76). Overuse injuries composed a larger proportion of injuries for the floor exercise and vault (31.7%, n = 51) than the balance beam and uneven bars (9.2%, n = 12; IPR = 3.43; 95% CI = 1.91, 6.16).

Ankle sprains were responsible for large proportions of injuries on all apparatuses (Table 7). Contact with the surface accounted for many of these injuries, followed by contact with the apparatus (ie, balance beam, uneven bars). Whereas only 10 concussions occurred on gymnastics apparatuses (plus 2 that occurred during general practice), 4 (40.0%) occurred on the uneven bars and composed one of the largest proportions of injuries reported with that apparatus. An additional 4 (40.0%) occurred during the floor exercise, and the remaining 2 (20.0%) occurred on the balance beam.

DISCUSSION

We used injury-surveillance data to describe the epidemiology of women's gymnastics at the NCAA level over 5 years. The study is the most robust assessment of women's gymnastics injuries to our knowledge, using surveillance data that have been checked thoroughly for validity and reliability and including NTL injuries. Such data can potentially drive the development of targeted interventions for prevention and health care related to those injuries in women's gymnastics.

Whereas much research exists regarding the epidemiology of women's gymnastics, only a small proportion of researchers have focused on the collegiate level.[7,8] The overall injury rate in our study from 2009–2010 through 2013–2014 (9.22/1000 AEs) was greater than that of previous NCAA surveillance data from 1988/1989 through 2003/2004 (6.07/1000 AEs).[7] This rate increase is due in part to the change in our data-collection method that resulted in an additional 254 NTL injuries that otherwise would not have been captured. When excluding these injuries, the TL injury rate was 3.62/1000 AEs, which is a decrease in the TL injury rate from previous years. This decrease may suggest that safety initiatives in women's gymnastics, such as sting mats, padded equipment, and a redesigned vault table, have contributed to minimizing the frequency and severity of injury.[14]

A larger proportion of injuries occurred during the preseason. In addition, the rate of injuries in the preseason was higher than that in the regular season and postseason combined. Marshall et al[7] speculated that this observation may be attributable to student-athletes learning new skills during the preseason. In addition, athletes not fully recovered from injuries may rest minor injuries and play through them during the regular season and postseason. This may be particularly true given the smaller difference in rates when restricted to TL injuries.

As seen in previous studies,[4,6–10,12] lower extremity injuries composed more than half of all reported injuries. In particular, the knee had the largest proportion of severe injuries and injuries requiring surgery, whereas the ankle and lower leg/Achilles tendon had large proportions of recurrent injuries. At the same time, overuse injuries accounted for approximately 3 in 10 of all reported injuries. Given that gymnastics is high impact, requiring upper and lower body kinetic chain load activity, interventions should focus on the kinesthesia and proprioception needed to perform the technical skills for each of the 4 apparatuses. At the same time, interventions should include examining variations of conditioning and corrective exercises that can reduce the incidence and severity of injury.

Researchers[7,9,10] have also noted the need to further examine lower back injuries. Authors using early NCAA ISP data have observed that lower back strains accounted for 6.1% of all practice injuries and 3.2% of competition injuries.[7] However, from 2009–2010 through 2013–2014, only 2 lower back strains resulting in time loss of at least 1 day were reported. At the same time, a low number of concussions were reported (n = 12). Yet one-third of reported concussions occurred during use of the uneven bars, all of which were sustained because of contact with the mat/floor. This observation may suggest that gymnasts either fell during their routines, possibly because of failed catch-release moves, or did not land properly during their dismounts. Given the low participation from sponsoring schools (approximately 6 teams per year), we emphasize the need for continued surveillance to better ascertain the incidence of lower back strains and concussions.

Our exposures did not distinguish participation by apparatus, so we could not calculate apparatus-specific injury rates. Such apparatus-specific exposure information would also allow us to better decipher the disproportionate number of injuries occurring during the floor exercise. Researchers[4–7] have highlighted the higher frequency of floor-exercise–related injuries, particularly to the knee and ankle. However, our observations may have been biased because of measurement error related to exposure ascertainment. Overuse injuries may be sustained because of cumulative exposure on apparatuses rather than the apparatus itself. Thus, future research may benefit from the collection of cumulative exposure data that can be stratified appropriately by apparatus to better determine the effectiveness of such interventions.

A large proportion of known injuries during the floor exercise affected the ankle and lower leg/Achilles tendon. Many injuries to these body parts were also recurrent. This high frequency of injury may be attributable to the mechanics of the floor exercise. The force on the lower extremities due to takeoffs and landings from repetitive tumbling may contribute to the incidence and severity of injury.[7,16] In addition, as student-athletes land from tumbles, they may not reach sufficient rotation (ie, underrotate), causing the angle of inclination in the ankle to be more acute (ie, sharper angle to the floor) and thus making it stretch farther than it should. A points ceiling exists in the collegiate scoring system (a perfect 10), and student-athletes may not be rewarded more points for more difficult variations of skills (eg, a double-twisting Yurchenko vault compared with a Yurchenko full). Still, Marshall et al[7] argued that recent judging may favor rewarding skills with higher degrees of difficulty as opposed to artistic aspects. Such focus on difficult tumbling routines may pressure gymnasts to perform high-risk skills in a repetitive fashion, in a fatigued state, or before mastering the skill. Therefore, Marshall et al[7] recommended a greater deduction for falls to reinforce performing skills only when the gymnast has mastered them. Future researchers should provide more in-depth examinations of skills performed to determine if degree of difficulty is associated with injury risk.

Marshall et al[7] noted that previous injury-surveillance data may not have fully captured the injuries occurring in women's gymnastics, as the methods did not capture or account for NTL injuries. Whereas injuries may restrict participation, student-athletes also may alter participation.[17] For example, a gymnast who sustains an ankle sprain still may train on the uneven bars but not land on the injured leg. Altered participation may result in risk of more severe future injury.[17] For example, continued participation with painful inflammation in the Achilles tendon may lead to a rupture.[8] To our knowledge, few investigators[18,19] have reported NTL injuries in general. The only researchers to study collegiate female student-athletes have reported that 84% of injuries were not associated with time loss.[18] However, gymnastics was not included. We are the first to our knowledge to examine NTL injuries in collegiate women's gymnastics, observing that almost 2 in 3 injuries seen by ATs did not restrict participation for at least 1 day. Including NTL injuries will help to ascertain the true burden of injury sustained by collegiate student-athletes and managed by ATs.

Our study had limitations. First, team participation in data collection was low, but the Datalys Center is making efforts to increase participation. Therefore, our observations may not be generalizable to the other collegiate women's gymnastics programs. In addition, AEs were unit based rather than time based. Thus, we could not report injury rates by minute or hour of practice and competition. This recording method provides consistency for comparisons across various sport-injury–surveillance research outcomes. This limitation was also necessary to reduce reporter burden. As mentioned, our exposures were not stratified by apparatus, so we were unable to estimate apparatus-specific injury rates. We also did not collect information about whether gymnasts were all-around competitors or apparatus specialists, both of which potentially may place student-athletes at risk for different types of injuries. All-around competitors may sustain injuries that may be partially attributable to previous events on different apparatuses. Practice routines and equipment (eg, foam landing pits, flooring, mats) also were not monitored.

CONCLUSIONS

We observed a lower TL injury rate for women's gymnastics than in earlier NCAA ISP data.[7] In addition, our results were consistent with previous research in which investigators found that lower extremity injuries composed the largest proportion of injuries. Injury distributions varied by apparatus, with the floor exercise responsible for the largest proportion of injuries. Sport-related injury-surveillance data can help drive the development of targeted research and injury-prevention interventions in women's gymnastics. These include better ascertainment of apparatus-specific exposures and athlete types (ie, all-around versus apparatus specialist). In future studies, researchers should also monitor and evaluate the use of injury-prevention strategies, including foam pits, low-impact cardiovascular routines, limited-impact routines, years in competitive gymnastics, participation with pain when injured, core stability programs, ankle braces and prophylactic tape, and equipment with padding to absorb shock.

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