The Epidemiology of High Ankle Sprains in National Collegiate Athletic Association Sports

Timothy C. Mauntel,*† PhD, ATC, Erik A. Wikstrom,‡ PhD, ATC, Karen G. Roos,§ PhD, MSPT, ATC, Aristarque Djoko,‖ MS, Thomas P. Dompier,‖ PhD, ATC, and Zachary Y. Kerr,‡ PhD, MPH
Investigation performed at the Datalys Center for Sports Injury Research and Prevention Inc, Indianapolis, Indiana, USA

Background: Ankle sprains are among the most common injuries experienced by collegiate athletes. The type of ankle sprain is rarely differentiated in epidemiological studies. This differentiation is necessary, as each ankle sprain type has a unique injury mechanism and recovery period. High ankle sprains commonly result in long recovery periods. Thus, a further examination of the epidemiology of high ankle sprains is warranted.

Purpose: To describe the epidemiology of high ankle sprains in National Collegiate Athletic Association (NCAA) sports during the 2009/2010-2014/2015 academic years.

Study Design: Descriptive epidemiology study.

Methods: NCAA Injury Surveillance Program high ankle sprain data and athlete-exposures (AEs) from 25 sports were evaluated. Certified athletic trainers recorded sport-related injury, event, and AE data during team-sanctioned events. High ankle sprain injury rates per 10,000 AEs were calculated. Percentage distributions were calculated for the amount of time lost from sport and percentage of recurrent injuries. Injury rate ratios (RRs) and 95% CIs compared injury rates by event type, participation restriction time, and sex. 95% CIs not containing 1.00 were considered statistically significant.

Results: The overall high ankle sprain injury rate was 1.00 per 10,000 AEs. Overall, 56.7% of high ankle sprain injuries occurred during competitions, and 9.8% of high ankle sprain injuries were recurrent. Men's football (2.42/10,000 AEs), wrestling (2.11/10,000 AEs), and ice hockey (1.19/10,000 AEs) had the highest high ankle sprain injury rates. In sex-comparable sports, men had higher injury rates (RR, 1.77; 95% CI, 1.28-2.44). Player contact was the most common injury mechanism (60.4%), and 69.0% of injuries resulted in $\geq$1 day of participation restriction, with 47.1% resulting in $\geq$7 days of participation restriction and 15.8% resulting in $>$21 days of participation restriction.

Conclusion: High ankle sprains resulted in significant participation restriction time from sport participation. The majority of high ankle sprain injuries resulted from player contact and were observed in contact/collision sports. The large proportion of high ankle sprains resulting from player contact, specifically in male contact sports, is worthy of further investigation.

Clinical Relevance: The enhanced understanding of the epidemiology of high ankle sprains provided in our study will aid clinicians in developing targeted injury prevention strategies to mitigate the negative consequences of these injuries.

Keywords: ankle; sprain; syndesmosis; distal tibiofibular joint

Ankle sprains are one of the most common injuries experienced by collegiate athletes.[1,2,11,14,17,22,28] Previous studies have demonstrated the high incidence of ankle sprains and the subsequent participation restriction time from athletic activity. However, few studies have differentiated between the rates of the various types of ankle sprains.[14,17,22,28] Furthermore, the focus of previous work has been isolated to single sports or institutions, and thus, a more comprehensive examination across multiple sports and institutions is required.[8,14,17,22,31]

Broadly, ankle sprains include lateral ligament complex sprains, medial ligament complex sprains, and distal tibiofibular joint ("high ankle") sprains.[13,14,17,28] Lateral ankle sprains are the most reported ankle ligamentous injury,[14,17,22,28] but high ankle sprains typically result in the longest recovery periods, averaging 13.9 days compared with 8.1 and 10.7 days for lateral and medial ankle sprains, respectively.[17,27,28] Thus, understanding the epidemiology and etiology of high ankle sprains is essential to help develop injury prevention interventions aimed at reducing the incidence and severity of these injuries.

The American Journal of Sports Medicine, Vol. 45, No. 9
DOI: 10.1177/0363546517701428

The distal tibiofibular ("high ankle") joint is composed of the distal tibia and fibula and superior surface of the talus. The joint is supported by the anterior- and posterior-inferior tibiofibular ligaments, interosseous ligament, and interosseous membrane.[9,29,32] Sprains to this ligamentous complex most commonly occur from contact with another player that results in ankle dorsiflexion and foot external rotation.[18,21] This unique mechanism of injury and associated recommendations for a slow progressing rehabilitation[13,18] highlight the necessity to better understand the epidemiology and etiology of high ankle sprains to prevent and better rehabilitate these injuries.

Presently, there is limited information on the incidence of high ankle sprains as an individual diagnosis, separated from ankle sprains in general. There is even less information on high ankle sprains in collegiate athletes that are non–time loss (NTL) injuries, that is, result in participation restriction of <24 hours. Including NTL injuries is important, as it better captures the breadth of injuries that are sustained within the sport setting. There is currently a plethora of information related to injuries with participation restriction of ≥24 hours (ie, time loss [TL] injuries). However, many injured patients are able to return to activity in <24 hours; thus, it is important to consider these injuries in addition to TL injuries. Furthermore, NTL injuries still require provider services; to improve the services rendered for these injuries, it is essential to understand their epidemiology. This study describes the epidemiology of high ankle sprains in 25 National Collegiate Athletic Association (NCAA) sports during the 2009/2010-2014/2015 academic years.

METHODS

The NCAA Injury Surveillance Program (NCAA-ISP) prospectively collects injury and athlete-exposure (AE) data from 25 varsity intercollegiate sports and is managed by the Datalys Center for Sports Injury Research and Prevention, an independent, nonprofit research organization. De-identified NCAA-ISP data on collegiate high ankle sprains and sport exposures from the 2009/2010-2014/2015 academic years were analyzed. This study was approved by the NCAA Research Review Board. The NCAA-ISP methodology during the 2009/2010-2014/2015 academic years has been previously described but is briefly summarized below.[15]

Data Collection

Data were collected from a convenience sample of NCAA varsity teams from 25 sports. The number of varsity teams providing data varied by sport and year. Certified athletic trainers reported data from participating teams during all team-sanctioned practices and competitions. Individual and "captain-led" practices were excluded. Exposure data included the number of athletes participating in each team-sanctioned event and details about the event (eg, competition vs practice, time in season).

Sport-related injury and illness data identified by or reported to the athletic training staff were documented in the universities' electronic medical records. Detailed sport-related injury and illness data included, but were not limited to, the affected body part, injury diagnosis, mechanism of injury, and activity at the time of injury. Athletic trainers reviewed and updated the data as needed throughout the academic year.

Common data elements (CDEs) were extracted from the electronic medical records. CDEs were de-identified and encrypted before export to the central aggregate research database. CDEs were directly extracted from the existing electronic medical records. Thus, athletic trainers did not have to separately enter injuries, illnesses, or additional information for surveillance purposes. Exported CDEs were automatically verified through a series of range and consistency checks. Data were reviewed and flagged for invalid values. Athletic trainers and data quality assurance staff were notified and worked to resolve issues, if present. Verified data were then placed into the aggregate research dataset. There was no manual exclusion of high ankle sprain injuries; all available cases were included in our analyses.

Definitions

Injury. A reportable injury occurred as a result of participation in a team-sanctioned event and required medical attention from an athletic trainer or physician. All injuries with a diagnosis of a high ankle sprain were included in our analyses.

Athlete-exposure. An AE was defined as 1 student-athlete participating in 1 team-sanctioned practice or competition in which he or she was exposed to the possibility of an athletic injury regardless of the time associated with that participation. Only athletes with actual playing time in a competition, including warm-ups, were included in competition exposures.

Event Type. The event type was classified as the specific type of event (ie, practice, competition) in which the high ankle sprain was reported to have occurred.

Injury Mechanism. The injury mechanism was defined as the cause of the student-athlete's high ankle sprain.

*Address correspondence to Timothy C. Mauntel, PhD, ATC, Walter Reed National Military Medical Center, 4494 North Palmer Road, Bethesda, MD 20889, USA (email: tmauntel@gmail.com).
†Walter Reed National Military Medical Center, Bethesda, Maryland, USA.
‡University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA.
§California State University, Long Beach, Long Beach, California, USA.
‖Datalys Center for Sports Injury Research and Prevention Inc, Indianapolis, Indiana, USA.
The x-axis of Figure 2 originally read ''hamstring strains'' in the initial PreView version. This has been corrected to ''high ankle sprains'' online and in print.
One or more of the authors has declared the following potential conflict of interest or source of funding: The National Collegiate Athletic Association (NCAA) Injury Surveillance Program data were provided by the Datalys Center for Sports Injury Research and Prevention. The Injury Surveillance Program was funded by the NCAA. The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of the NCAA.

In the NCAA-ISP, athletic trainers selected from a preset list of options including player contact, surface contact, equipment contact, contact with an out-of-bounds object, noncontact, overuse, illness, infection, and other/unknown. Given the rarity of injuries being caused by equipment contact, contact with an out-of-bounds object, overuse, illness, or infection, these were grouped into the "other/unknown" category.

Recurrence. Athletic trainers identified high ankle sprains that were recurrent to the ipsilateral ankle (ie, a recurrence of the same injury that was sustained either earlier in the current or prior academic year).

Participation Restriction Time. High ankle sprains were categorized by the number of days lost from sport (ie, the date of injury subtracted from the date of return to activity). NTL injuries resulted in <24 hours of participation restriction; TL injuries resulted in ≥24 hours of participation restriction. Among TL injuries, severe injuries were defined as TL injuries resulting in participation restriction of >21 days or the student-athlete's season prematurely ending as the result of self-selection or being directed to do so by a medical professional. Within data reporting by the athletic trainers, we emphasized that classifying injuries as season ending should be limited to those injuries that prematurely ended a season because of severity and not because of sustaining a relatively minor injury that happened just before the completion of the season.

Data Analysis

Counts, percentages, and rates of high ankle sprain injuries per 10,000 AEs were calculated, using injury counts and AEs. Percentage distributions were calculated for injury mechanisms, recurrence, and participation restriction by individual sport and sex-comparable sports. Sports with <5 high ankle sprains were not included in analyses of sport-stratified and sex-comparable sports. Rate ratios (RRs) were calculated to compare rates of high ankle sprain injuries by event type and sex and for sex-comparable sports overall and within each sport (ie, soccer, basketball, ice hockey, lacrosse, baseball/softball, indoor track, outdoor track, cross-country, swimming and diving, tennis). Standard large-sample Poisson assumptions were used for count data to compute 95% CIs for all injury rates and RRs. The following is an example of an RR comparing high ankle sprain rates in competition and practice:

$$RR = \frac{\left(\frac{\sum competition\ high\ ankle\ sprains}{\sum competition\ athlete-exposures}\right)}{\left(\frac{\sum practice\ high\ ankle\ sprains}{\sum practice\ athlete-exposures}\right)}.$$

Injury proportion ratios (IPRs) examined sex differences in the distributions of injury mechanism, recurrence, and participation restriction time. The following is an example of an IPR comparing the proportion of high ankle sprains that were recurrent in men and women:

$$IPR = \frac{\left(\frac{\sum recurrent\ high\ ankle\ sprains\ in\ men}{\sum total\ high\ ankle\ sprains\ in\ men}\right)}{\left(\frac{\sum recurrent\ high\ ankle\ sprains\ in\ women}{\sum total\ high\ ankle\ sprains\ in\ women}\right)}.$$

All 95% CIs not containing 1.00 were considered statistically significant.[7] Data were analyzed using SAS Enterprise Guide software (version 5.1; SAS Institute Inc).

RESULTS

Overall Frequencies and Rates

Overall, 480 high ankle sprains were reported in 25 NCAA sports from the 2009/2010-2014/2015 academic years, resulting in an overall high ankle sprain rate of 1.00 per 10,000 AEs (Table 1). The majority of high ankle sprains occurred during competitions (56.7%). High ankle sprains occurred at higher rates during competitions compared with practices for all sports (overall RR, 5.79; 95% CI, 4.83-6.93). Similar trends were observed between competitions and practices for men (RR, 5.14; 95% CI, 3.55-7.44) and women (RR, 5.49; 95% CI, 3.20-9.41) participating in sex-comparable sports.

The sports with the highest rates of high ankle sprains were men's football (2.42/10,000 AEs), men's wrestling (2.11/10,000 AEs), and men's ice hockey (1.19/10,000 AEs). In sex-comparable sports, men had higher high ankle sprain rates compared with women (RR, 1.77; 95% CI, 1.28-2.44). This finding was maintained when analyses were restricted to either competitions (RR, 1.75; 95% CI, 1.15-2.68) or practices (RR, 1.87; 95% CI, 1.13-3.09). Examining sport-specific sex differences, men had higher rates of high ankle sprains during ice hockey competitions (RR, 2.64; 95% CI, 1.03-6.78) and basketball practices (RR, 6.20; 95% CI, 1.42-27.12).

Injury Mechanism

The most common injury mechanisms for high ankle sprains were player contact (60.4%), noncontact (17.5%), and surface contact (16.9%) (Figure 1). Player contact was the leading mechanism of injury for all sports with a sufficient incidence of reported high ankle sprains (>5). However, large proportions of high ankle sprains due to surface contact were found in women's volleyball (45.5%) and men's lacrosse (33.3%), and large proportions due to noncontact mechanisms were found in men's ice hockey (33.3%). Among sex-comparable sports, no differences in the distributions of injury mechanisms were found.

Recurrence

Overall, 9.8% of high ankle sprains were recurrent (Figure 2). All sports with >5 high ankle sprains reported a minimum of 1 recurrent ankle sprain. Women's ice hockey had the highest percentage of recurrence (42.9%), followed by

TABLE 1
High Ankle Sprain Frequencies and Rates in 25 NCAA Sports[a]

Sport	No. of Team Seasons[b]	No. of High Ankle Sprains			Rates per 10,000 AEs[c] (95% CI)		
		Competition	Practice	Overall	Competition	Practice	Overall
Men's football	153	159	113	272	14.52 (12.27-16.78)	1.12 (0.91-1.32)	2.42 (2.13-2.71)
Men's wrestling	41	8	13	21	7.51 (2.31-12.72)	1.46 (0.67-2.25)	2.11 (1.20-3.01)
Women's volleyball	162	4	7	11	0.70 (0.01-1.39)	0.49 (0.13-0.86)	0.55 (0.23-0.88)
Women's field hockey	32	1	1	2	0.88 (0.84-2.60)	0.28 (0.00-0.82)	0.42 (0.00-1.00)
Women's gymnastics	35	1	3	4	1.94 (0.00-5.73)	0.58 (0.00-1.24)	0.71 (0.01-1.40)
Men's ice hockey	147	33	15	48	3.36 (2.21-4.50)	0.49 (0.24-0.74)	1.19 (0.85-1.52)
Women's ice hockey	67	5	2	7	1.27 (0.16-2.38)	0.18 (0.00-0.44)	0.47 (0.12-0.82)
Men's soccer	103	14	7	21	3.42 (1.63-5.21)	0.47 (0.12-0.81)	1.10 (0.63-1.57)
Women's soccer	166	14	8	22	2.17 (1.03-3.30)	0.39 (0.12-0.67)	0.82 (0.48-1.17)
Men's basketball	172	10	15	25	1.63 (0.62-2.64)	0.68 (0.33-1.02)	0.88 (0.54-1.23)
Women's basketball	174	7	2	9	1.24 (0.32-2.17)	0.11 (0.00-0.26)	0.38 (0.13-0.62)
Men's lacrosse	63	6	6	12	1.83 (0.37-3.29)	0.36 (0.07-0.65)	0.60 (0.26-0.94)
Women's lacrosse	83	4	2	6	1.47 (0.03-2.92)	0.17 (0.00-0.41)	0.42 (0.08-0.76)
Men's baseball	82	2	1	3	0.24 (0.00-0.57)	0.07 (0.00-0.21)	0.13 (0.00-0.29)
Women's softball	128	3	2	5	0.38 (0.00-0.81)	0.15 (0.00-0.37)	0.24 (0.03-0.45)
Men's indoor track and field	43	0	2	2	0.00	0.14 (0.00-0.34)	0.13 (0.00-0.31)
Women's indoor track and field	47	0	3	3	0.00	0.21 (0.00-0.45)	0.19 (0.00-0.41)
Men's outdoor track and field	39	1	0	1	0.65 (0.00-1.92)	0.00	0.09 (0.00-0.28)
Women's outdoor track and field	41	0	2	2	0.00	0.26 (0.00-0.63)	0.22 (0.00-0.52)
Men's cross-country	60	0	3	3	0.00	0.57 (0.00-1.21)	0.52 (0.00-1.10)
Women's cross-country	57	0	1	1	0.00	0.20 (0.00-0.59)	0.18 (0.00-0.54)
Men's swimming and diving	30	0	0	0	0.00	0.00	0.00
Women's swimming and diving	38	0	0	0	0.00	0.00	0.00
Men's tennis	34	0	0	0	0.00	0.00	0.00
Women's tennis	51	0	0	0	0.00	0.00	0.00
Men's sports total[d]	773	66	49	115	1.78 (1.35-2.21)	0.35 (0.25-0.44)	0.64 (0.53-0.76)
Women's sports total[d]	852	33	22	55	1.02 (0.67-1.36)	0.19 (0.11-0.26)	0.36 (0.27-0.46)
Overall total	2048	272	208	480	3.06 (2.70-3.42)	0.53 (0.46-0.60)	1.00 (0.91-1.08)

[a]AE, athlete-exposure; NCAA, National Collegiate Athletic Association.
[b]One team participating in 1 season.
[c]One student-athlete participating in 1 practice or 1 competition.
[d]Only includes sports in which both sexes participated (ie, ice hockey, soccer, basketball, lacrosse, baseball/softball, indoor track, outdoor track, cross-country, swimming and diving, tennis).

women's basketball (33.3%), men's lacrosse (25.0%), and women's volleyball (18.2%). Among sex-comparable sports, the proportions of high ankle sprains that were recurrent in men and women did not differ (IPR, 0.62; 95% CI, 0.29-1.33).

Participation Restriction Time

The majority (69.0%) of high ankle sprains were TL injuries (Figure 3). In general, high ankle sprains resulted in substantial participation restriction time, with 47.1% resulting in ≥7 days of participation restriction time. Of these 226 high ankle sprains, 33.6% (15.8% of all reported high ankle sprains) were severe (>21 days of participation restriction time). Men's lacrosse (33.3%) and men's ice hockey (33.3%) had the largest percentages of severe injuries. Women's lacrosse (66.7%) and women's basketball (55.6%) had the largest percentages of NTL injuries. Among sex-comparable sports, men and women did not differ in the proportion of high ankle sprains that were TL injuries (IPR, 1.16; 95% CI, 0.88-1.51). However, the proportion of high ankle sprains resulting in ≥7 days of participation restriction time was higher in men than women (IPR, 1.80; 95% CI, 1.07-3.03); this IPR increased for severe high ankle sprains but was not statistically significant (IPR, 2.07; 95% CI, 0.91-4.74).

DISCUSSION

The major finding of this study is that nearly 1 in 6 (15.8%) collegiate athletes with a high ankle sprain injury will miss >21 days of sport participation after the injury and 47.1% of high ankle sprains result in ≥7 days of participation restriction. The percentage of severe high ankle sprains is 4.4 times and 2.4 times greater than severe lateral (3.6%) or medial (6.6%) ankle sprains, respectively.[10,24] Thus, while high ankle sprains do not occur as often as lateral or medial ankle sprains, it is evident that their consequences on sport participation is substantial.[10,17,24]

The overall rate of high ankle sprains (1.00/10,000 AEs) and 9.8% recurrent injuries observed in our study are less than the incidence rate and recurrence of lateral ankle sprains (4.95/10,000 AEs; recurrence = 11.9%) and similar to the incidence rate and recurrence of medial ankle sprains (0.77/10,000 AEs; recurrence = 8.2%) in the same study population.[10,24] However, high ankle sprains result in substantially more participation restriction time from

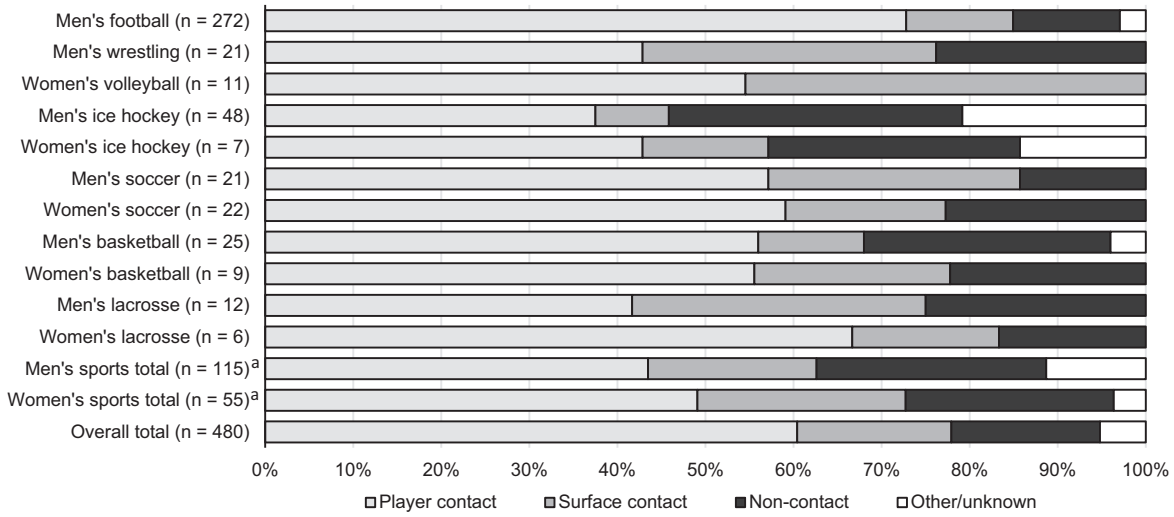

Figure 1. Distributions of high ankle sprains, by injury mechanism, among college student-athletes in 25 sports: National Collegiate Athletic Association Injury Surveillance Program, 2009/2010-2014/2015 academic years. Sports with high ankle sprain counts <5 were excluded (ie, men's baseball, indoor track and field, outdoor track and field, cross-country, tennis, and swimming and diving and women's field hockey, gymnastics, softball, indoor track and field, outdoor track and field, cross-country, swimming and diving, and tennis). [a]Only includes sports in which both sexes participated (ie, ice hockey, soccer, basketball, lacrosse, baseball/softball, indoor track, outdoor track, cross-country, swimming and diving, and tennis).

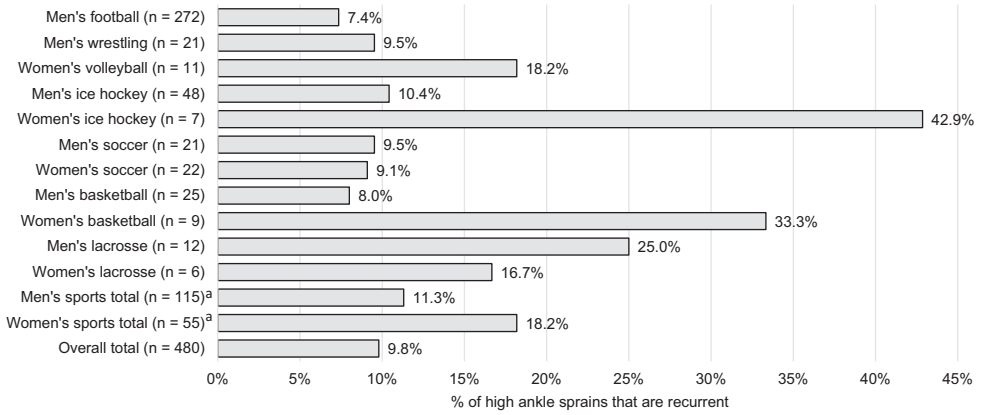

Figure 2. Proportion of high ankle sprains that were recurrent among college student-athletes in 25 sports: National Collegiate Athletic Association Injury Surveillance Program, 2009/2010-2014/2015 academic year. Sports with high ankle sprain counts <5 were excluded (ie, men's baseball, indoor track and field, outdoor track and field, cross-country, tennis, and swimming and diving and women's field hockey, gymnastics, softball, indoor track and field, outdoor track and field, cross-country, swimming and diving, and tennis). [a]Only includes sports in which both sexes participated (ie, ice hockey, soccer, basketball, lacrosse, baseball/softball, indoor track, outdoor track, cross-country, swimming and diving, and tennis).

sport per injury.[10,24] Therefore, the acute severity of high ankle sprains and the potential long-term consequences of associated chronic sequelae make it essential to understand their epidemiology and associated etiology.[3,4] Until this information is elucidated, efficacious injury prevention strategies cannot be developed and implemented.

High ankle sprains most commonly occur when the ankle is forcefully dorsiflexed and the foot is externally rotated.[18,21] This motion normally occurs during gait and other weightbearing activities.[6] Thus, the most common biomechanical mechanism of injury (ankle dorsiflexion with foot external rotation) is replicated during each step. This results in the talus repeatedly pushing superiorly, separating the tibia and fibula,[18,21] resulting in stress on the syndesmotic ligaments.[13] To avoid the continued stresses on the syndesmotic ligaments, early nonweightbearing is recommended after high ankle sprains. This period of nonweightbearing is one of the primary reasons why high ankle sprains require significantly longer recovery periods than either lateral or medial ankle sprains.[13]

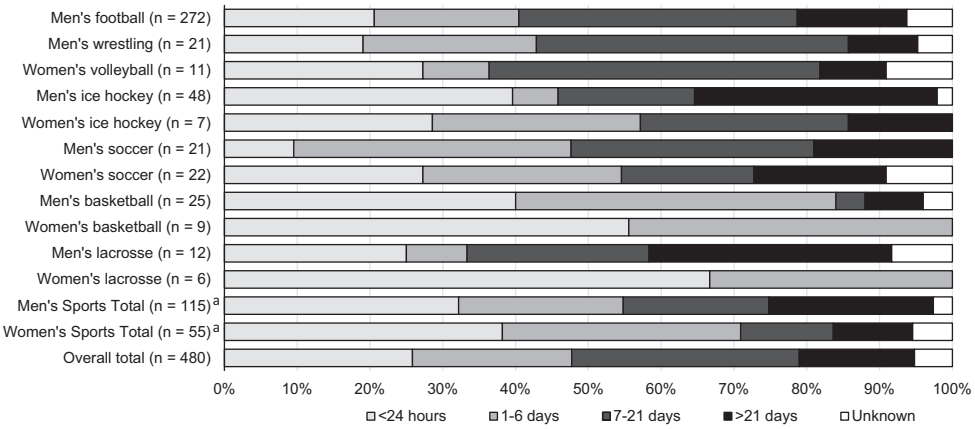

Figure 3. Distributions of high ankle sprains, by participation restriction time, among college student-athletes in 25 sports: National Collegiate Athletic Association Injury Surveillance Program, 2009/2010-2014/2015 academic years. Sports with high ankle sprain counts <5 were excluded (ie, men's baseball, indoor track and field, outdoor track and field, cross-country, tennis, and swimming and diving and women's field hockey, gymnastics, softball, indoor track and field, outdoor track and field, cross-country, swimming and diving, and tennis). [a]Only includes sports in which both sexes participated (ie, ice hockey, soccer, basketball, lacrosse, baseball/softball, indoor track, outdoor track, cross-country, swimming and diving, and tennis).

Player contact accounted for 60.4% of high ankle sprain injuries. This finding agrees with previous work that showed that the majority of high ankle sprains result from contact with another player.[21] The sports in our study with the highest rates of high ankle sprains were men's football, men's wrestling, and men's ice hockey; these findings are consistent with previous studies.[8,12,21,31] Intentional and unintentional player contact is common during these sports, which can result in athletes stepping or landing on another player while forcing the foot into dorsiflexion and external rotation.[18,21]

High ankle sprain rates and counts are higher during competition than practice. This is an interesting finding, as previous work with collegiate athletes found higher injury rates during competitions but higher injury counts during practices.[16] These authors[16] concluded that practices may be the best time to incorporate injury prevention strategies, especially strategies that focus on proprioception and balance. However, our findings suggest that interventions during competitions may be more effective in limiting the incidence of high ankle sprains. Higher injury rates and counts in games, particularly given fewer game-related AEs, highlight the need for further research into specific contact patterns that result in high ankle sprains. Such information in conjunction with current evidence demonstrating that high ankle sprains are most commonly caused by player contact[18,21] could inform potential rule changes.

Men in our study had higher high ankle sprain injury rates than women involved in sex-comparable sports (RR, 1.77; 95% CI, 1.28-2.44). Furthermore, the proportion of high ankle sprains resulting in $\geq$7 days of participation restriction time was higher in men than women; this difference increased for severe high ankle sprains but was not statistically significant. This is in contrast to Waterman et al,[28] who found no differences in the rates of high ankle sprains or participation restriction time due to high ankle sprains between collegiate male and female athletes. Waterman et al[28] reported that women, on average, had more days of participation restriction (mean, 18.3 days) than men (mean, 13.4 days), but this difference was not statistically significant. It is unclear if these authors limited these comparisons to sex-comparable sports or not. It is possible that the differences in sports included in their aggregate statistics, as well as differences in data collection methods, namely, the inclusion of NTL injuries in our study, may account for the differences between studies. Additional research is needed to explore if differences exist between male and female collegiate athletes as well as other physically active populations.

Our study found that 9.8% of high ankle sprains were recurrent. This finding is comparable with data regarding lateral ankle sprains in this same population, where 11.9% of injuries were recurrent.[24] Also, in concordance with data regarding lateral ankle sprains, we found that the highest proportion of high ankle sprain recurrences were in women's sports, specifically, women's ice hockey (42.9%) and basketball (33.3%). However, our proportions of high ankle sprain recurrences in women's sports were much higher than those for lateral ankle sprains in which women's outdoor track and field and basketball had the highest proportions (21.1%).[24] The high proportions of high ankle sprain recurrences in women's sports differ from those in the literature, where high proportions of ankle sprain recurrences were found in football (60%)[26] and adolescent soccer players (56%).[25] Our findings indicate that high ankle sprains recur less than 10% of the time in these sports. The higher proportions of recurrences in women's sports in our investigation may be caused by differences in study populations, and specifically injury definitions, as our study is limited to high ankle sprains only. Differences in recurrence rates between the sexes may also be attributable to sex differences in injury recovery or rehabilitation after high ankle sprains. It is also

important to note that the variable "recurrence" may have resulted in misclassification errors, such that some "recurrent" injuries may actually be "repeat" injuries and not necessarily true recurrent injuries. This issue primarily stems from the unique mechanisms of injury, contact, or forced dorsiflexion with foot external rotation that are associated with high ankle sprain injuries. Further research into potential causes and measures preventing high ankle sprain recurrences in women's sports is warranted.

Beyond the initial participation restriction time from sport, the long-term consequences of an ankle injury can be debilitating. A previous study found that 79.5% of patients with ankle osteoarthritis developed the condition after an acute injury.[3] Approximately 10% of these patients develop posttraumatic ankle osteoarthritis after an ankle sprain.[3] The short- and long-term consequences of high ankle sprains demonstrate the necessity for the development and implementation of targeted high ankle sprain injury prevention strategies. High ankle sprain injury prevention strategies likely differ from injury prevention strategies that target lateral or medial ankle sprains. Lateral and medial ankle sprains typically result from noncontact or surface contact mechanisms of injury and can be mitigated through intervention programs targeting proprioception and balance.[5,10,23,24] High ankle sprains, however, commonly result from contact with another player, and thus, mechanical interventions (eg, ankle braces)[19,20] or changes to game play rules may be successful in minimizing the risk of injuries.

Our study is not without its limitations. First, surveillance data have both strengths and weaknesses that must be considered when interpreting the findings of our study. For example, with surveillance data, it is difficult to account for variations that occur at the team level (eg, implementation of various ankle sprain prevention programs) and at the data collector level (eg, variations in the detection of reporting of injuries). Issues at the collector level may be more pronounced in this study than other similar studies, as it may be difficult to properly diagnosis high ankle sprains. The diagnosis of a high ankle sprain may be difficult because clinical diagnostic tests are not overly specific or sensitive for detecting high ankle sprains.[30] Thus, some high ankle sprain injuries may have been misdiagnosed or missed entirely. Utilizing athletic trainers to collect data helps to minimize this potential; however, future research should consider data collection methods to account for such potential sources of error with reported injury incidences. Second, our findings may not be generalizable to other settings, particularly to programs that are outside of the NCAA setting. Approximately half of the sports included in this analysis reported few ($\leq$5) high ankle sprains, which limited our ability to provide more in-depth analyses of the epidemiology of high ankle sprains within those sports. Third, recurrent high ankle sprains were identified by the athletic trainers, who may not have accounted for high ankle sprains that occurred before the student-athlete's arrival. As a result, estimates of high ankle sprain recurrence may be conservative. Fourth, our measure of an AE did not account for the individual variations in participation time during competitions and practices; however, acquiring individual participation times may have been too burdensome for athletic trainers collecting data. Finally, our study was the first to include NTL high ankle sprain injuries in its analyses. This may have affected our ability to make comparisons to various studies, but we believe that NTL injuries are important to consider because they require sports medicine services and they have the potential to result in an increased future injury risk.

CONCLUSION

Nearly half of collegiate athletes sustaining a high ankle sprain will miss $\geq$7 days of sport participation; nearly 1 in 6 athletes will miss $>$21 days. High ankle sprain rates and counts were higher during competitions than practices. This contrasts with previous epidemiological work on collegiate athletes, where injury rates were higher in competitions, but injury counts were higher in practices.[15] The long- and short-term consequences of high ankle sprain injuries, especially the initial participation restriction time from sport participation after an injury, make them a priority for sports medicine clinicians to develop and implement targeted primary injury prevention programs.

REFERENCES

1. Agel J, Evans T, Dick R, Putukian M, Marshall S. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. *J Athl Train*. 2007;42(2):270-277.
2. Agel J, Palmieri-Smith R, Dick R, Wojtys E, Marshall S. Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train*. 2007;42(2):295-302.
3. Brown T, Johnston R, Saltzman C, Marsh J, Buckwalter J. Posttraumatic osteoarthritis: a first estimate of incidence, prevalence, and burden of disease. *J Orthop Trauma*. 2006;20(10):739-744.
4. Calder JD, Bamford R, Petrie A, McCollum GA. Stable versus unstable grade II high ankle sprains: a prospective study predicting the need for surgical stabilization and time to return to sports. *Arthroscopy*. 2016;32(4):634-642.
5. Cumps E, Verhagen E, Meeusen R. Efficacy of a sports specific balance training programme on the incidence of ankle sprains in basketball. *J Sports Sci Med*. 2007;6(2):212-219.
6. Czerniecki JM. Foot and ankle biomechanics in walking and running: a review. *Am J Phys Med Rehabil*. 1988;67(6):246-252.
7. Du Prel J, Hommel G, Rohrig B, Blettner M. Confidence interval or P-value? *Dtsch Arzteble Int*. 2009;106(19):335-339.
8. Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med*. 2005;33(2):183-187.
9. Hermans JJ, Beumer A, de Jong TA, Kleinrensink GJ. Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach. *J Anat*. 2010;217(6):633-645.
10. Hibberd EE, Kopec TJ, Roos KG, Djoko A, Dompier TP, Kerr ZY. The epidemiology of deltoid ligament sprains in 25 National Collegiate Athletic Association sports, 2009-2010 through 2014-2015 academic years [published online ahead of print March 20, 2017]. *J Athl Train*. doi:10.4085/1062.6050-52.2.01.
11. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2):311-319.
12. Hopkinson WJ, St Pierre P, Ryan JB, Wheeler JH. Syndesmosis sprains of the ankle. *Foot Ankle*. 1990;10(6):325-330.
13. Hunt KJ, Phisitkul P, Pirolo J, Amendola A. High ankle sprains and syndesmotic injuries in athletes. *J Am Acad Orthop Surg*. 2015;23(11):661-673.

14. Kaplan LD, Jost PW, Honkamp N, Norwig J, West R, Bradley JP. Incidence and variance of foot and ankle injuries in elite college football players. *Am J Orthop (Belle Mead NJ)*. 2011;40(1):40-44.
15. Kerr Z, Dompier T, Snook E, 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.
16. Kerr ZY, Marshall SW, Dompier TP, Corlette J, Klossner DA, Gilchrist J. College sports-related injuries: United States, 2009-10 through 2013-14 academic years. *MMWR Morb Mortal Wkly Rep*. 2015; 64(48):1330-1336.
17. Lievers WB, Adamic PF. Incidence and severity of foot and ankle injuries in men's collegiate American football. *Orthop J Sports Med*. 2015;3(5):2325967115581593.
18. Markolf KL, Jackson SR, McAllister DR. Syndesmosis fixation using dual 3.5 mm and 4.5 mm screws with tricortical and quadricortical purchase: a biomechanical study. *Foot Ankle Int*. 2013;34(5):734-739.
19. McGuine TA, Brooks A, Hetzel S. The effect of lace-up ankle braces on injury rates in high school basketball players. *Am J Sports Med*. 2011;39(9):1840-1848.
20. McGuine TA, Hetzel S, Wilson J, Brooks A. The effect of lace-up ankle braces on injury rates in high school football players. *Am J Sports Med*. 2012;40(1):49-57.
21. Nussbaum ED, Hosea TM, Sieler SD, Incremona BR, Kessler DE. Prospective evaluation of syndesmotic ankle sprains without diastasis. *Am J Sports Med*. 2001;29(1):31-35.
22. Reeser JC, Gregory A, Berg RL, Comstock RD. A comparison of women's collegiate and girls' high school volleyball injury data collected prospectively over a 4-year period. *Sports Health*. 2015;7(6):504-510.
23. Riva D, Bianchi R, Rocca F, Mamo C. Proprioceptive training and injury prevention in a professional men's basketball team: a six-year prospective study. *J Strength Cond Res*. 2016;30(2):461-475.
24. Roos KG, Kerr ZY, Mauntel TC, Djoko A, Dompier TP, Wikstrom EA. The epidemiology of lateral ligament complex ankle sprains in National Collegiate Athletic Association (NCAA) sports. *Am J Sports Med*. 2017;45(1):201-209.
25. Soderman K, Adolphson J, Lorentzon R, Alfredson H. Injuries in adolescent female players in European football: a prospective study over one outdoor soccer season. *Scand J Med Sci Sports*. 2001;11(5): 299-304.
26. Tyler TF, McHugh MP, Mirabella MR, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school football players: the role of previous ankle sprains and body mass index. *Am J Sports Med*. 2006;34(3):471-475.
27. Waterman B, Owens B, Davey S, Zacchilli M, Belmont PJ. The epidemiology of ankle sprains in the United States. *J Bone Joint Surg Am*. 2010;92(13):2279-2284.
28. Waterman BR, Belmont PJ Jr, Cameron KL, Svoboda SJ, Alitz CJ, Owens BD. Risk factors for syndesmotic and medial ankle sprain: role of sex, sport, and level of competition. *Am J Sports Med*. 2011;39(5):992-998.
29. Williams BT, Ahrberg AB, Goldsmith MT, et al. Ankle syndesmosis: a qualitative and quantitative anatomic analysis. *Am J Sports Med*. 2015;43(1):88-97.
30. Williams GN, Jones MH, Amendola A. Syndesmotic ankle sprains in athletes. *Am J Sports Med*. 2007;35(7):1197-1207.
31. Wright RW, Barile RJ, Surprenant DA, Matava MJ. Ankle syndesmosis sprains in National Hockey League players. *Am J Sports Med*. 2004;32(8):1941-1945.
32. Xenos JS, Hopkinson WJ, Mulligan ME, Olson EJ, Popovic NA. The tibiofibular syndesmosis: evaluation of the ligamentous structures, methods of fixation, and radiographic assessment. *J Bone Joint Surg Am*. 1995;77(6):847-856.