

Incidence and Severity of Foot and Ankle Injuries in Men's Collegiate American Football

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Background: American football is an extremely physical game with a much higher risk of injury than other sports. While many studies have reported the rate of injury for particular body regions or for individual injuries, very little information exists that compares the incidence or severity of particular injuries within a body region. Such information is critical for prioritizing preventative interventions.

Purpose: To retrospectively analyze epidemiological data to identify the most common and most severe foot and ankle injuries in collegiate men's football.

Study Design: Descriptive epidemiology study.

Methods: Injury data were obtained from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) for all foot and ankle injuries during the 2004-2005 to 2008-2009 seasons. Injuries were analyzed in terms of incidence and using multiple measures of severity (time loss, surgeries, medical disqualifications). This frequency and severity information is summarized in tabular form as well as in a 4 × 4 quantitative injury risk assessment matrix (QIRAM).

Results: The rate of foot and ankle injuries was 15 per 10,000 athletic exposures (AEs). Five injuries were found to be responsible for more than 80% of all foot and ankle injuries: lateral ankle ligament sprains, syndesmotomotic (high ankle) sprains, medial ankle ligament sprains, midfoot injuries, and first metatarsophalangeal joint injuries. Ankle dislocations were found to be the most severe in terms of median time loss (100 days), percentage of surgeries (83%), and percentage of medical disqualifications (94%), followed by metatarsal fractures (38 days, 36%, and 49%, respectively) and malleolus fractures (33 days, 41%, and 59%, respectively). Statistical analysis suggests that the 3 measures of severity are highly correlated ($r > 0.94$), thereby justifying the use of time loss as a suitable proxy for injury severity in the construction of the QIRAM.

Conclusion: Based on the QIRAM analysis, the 5 highest risk injuries were identified based on both incidence and severity (ankle dislocations, syndesmotomotic sprains, lateral ankle ligament sprains, metatarsal fractures, and malleolus fractures). A better understanding of the relative incidence and severity of these injuries will allow coaches, trainers, and researchers to more effectively focus their preventative interventions.

Keywords: football; injuries; foot; ankle

American football is a physical game that involves high-energy impacts between large, powerful players. Consequently, there is a high risk of injury associated with

participation in the sport. This risk is typically reported in terms of injuries per athletic exposure (AE), where an AE represents 1 athlete participating in an official sport-specific event such as a practice or competition. One study of 15 collegiate sports by Hootman et al¹⁷ found that football had the highest rate of injury during competitions: 35.9 injuries per 1000 AEs. The next closest sport was men's wrestling (26.4 injuries per 1000 AE), with all other sports studied with fewer than 20 injuries per 1000 AEs. While the risk of injury cannot be completely eliminated, it is clear that the prevention of injuries within football players deserves particular attention.

Effective injury prevention efforts require knowledge about prevalence and severity so that the most serious injuries can be targeted. Traditionally, 1 of 2 approaches has been adopted when studying football injuries. The first is to consider injuries by body region such as the head, neck,

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knee, or foot. Such studies have been performed with youth,^{12,39} high school,^{2,5,6,16,28,31,32,37} collegiate,^{3,37,43} and professional football players.^{15,30} Various population (eg, high school vs professional) and methodological differences (eg, injury definitions, pooling of body regions) can hinder comparisons among these studies, yet they provide valuable high-level information about those body regions where most injuries occur. For example, based on the epidemiological studies cited above, approximately 20% of football-related injuries involve the knee and about 17% involve the foot and ankle. Nevertheless, a significant limitation of this approach is that it ignores the diversity of injuries that can occur within a body region. Blisters and ankle dislocations are both classified as foot and ankle injuries, yet they have very little in common in terms of mechanism, prevalence, or severity. From the standpoint of prevention, these overall values are useful to highlight particularly at-risk regions of the body but are insufficient to guide meaningful interventions.

The second approach is to focus exclusively on a particular injury. For example, various authors have studied specific foot and ankle injuries such as syndesmotic sprains,¹⁸ tarsometatarsal dislocations,^{20,26} or turf toe^{11,36} in some detail. These studies provide unquestionable benefit by improving our understanding of the mechanisms, prevalence, and severity of these injuries. Nevertheless, the exclusive focus of injury-level studies is also a limitation. Effectively targeted prevention efforts require that specific injuries be understood within the broader population of injuries.

Many studies describe injuries at the macroscale (specific body regions) and at the microscale (specific injuries); however, there is very little information at the mesoscale, that is, within body regions. One notable exception is a study by Kaplan et al¹⁹ of the history of foot and ankle injuries in collegiate players invited to the National Football League (NFL) Combine. They list the 5 most common injuries (lateral ankle sprains, syndesmotic sprains, metatarsophalangeal [MTP] joint dislocations and turf toe, fibular fractures, and Jones fractures); however, there is not enough information to determine the rate of injury. Moreover, while the percentage of players requiring surgery is indicated, there are no other indications of the severity of the injuries. It must also be recognized that selection bias may underestimate both incidence and severity; those whose injuries forced them to retire from football would never be invited to the NFL Combine.

The current work identifies the relative incidence and severity of foot and ankle injuries in men's football using data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS). Since "severity" can be quantified in multiple ways, results are presented in terms of median time loss per injury, the percentage of injuries that resulted in surgery, and the percentage of medical disqualifications (season- or career-ending injuries). Two-dimensional quantitative injury risk assessment matrices (QIRAM) are used to visualize the relative frequencies and severities of the injuries studied. A better understanding of injuries within body regions will allow for better prioritization of injury prevention efforts.

METHODS

This study was performed using data from the NCAA ISS. The ISS first began collecting data in 1982 and now collects injury information from participating schools across 16 different sports. Inclusion in the ISS requires that 3 criteria be satisfied: (1) the injury must have occurred during participation in an official practice or game, (2) the injury must require medical attention from a trainer or physician, and (3) the injury must restrict athletic participation for 1 or more days. Individual schools are selected from the 3 divisions and represent a minimum of 10% of each division.^{7,21}

A complete discussion of the details of the NCAA ISS, such as data collection methods and injury definitions, are beyond the scope of this article. Interested readers should consult more extensive descriptions given elsewhere.^{7,21} Nevertheless, a brief discussion of some aspects will be helpful for assessing the reliability of the data. Injury and exposure data from participating schools were entered on a weekly basis by the team athletic trainer (AT) using a web-based system. There was a 30-day window in which the data could be updated by the ATs; it was unchangeable after that point. Data quality-control staff manually checked the information supplied by the participating programs.

NCAA ISS data are administered by the Datalys Center. Data for all injuries to the foot and ankle were requested from Datalys for 5 football seasons (2004-2005 to 2008-2009^{||}) representing the injuries sustained at 60 of the 616 teams (9.74%) in the 3 divisions. It should be noted that the data are fully anonymized and therefore were deemed by our institutions' research ethics board (REB) to be exempt from REB oversight. The final data set contained a total of 3326 foot and ankle injuries, comprised of a total of 63 distinct injury codes. Summary statistics were generated for injuries to the foot and ankle, both separately and combined, based on the body region coding. The total incidence of injury to each body region was calculated using the raw numbers, as well as in terms of the rate per 10,000 athletic exposures (AEs). Rates were calculated based on a total 2,222,155 AEs in the 5-year period covered by the data set.¹⁸

Three measures of injury severity are also reported. Time loss, as measured in days where an athlete is prevented from participating in his or her sport, is a common measure of severity. It should be noted that while a minimum of 1 day of time loss is required for inclusion in the ISS, there will be no time-loss values for players who did not return to play. Therefore, only a subset of the total injuries was used to calculate both median and total time loss. The number of surgeries, or percentage of injuries requiring surgery, is also an indicator of injury severity. Caveats with this measure include school-to-school variation in access to medical care as well as different treatment approaches. Finally, the severity of an injury is also indicated by athletes who did not return to participation. Only season-ending or career-ending medical

^{||}The 2004-2005 to 2008-2009 data were the most recent available from Datalys when this study was commenced.

disqualifications (MDQs) were considered in this study. While there are other reasons included in the ISS data for why players did not return to competition (eg, released from the team, athlete chose to depart), it is unclear the extent to which the injury is responsible for these outcomes. Therefore, these other indicators were not considered in the analysis and only the number and percentage of injuries that resulted in an MDQ are reported. This approach was seen as a conservative indicator of injury-induced failure to return.

For individual injuries of the foot and ankle, a total of 63 distinct injury codes were contained within the data set. Two strategies were employed to reduce the overall number of distinct injuries to be analyzed. First, 2 or more injuries were grouped together for analysis when unique codes were used to report differing severities of the same injury. For example, syndesmotic (high ankle) sprains may be identified as either a partial or complete sprain in the ISS; they are analyzed as a single injury in this study. Such grouping was performed for lateral ankle sprains, medial ankle sprains, midfoot injuries, injuries of the first metatarsophalangeal joint (MTP1), malleolus fractures, and tears of the forefoot extensors. All metatarsal fractures were also grouped together. While these grouped values were used when analyzing the injuries, the individual coded injuries are also reported so that any important distinctions are not obscured.

The second strategy for reducing the total number of injuries was to exclude so-called "rare" injuries. Any injury or injury group must have 10 or more entries for inclusion in the analysis. This somewhat arbitrary threshold was used to ensure a reasonable sample size for calculating time loss and other parameters. Injuries with 9 or fewer occurrences were pooled and reported as "All other injuries" but broken down according to whether the injury was to the foot or ankle. This step was performed after the grouping described in the previous paragraph; therefore, some injury groups contain individual injuries with fewer than 10 reported cases.

While summary statistics offer detailed indicators of the incidence and severity of individual foot and ankle injuries, a method of representing this data in visual form is useful for communicating their relative risk. One common method for doing so is the risk assessment matrix (RAM).²⁷ It is a technique that is frequently employed in government and industry for identifying and evaluating risk; however, it is used more rarely in sports-related studies.^{8,10} Injuries are grouped in the cells of a 2-dimensional (2D) matrix to indicate their relative frequency and severity; the overall risk is indicated by the product of these 2 variables. Therefore, items in the top right (highest frequency, highest severity) have the highest risk and are given the highest priority, items along the diagonal (top left to bottom right) are given intermediate priority, while items in the bottom left are given the lowest priority.

Risk assessment matrices are often populated qualitatively because the probability or severity of a particular event may be unknown. The subjectivity of these classifications is often highlighted as a deficiency of this technique.⁴ For this study, a fully objective and quantitative injury risk

assessment matrix (QIRAM) can be created using the data from the NCAA ISS. The frequency of a particular injury was taken as the rate per AE. Three potential measures of injury severity (median time loss, percentage of surgeries, percentage of MDQs) were investigated. A composite measure of severity that takes into account each of these 3 measures would be desirable; however, the extent to which these 3 values may be related is unknown. The Pearson correlation coefficient (r) was calculated for each pairing of the 3 variables to check for independence.

K-means clustering²⁴ was used to group each injury along 2 axes: frequency and severity. These 2 groupings then determined which cell in the injury RAM each injury was to be located. Note that, because of the use of clustering, each row or column of the QIRAM does not represent equal increments of either frequency or severity.

RESULTS

All foot and ankle injuries recorded in the NCAA ISS were included in the analysis. This resulted in a total of 3326 injuries, of which 2523 involved the ankle and the remaining 803 involved the foot. Thus, the combined injury rate for foot and ankle injuries in collegiate football is 14.97 per 10,000 AEs, with individual rates of 11.35 (ankle) and 3.61 (foot) per 10,000 AEs. A total of 235 (7.1%) athletes did not return to participation due to an MDQ. Foot injuries more frequently resulted in failure to return (98 athletes; 12.2%) compared with ankle injuries (137 athletes; 5.4%). These values represent the injuries sustained in all types of athletic events; however, it should be noted that the rate of foot and ankle injuries during competitions (78.94 per 10,000 AEs) is much higher than that in practices (8.99 per 10,000 AEs).

There were a total of 63 unique injury codes. After grouping similar injuries and then removing those with fewer than 10 entries, a total of 17 distinct injury groups were created. Summary statistics showing the incidence of injury, median and total time loss, and surgeries required per injury group, as well as the number of MDQs, are given in Table 1. The other injuries (37 in total) are only included in this summary table; they are not included in any of the subsequent analyses.

Lateral ankle sprains were the most common foot and ankle injury ($n = 1498$), accounting for almost half (45%) of all injuries, as well as the greatest total time loss (12,726 days). Ankle dislocations resulted in the highest rate of surgeries per injury (83%) as well as the highest percentage of MDQs (94%). They also resulted in the highest median time loss (100 days); however, this value was based on a single injury. Metatarsal and malleolus fractures were the next highest median time-loss injuries (38 and 33 days, respectively) and were calculated using much larger samples.

When considering individual injuries, partial sprains of the lateral ankle were the most frequent ($n = 1469$) and resulted in the greatest total time loss (12,471 days). Fractures of the fifth metatarsal, which include Jones fractures, resulted in the highest median time loss (42 days). Full sprains of the medial ligament and lateral malleolus

TABLE 1
Summary of Foot and Ankle Injuries From NCAA Injury Surveillance System^a

Injury	Incidence		Time Loss			Surgeries, n (%)	MDQs, n (%)
	n	Per 10,000 AEs	Injuries, n	Days, Median	Days, Total		
Lateral ankle ligament sprain	1498	6.74	1422	6.0	12,726	6 (0.4)	47 (3.1)
Partial	1469	6.61	1404	6.0	12,471	4 (0.3)	40 (2.7)
Complete	29	0.13	18	7.0	255	2 (6.9)	7 (24.1)
Syndesmotic (high ankle) sprain	573	2.58	509	13.0	8517	16 (2.8)	48 (8.4)
Partial	533	2.40	485	12.0	7661	2 (0.4)	34 (6.4)
Complete	40	0.18	24	23.0	856	14 (35.0)	14 (35.0)
Medial ankle ligament sprain	261	1.17	231	7.0	2575	10 (3.8)	28 (10.7)
Partial	247	1.11	227	7.0	2464	2 (0.8)	18 (7.3)
Complete	14	0.06	4	31.5	111	8 (57.1)	10 (71.4)
Midfoot injuries	226	1.02	191	6.0	2476	12 (5.3)	30 (13.3)
Sprain	214	0.96	188	6.0	2406	6 (2.8)	22 (10.3)
Lisfranc dislocation	12	0.05	3	20.0	70	6 (50.0)	8 (66.7)
First metatarsophalangeal joint	146	0.66	136	5.5	1311	2 (1.4)	8 (5.5)
Sprain	141	0.63	131	5.0	1153	2 (1.4)	8 (5.7)
Dislocation	5	0.02	5	20.0	158	0 (0.0)	0 (0.0)
Foot/toe contusion	130	0.59	122	4.0	665	1 (0.8)	5 (3.8)
Metatarsal fracture	73	0.33	37	38.0	1235	26 (35.6)	36 (49.3)
Metatarsal 5/Jones	54	0.24	26	41.5	1025	23 (42.6)	28 (51.9)
Metatarsal 2-4	13	0.06	7	25.0	141	2 (15.4)	6 (46.2)
Metatarsal 1	6	0.03	4	14.0	69	1 (16.7)	2 (33.3)
Ankle contusion	57	0.26	57	6.0	484	1 (1.8)	0 (0.0)
Malleolus fracture	49	0.22	19	33.0	967	20 (40.8)	29 (59.2)
Lateral malleolus	28	0.13	9	37.0	585	13 (46.4)	18 (64.3)
Medial malleolus	21	0.09	10	26.0	382	7 (33.3)	11 (52.4)
Metatarsal stress fracture	36	0.16	26	15.0	479	3 (8.3)	9 (25.0)
Plantar fasciitis	30	0.14	28	6.5	286	0 (0.0)	2 (6.7)
Forefoot extensor tear: partial	28	0.13	27	5.0	173	0 (0.0)	0 (0.0)
Forefoot flexor tear	23	0.10	21	6.0	206	0 (0.0)	1 (4.3)
Partial	20	0.09	18	6.0	175	0 (0.0)	1 (5.0)
Complete	3	0.01	3	7.0	31	0 (0.0)	0 (0.0)
Foot infection	18	0.08	18	4.0	97	4 (22.2)	0 (0.0)
Ankle dislocation	18	0.08	1	100.0	100	15 (83.3)	17 (94.4)
Phalangeal fracture	11	0.05	11	4.0	60	0 (0.0)	0 (0.0)
Foot/toe blisters	10	0.05	10	3.0	47	0 (0.0)	0 (0.0)
All other injuries	139	0.63	108	6.0	1566	20 (14.4)	24 (17.3)
Foot	72	0.32	55	5.0	779	13 (18.1)	14 (19.4)
Ankle	67	0.30	53	6.0	787	7 (10.4)	10 (14.9)

^aAE, athletic exposure; MDQ, medical disqualification; NCAA, National Collegiate Athletic Association.

fractures resulted in the highest percentage of surgeries per injury (57% and 43%, respectively) and also resulted in the highest percentage of MDQs (71% and 64%, respectively) along with Lisfranc dislocations (67%).

Pearson correlation was used to identify the level of independence between the 3 measures of severity (median time loss, percentage of surgeries, and percentage of MDQs) for the 17 injury groups. Pairwise comparisons revealed that the 3 measures were highly correlated with one another ($r > 0.94$ for all 3 comparisons). Based on these results, it was decided that median time loss could be used as a surrogate measure of severity. It should be noted that 1 injury (ankle dislocations) had much larger severity values than the others; this was expected to inflate the r value because of the sensitivity of this measure to outliers. When ankle dislocations were excluded from the analysis,

the pairwise correlations (all $r > 0.86$) still supported the use of a single value as a surrogate.

The K-means algorithm was used to cluster the 17 injury groups into 4 unique clusters based on the rate of injuries per 10,000 AEs. Four ranges of injury frequency were determined based on these calculated means. Likewise, 4 clusters and ranges were created based on the median time loss of those injury groups. These 2 objectively determined ranges were then used to generate a 4×4 quantitative injury risk assessment matrix (QIRAM). The cells of the QIRAM were then populated based on the quantitative values for each injury group (Figure 1).

The grouping process combined injuries that share similar mechanisms but may differ dramatically in severity and frequency. For example, partial sprains of the medial ankle ligaments are much more common (1.11 vs 0.06 per 10,000

Median Time-Loss, days	>67	<ul style="list-style-type: none"> • Ankle dislocation 			
	24-67	<ul style="list-style-type: none"> • Metatarsal fractures • Malleolus fracture 			
	9-24	<ul style="list-style-type: none"> • Metatarsal stress fracture 		<ul style="list-style-type: none"> • Syndesmotom (high ankle) sprain 	
	<9	<ul style="list-style-type: none"> • Ankle contusion • Plantar fasciitis • Forefoot extensor tear: partial • Forefoot flexor tear • Foot infection • Phalangeal fracture • Foot/toe blisters 	<ul style="list-style-type: none"> • Medial ankle ligament sprain • Midfoot injuries • MTP1 joint injuries • Foot/toe contusion 		<ul style="list-style-type: none"> • Lateral ankle ligament sprain
		<0.5	0.5-1.7	1.7-4.7	>4.7
		Injuries (per 10,000 AEs)			

Figure 1. Quantitative injury risk assessment matrix (QIRAM) of the 17 injury groups. AE, athletic exposure; MTP1, first metatarsophalangeal.

AE) but much less severe (median time loss, 7.0 vs 31.5 days) than complete sprains. A second QIRAM was created to examine the grouped injuries individually (Figure 2). The ranges for incidence and severity determined for the grouped injuries were preserved.

DISCUSSION

The risk of injury in men's football is higher than in any other collegiate sport.¹⁷ While these risks can never be completely eliminated, prophylactic interventions (eg, equipment improvements or rule changes) can reduce the incidence or severity of these injuries.^{14,22} However, more information is needed to prioritize these prevention efforts.

The goal of the current work is to provide the contextual information needed to compare the relative importance of various foot and ankle injuries. More than 3300 injuries were obtained covering 5 seasons (2004-2005 through 2008-2009) of the NCAA ISS. Incidence was reported in terms of the raw numbers of injuries as well as the rate of injury per 10,000 AEs. The severity of these injuries was also indicated using median time loss, the percentage of injuries requiring surgery, and the percentage of injuries resulting in season- or career-ending MDQs.

The summary statistics in Table 1 suggest that the 5 most frequent injuries are lateral ankle ligament sprains, high ankle sprains, medial ankle ligament sprains, midfoot

injuries, followed by injuries of the first metatarsophalangeal (MTP1) joint. These 5 account for 81% of all foot and ankle injuries. Kaplan et al¹⁹ reported the history of foot and ankle injuries in 231 (72%) of the 320 players invited to the 2006 NFL Combine. As in the current study, lateral ankle sprains and high ankle sprains were the 2 most common injuries reported. Kaplan et al¹⁹ also reported, however, that injuries of the MTP1 joint (dislocation or turf toe) were the next most frequent injury, followed by fibular fractures, Jones fractures, Lisfranc sprains, and medial ankle sprains. The differences in the 2 studies likely result from methodological differences. For example, the current study has a much larger sample size (3326 vs 286) covering a larger number of injuries. There is also a selection bias associated with the NFL Combine study. While the ISS data are gathered on all the players of reporting teams regardless of outcome, evaluating only those invited to the Combine excludes players whose injuries adversely affected their performance and careers.

In addition to confirming earlier observations about many of the most common foot and ankle injuries, the current results have highlighted some severe injuries that are often overlooked because of their relative infrequency. Ankle dislocations are one example. These rare injuries are most common in motor vehicle accidents, but have been observed in sports such as soccer and basketball.^{29,35,40} Examples of football-related ankle dislocations are even less common.³³ Of the 18 cases recorded in the

Median Time-Loss, days	>67				
	24-67	<ul style="list-style-type: none"> • Lateral malleolus fracture • Medial malleolus fracture • Metatarsal 5/Jones fracture • Metatarsal 2-4 fracture • Medial ankle ligament sprain: complete 			
	9-24	<ul style="list-style-type: none"> • Metatarsal 1 fracture • MTP1 joint dislocation • Midfoot (Lisfranc) dislocation • Syndesmotic (high ankle) sprain: complete 		<ul style="list-style-type: none"> • Syndesmotic (high ankle) sprain: partial 	
	<9	<ul style="list-style-type: none"> • Forefoot flexor tear: partial • Forefoot flexor tear: complete • Lateral ankle ligament sprain: complete 	<ul style="list-style-type: none"> • MTP1 joint (turf toe) sprain • Midfoot sprain • Medial ankle ligament sprain: partial 		<ul style="list-style-type: none"> • Lateral ankle ligament sprain: partial
		<0.5	0.5-1.7	1.7-4.7	>4.7
		Injuries (per 10,000 AEs)			

Figure 2. Quantitative injury risk assessment matrix (QIRAM) with ungrouped injuries. AE, athletic exposure; MTP1, first metatarsophalangeal.

ISS data, 17 athlete injuries resulted in season- or career-ending medical disqualification. The single player who did return lost 100 days to the injury. While this single data point makes time-loss estimates suspect, the large number of surgeries and lost seasons underscore the severity of this injury.

Risk assessment matrices are uncommon in the biomedical literature; however, they are employed extensively in government and industry for assessing, managing, and communicating risk.²⁷ For example, the National Aeronautics and Space Administration (NASA) uses RAM to communicate risk associated with space flights.³⁴ Commonly cited limitations of this approach include poor resolution due to the finite number of categories, as well as the subjectivity of determining frequency or severity when these values are unknown.^{1,4,38} The latter problem has been avoided in the current study because the injury likelihood and injury outcomes have been quantified using the ISS data. The term *quantitative injury risk assessment matrix* (QIRAM) has been adopted in this work to emphasize this objective aspect. While the issue of resolution has been somewhat mitigated by the objective clustering of the injuries, direct comparison of injuries within the same grid still requires consultation of the data in Table 1. The resolution could be increased by adding more levels; however, the QIRAM would become increasingly sparse. We feel that the use of a 4 × 4 representation strikes a good balance between resolution and readability for the

number of injuries under consideration in the current study. Despite these acknowledged limitations, the QIRAM is a convenient way for visualizing and comparing the relative risk posed by different injuries.

Quantifying the severity of an injury is a challenge. The current study considered 3 possible definitions based on the ISS data: median time loss, percentage of injuries requiring surgery, and percentage of injuries resulting in MDQs. The 3 metrics yielded similar rankings of the most severe injuries. Ankle dislocations were the most severe injuries according to all 3 metrics. Metatarsal fractures and malleolus fractures were the next most severe injuries; however, their orders were reversed depending on which metric was used. Pairwise comparisons using Pearson correlation ($r > 0.94$) suggest that these 3 metrics provide much of the same information. We feel that this result justifies the time loss alone as the severity indicator incorporated into the QIRAM, rather than some composite measure of injury that incorporated all 3 metrics.

A further limitation associated with quantifying injury severity is that all 3 measures studied focus only on near-term effects. It must be recognized that certain injuries are known to be associated with an increased likelihood of developing long-term conditions.^{13,23} While these outcomes cannot be examined using the ISS data, future work should consider more holistic measures of injury severity. It should also be recognized that the data are also limited to a subset (10%) of all active football programs. Since the current

results indicate that the most severe injuries are also the rarest, it is reasonable to expect that some important injuries were not captured by the sample population. This limitation should be considered when interpreting the incidence and severity of these less common injuries based on the NCAA ISS data. Larger, more focused studies may be needed. Nevertheless, the current work provides a useful survey of foot and ankle injuries that can serve as the basis for future study and intervention initiatives.

Prioritizing injury interventions can be complicated by the fact that common injuries are typically less severe, whereas the more severe injuries tend to be less common. One of the benefits of the QIRAM is to help interpret these 2 competing variables. Items in the top right corner (high incidence, high severity) are given the greatest priority. Items in the bottom left corner (low incidence, low severity) are given the lowest priority. Therefore, for the injuries in Figure 1, those closest to the diagonal should be given the greatest priority: ankle dislocations, syndesmotom sprains, lateral ankle ligament sprains, metatarsal fractures, and malleolus fractures.

Identifying and prioritizing particular injuries is just the first step to injury prevention. The actual intervention may take 1 of 3 forms. First, specific training regimens can be adopted to reduce the likelihood of particular injuries.^{25,41} The NCAA has, in the past, modified rules related to kick-offs and spearing to reduce concussions and head/neck injuries.²¹ Further rule changes may be considered to improve player safety. Finally, modified sports equipment or playing surfaces may be developed that reduce the likelihood of injurious loading.^{9,42} Future work must consider the application of these techniques to reduce the rate of injury.

The current work has analyzed the 3326 foot and ankle injuries recorded in the NCAA ISS. While just 5 injuries (lateral ankle ligament sprains, high ankle sprains, medial ankle ligament sprains, midfoot injuries, MTP1 joint injuries) were found to be responsible for more than 80% of foot and ankle injuries sustained by collegiate football players, many of these injuries were also found to have low severities. Based on the QIRAM analysis, which considers both incidence and severity, the 5 highest risk injuries were identified: ankle dislocations, syndesmotom sprains, lateral ankle ligament sprains, metatarsal fractures, and malleolus fractures. A better understanding of the relative incidence and severity of foot and ankle injuries will allow coaches, trainers, and researchers to more effectively focus their preventative efforts.

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