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Epidemiology of Ankle Sprain at the United States Military Academy

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Background: Ankle sprain is a common injury in athletic populations that results in significant time lost to injury.

Hypothesis: The incidence rates (IRs) of ankle ligament sprains are influenced by gender, height, weight, body mass index (BMI), physical conditioning, level of competition, type of sport, and athlete exposure to sport.

Study Design: Cohort study; Level of evidence, 2.

Methods: A longitudinal cohort study was performed to determine the effect of risk factors for ankle sprain at the United States Military Academy between 2005 and 2007.

Results: A total 614 cadets sustained new ankle sprains during 10 511 person-years at risk, resulting in an overall IR of 58.4 per 1000 person-years. Women (96.4), compared with men (52.7), had a significantly increased rate ratio (IRR) for ankle sprain of 1.83 (95% confidence interval [CI], 1.52-2.20). Men with ankle sprains had higher mean height, weight, and BMI than uninjured men ($P < .001$). Men with ankle sprains had higher average scores in push-ups, sit-ups, and run time than uninjured men ($P < .001$). Ankle sprain occurred most commonly during athletics (64.1%). Ankle sprain IR did not significantly differ between intercollegiate and intramural athletic competition after controlling for athlete-exposure (IRR, 1.05; 95% CI, 0.81-1.37). The ankle sprain IRR of female compared with male intercollegiate athletes was 0.93 (95% CI, 0.67-1.32) per 1000 person-years and 1.04 (95% CI, 0.74-1.47) per 1000 athlete-exposures. The intercollegiate sports of men's rugby, women's cheerleading, and men's/women's basketball, soccer, and lacrosse had the highest ankle sprain IR.

Conclusion: Higher mean height and weight in men, increased BMI in men, greater physical conditioning in men, and athlete exposure to selected sports were all risk factors for ankle sprain.

Keywords: ankle; sprain; epidemiology; risk factor; military

Ankle sprain is the most common injury in young athletes[10,23,24,31,53] and active-duty military service members[46] and accounts for 10% to 30% of all single sport injuries.[5,23,33] Epidemiological studies have estimated incidence rates (IRs) of ankle sprain in the general population to be between 5 to 7 sprains per 1000 person-years.[14,30] Worldwide, approximately 1 ankle sprain occurs per 10 000 person-days,[7,37] and an estimated 2 million acute ankle sprains occur each year in the United States alone, resulting in an annual aggregate health care cost of 2 billion dollars.[56] In addition to financial costs, these injuries are also associated with significant time lost to injury, delayed return to duty, and long-term disability in up to 60% of patients.[25,62]

Risk factors have been investigated and are traditionally organized into intrinsic and extrinsic factors.[10,48] Intrinsic factors include age, gender, height, weight, body mass index (BMI), previous injury, aerobic fitness, limb dominance, flexibility, limb girth, muscle strength, proprioception, reaction time, postural stability, anatomical alignment, foot morphological characteristics, and inadequate rehabilitation. Extrinsic factors include the sport, level of competition, shoe type, use of ankle tape and/or brace, and playing surface. More recently, injury epidemiologists have shifted their focus to classifying risk factors as modifiable and nonmodifiable with particular interest on modifiable risk factors because they are amenable to intervention.

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There are little data from large-scale (greater than 10 000 person-years at risk) population-based studies with corresponding athlete-exposure data regarding ankle sprain IR and the associated risk factors.[23] The purpose of this study was to estimate ankle sprain IR within the physically active cadet cohort at the United States Military Academy (USMA). Additionally, the study examined the relationship between gender, height, weight, BMI, physical conditioning, type of sport, level of competition, and the incidence of ankle sprain injuries in a homogeneous cohort with the resultant time lost to injury. On the basis of previous epidemiological studies of ankle sprain, we hypothesized that female sex, higher BMI, lower levels of physical conditioning, lower level of competition, and involvement in athletics are associated with higher rates of ankle sprain.

MATERIALS AND METHODS

Study Design and Settings

A longitudinal cohort study was performed to examine the epidemiology of ankle sprain over a 2-year time period between 2005 and 2007 within the cadet population at the USMA utilizing the Cadet Illness and Injury Tracking System (CIITS). The population for this study included all cadets in attendance during the study period. USMA cadets are required to meet their service's physical induction standards when joining the military, which excludes from service those individuals with certain pre-existing medical conditions to include potential causes for chronic ankle instability (inadequate healing, poor rehabilitation, multiple recurrences after primary ankle sprain, heritable connective tissue or other genetic disorder, prior ankle surgery). All cadets are required to participate in intramural, club, or intercollegiate sports in at least 6 semesters of their USMA attendance. Cadets also participate in Department of Physical Education courses and activities, some of which may be gender specific, as well as the Army Physical Fitness Test (APFT). Mandatory military training occurs throughout cadets' USMA attendance. Cadets participate in intensive physical training programs and field-training exercises in addition to mandatory participation in either intramural or intercollegiate athletics. Because of USMA requirements, documented attendance is required for cadets at all places of duty to include athletics. Attendance is taken and reported for all sporting events, games, and practices. Exposure data are based on daily attendance data documented for every practice and game at the intramural, club, or varsity sport level. The data are reported online through the USMA student information system, which then provides athlete-exposure data for CIITS.

All cadets receive medical care through the closed health care system at USMA, and all injuries are evaluated through its associated sports medicine and orthopaedic clinics. All injuries resulting in time lost to sports or activity and requiring presentation at a receiving clinic are documented in CIITS at USMA. Diagnoses are made by an orthopaedic surgeon, physician assistant, or certified athletic trainer based on patient history and physical examination. The West Point Ankle Grading System[25] was used for diagnosing type and severity of ankle sprain based on the following criteria: location of tenderness, presence of edema or ecchymosis, weightbearing ability, ligament damage, reaction to manual stress testing, and evidence of instability. Lateral ankle sprain was diagnosed based on a history of an inversion or plantarflexion ankle injury, tenderness in the distribution of the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL), and pain with passive inversion or anterior translation. Medial ankle sprain was diagnosed by a history of eversion or dorsiflexion ankle injury, tenderness in the deltoid ligament distribution, and/or pain with passive external rotation. Syndesmotic ankle sprain was diagnosed based on a history of external rotation or dorsiflexion injury, focal tibiofibular tenderness, positive special testing (external rotation stress test, squeeze test) results, or radiographic mortise widening.

Data Acquisition and Outcome Assessment

This study was approved by the Institutional Review Board. Injury data were extracted from the CIITS database, and all ankle injuries, specifically ankle sprains, were isolated. New ankle sprains were defined as primary ankle sprains resulting in time lost to sport and activity that occurred within the study period. Injuries sustained before the study period were not included as new ankle sprains in this study. Primary measured outcomes were the incidence of new ankle sprain per 1000 person-years at risk and the incidence of new ankle sprain per 1000 athlete-exposures. Athlete-exposures were defined as one cadet participating in one activity session (eg, game or practice). Subsequent ankle sprains were not included in the calculation of IR. The IR is calculated by dividing the total number of injuries observed in a population by a measure of person-time at risk to injury. While athlete exposure to injury has commonly been used as a measure of person-time at risk in sports injury research, person-years at risk is a more widely used measure of exposure in population-based epidemiological studies. Knowles et al[39] recommended collecting data for person-time at risk to injury as precisely as possible.

Time lost to injury was used to evaluate the severity of ankle sprain injuries. Time lost to injury is the period of disability calculated from start and end dates on the temporary physical profile (DA Form 3349), which determines physical limitations imposed by health care providers for cadets during athletics and other physical training. When the physical profile is discontinued, this marks the full, unrestricted return to athletics and/or physical training irrespective of sport or level of activity. Severity of ankle sprain was measured by the extent of recorded time lost to injury using the definitions set forth by Powell and Barber-Foss[53]: minor (<8 days), moderate (8-21 days), or severe (>21 days).

Anthropometric factors and level of conditioning were also assessed for association with ankle injury. Height in

inches, weight in pounds, and BMI (kg/m^2) were among risk factors analyzed. Performance on the APFT was used as a surrogate measure of the level of physical conditioning. The APFT is composed of 3 components: number of push-ups completed in 2 minutes, number of sit-ups completed in 2 minutes, and 2-mile run time. Cadets are required to complete and achieve baseline scores on the APFT on a semiannual basis, as well as for a USMA graduation requirement.

Statistical Methods and Data Analysis

Using data extracted from the CIITS database, IRs with 95% confidence intervals (CIs) were calculated per 1000 person-years at risk and by gender, sport, and level of competition. To control for athlete-exposures, IRs with 95% CIs were also calculated per 1000 athlete-exposures by gender, sport, and level of competition. Level of competition categories included involvement on an intercollegiate or an intramural level. Intercollegiate sport categories included sports with both men's and women's athletic teams (basketball, cheerleading, team handball, lacrosse, rugby, soccer, track sports, volleyball), as well as single-gender athletic teams (men's baseball, football, hockey, and wrestling; women's softball and gymnastics). Intramural sport categories included basketball, flag football, biathlon, boxing, combat grappling, football, orienteering, pass-n-go, soccer, team handball, Ultimate Frisbee, and wrestling. Incidence rate ratios (IRRs) and respective CIs were calculated between male and female cadets, intercollegiate and intramural athletes, and men's and women's intercollegiate athletes involved in selected sports. χ^2 and Poisson regression analyses were used to examine the relationship between the variables of interest and the incidence of ankle sprain. Statistical means with CIs were calculated for height, weight, BMI, raw sit-up score, raw push-up score, and raw run time for both male and female cadets with and without ankle sprains. A Student t test was used to examine for differences in mean values between groups. χ^2 and Poisson regression analyses were used to assess for statistical significance in the relationship of variables of interest. Time lost to injury for lateral, medial, and syndesmotic ankle sprains was compared using an F test to assess for statistical difference. All analyses were carried out using SAS (version 9.1.3; Cary, North Carolina), with statistical significance set at $P < .05$ for all comparisons.

RESULTS

Between 2005 and 2007, there were 885 new ankle injuries and 1631 injury-related clinic encounters. Sprain was the most common presenting ankle injury (699 sprains, 78% of injuries), followed by contusion (5%), fracture (3%), and strain (2%). During the study period, 614 cadets sustained new ankle sprains during 10 511 cadet person-years for an overall IR of 58.4 per 1000 person-years. Of these 614 cadets with new ankle sprains, 75 cadets sustained multiple ankle sprains (160 ankle sprains), resulting in a total of 699 ankle sprains.

Of these 614 new sprains, 588 (95.8%) had laterality documented. A similar proportion of subjects sustained ankle sprain of the right (296 sprains, 48.2%) and left (292 sprains, 47.6%) ankle, with 26 indeterminate ankle sprains. The majority of ankle sprains involved the lateral ligamentous complex (508 sprains, 82.7%), followed by syndesmotic (31 sprains, 5.0%) and medial (21 sprains, 3.4%) sprains.

Of 614 subjects with ankle sprains, 523 subjects (85.2%) had reportable time lost information. Ankle sprain resulted in at least 4252 total days lost to injury and an average of 8.1 days lost per cadet. Severity of ankle sprain was classified as minor (<8 days time lost: 327 cadets, 62.5%), moderate (8-21 days time lost: 177 cadets, 33.8%), and severe (>21 days time lost: 19 cadets, 3.6%). The average time lost to injury for syndesmotic sprains was 9.82 days compared with lateral at 7.94 days and medial ankle sprains at 5.80 days; however, this did not achieve significance ($P = .18$).

Gender

During the study, 133 women (14.5% of female cadets) sustained an ankle sprain for an IR of 96.4 sprains per 1000 female person-years. Among the men, 481 individuals (9.2% of male cadets) sustained an ankle sprain for an IR of 52.7 sprains per 1000 male person-years. Women, when compared with men, had a significantly increased IRR for ankle sprain of 1.83 (95% CI, 1.52-2.20) when rates were calculated using person-years as a measure of exposure.

Body Mass Index

Men with ankle sprains had a higher mean height, weight, and BMI than uninjured men ($P < .001$). In contrast, injured and uninjured women demonstrated no statistically significant differences in height, weight, or BMI ($P = .36$, .58, and .77, respectively) (Table 1).

Physical Conditioning

Men with ankle sprains had higher mean raw scores in push-ups and sit-ups, as well as a faster mean 2-mile run time when compared with uninjured men ($P < .001$). There were no statistically significant differences in the average push-up, sit-up, and run time raw scores between injured and uninjured women ($P = .68$, .84, and .88, respectively) (Table 1).

Level of Competition

Of 2910 at-risk intercollegiate athletes, 173 athletes (128 male, 45 female) sustained 189 ankle sprains during 236 523 (176 944 male, 59 579 female) athlete-exposures for an overall IR of 59.5 new ankle sprains per 1000 person-years and 0.73 new ankle sprains per 1000 athlete-exposures. The ankle sprain IRR of women compared with men involved in intercollegiate athletes was 0.93 (95% CI,

TABLE 1
Height, Weight, Body Mass Index (BMI), and Army Physical Fitness Test Scores in Cadets With and Without Ankle Sprain

	Uninjured Women	Women With Ankle Sprains	Uninjured Men	Men With Ankle Sprains
Height, in	65.14	65.38	69.40	70.14[a]
Weight, lb	140.08	141.033	167.64	176.33[a]
BMI, kg/m^2	23.17	23.12	24.40	25.14[a]
Raw push-up (repetitions)	33.88	33.36	54.00	57.84[a]
Raw sit-up (repetitions)	53.85	53.62	57.69	59.16[a]
Raw run time, s	1046.53	1042.96	885.44	858.25[a]

[a]Men with ankle sprains had higher height, weight, body mass index, raw push-up score, and raw sit-up score and had lower raw run time score than uninjured men ($P < .001$).

0.67-1.32) per 1000 person-years and 1.04 (95% CI, 0.74-1.47) per 1000 athlete-exposures. Of 9348 at-risk intramural athletes, 80 athletes (78 male, 2 female) sustained 87 ankle sprains during a total 114 986 athlete-exposures for an overall incidence of 8.6 sprains per 1000 person-years and 0.70 sprains per 1000 athlete-exposures. Intercollegiate athletes, when compared with intramural athletes, had a 7-fold increased IRR of ankle sprain per 1000 person-years: 6.95 (95% CI, 5.33-9.05). However, when controlling for exposures, the ankle sprain IRs were comparable between intramural athletes and intercollegiate athletes, resulting in an IRR of 1.05 (95% CI, 0.81-1.37).

Incidence by Sport

The incidence of ankle sprain in selected intercollegiate sports is listed in Appendix 1 (available online at http://ajs.sagepub.com/supplemental). In intercollegiate sports, basketball (men's, 1.67; women's, 1.14), women's cheerleading (1.58), men's rugby (1.53), men's lacrosse (1.34), soccer (men's, 1.28; women's, 1.51), and women's volleyball (1.11) had the highest IRs per 1000 athlete-exposures. When examining men's intercollegiate athletics, the IRRs of men's basketball (4.02, 95% CI, 1.67-9.71), rugby (3.68, 95% CI, 1.65-8.19), lacrosse (3.22, 95% CI, 1.36-7.63), and soccer (3.09, 95% CI, 1.10-8.67) were significantly higher in comparison with track sports. Among women's sports, there were no statistically significant differences.

Overall, the ankle sprain IRR in male athletes participating in intercollegiate rugby was over 3 times greater than that of female participants: 3.11 (95% CI, 1.05-9.18). However, when controlling for athlete-exposures, the ankle sprain IRs were comparable between male and female rugby players: 2.61 (95% CI, 0.88-7.71). Additionally, no statistically significant differences were detected in the IRR when analyzing person-years at risk or athlete-exposures between female and male intercollegiate athletes involved in basketball, handball, lacrosse, soccer, track, and volleyball (Table 2).

The incidence of lateral, medial, and syndesmotic ankle sprain in selected intercollegiate sports is listed in Appendix 2 (available online at http://ajs.sagepub.com/supplemental). In intercollegiate sports, men's gymnastics (0.22) and men's rugby (0.17) had the highest IRs of medial ankle sprain. Also, men's soccer (0.42) and men's wrestling (0.30) had the highest rates of syndesmotic ankle sprain per 1000 athlete-exposures.

TABLE 2
Incidence Rate Ratios (IRRs) of Ankle Sprain Among Female and Male Intercollegiate Athletes[a]

Sport	IRR per 1000 Person-Years (Male:Female)	IRR per 1000 Athlete-Exposures (Male:Female)
Rugby	3.11[b] (1.05-9.18)	2.61 (0.88-7.71)
Handball	3.10 (0.32-29.76)	1.84 (0.19-17.65)
Basketball	1.27 (0.51-3.16)	1.46 (0.59-3.64)
Track sports	0.93 (0.31-2.78)	1.07 (0.36-3.20)
Lacrosse	0.92 (0.30-2.84)	1.40 (0.45-4.35)
Soccer	0.60 (0.22-1.65)	0.85 (0.31-2.34)
Volleyball	0.54 (0.10-2.94)	0.67 (0.12-3.67)

[a]Numbers in parentheses are 95% confidence intervals.
[b]Male rugby athletes were at a significantly increased risk of sustaining ankle sprain per 1000 person-years at risk when compared to female counterparts.

DISCUSSION

In this longitudinal cohort study, we found that higher mean height and weight in men, increased BMI in men, higher level of physical conditioning in men, and athlete exposure to selected sports were factors associated with sustaining an ankle sprain within the cohort of USMA cadets. Previous incidence studies of ankle sprain have reported overall IR in the general population to be between 5 and 7 per 1000 person-years, with the highest IR occurring in men between ages 20 and 30 years and in girls and women between ages 10 and 20 years.[14,30] The IR of ankle sprains in the USMA cadet population was 58.4 per 1000 person-years, with a male rate of 52.7 and a female rate of 96.4 per 1000 person-years. The nearly 10-fold increase in the overall IR is attributable to the young, athletically active USMA cadet cohort. The high ankle sprain IR reported in this study further substantiates the findings reported by Jackson et al[34] over 35 years ago, which showed that nearly one third of cadets sustained an ankle sprain during their attendance at USMA.

Our results found an overall increased risk for sustaining ankle sprain injury in women compared with men, with an IRR of 1.83 (95% CI, 1.52-2.20). However, this relationship did not hold true when athlete-exposures were controlled for. Previous studies have shown female gender to be associated with an increased incidence of lower extremity injuries in athletes,[8,16,36,38] particularly ACL injuries.[1,2,9,13,17,29,41,47,54,55,57] However, previous incidence studies of ankle sprain have reported mixed results to include an increased incidence among women,[12,32,42] as well as studies citing a lack of a gender difference.[11,14,41] Beynnon et al[12] showed that competitive female basketball players were at 4-fold increased risk of ankle sprain compared with male basketball players. Hosea et al[33] demonstrated that female compared with male basketball players at the high school and college level were at a 25% increased risk of sustaining a grade I ankle sprain.

Military academies have stringent entry criteria for weight, body fat content, and physical fitness measures. As a result, cadets are tightly clustered in parameters such as BMI, and few cadets qualify as overweight or obese on standardized measurements. In the current study, injured and uninjured cohorts had an average BMI that was normal using normative data provided by the Centers for Disease Control.[49] Additionally, the difference between injured and uninjured cadets for BMI was only 0.64 kg/m^2. Despite the narrow ranges in these parameters, we have shown that male cadets with higher mean height, weight, and BMI were associated with a higher incidence of ankle sprain. This supports the current hypothesis that ankle sprain and other lower extremity injuries result from the higher mass moment of inertia acting about the ankle.[27,36,46,59] Prior incidence studies of ankle sprain have reported conflicting results with regard to the relationship between height, weight, and the incidence of ankle sprain. Some studies have demonstrated an increased incidence in individuals who are taller[46,60] and heavier,[46] while other studies have reported no difference in the incidence of ankle sprain injury.[11,21] With respect to BMI, 2 studies have reported an increased incidence of lower extremity injuries[27] and ankle sprain[59] in only those football players with an above-average BMI. Gomez et al[27] reported that athletes in high school football with a higher BMI were at a greater risk of lower extremity injury than those with lower BMI, with ankle sprain being the most common injury; there were no associations with weight, lean body mass, or percentage of body fat. Tyler et al[59] showed that male high school athletes with a greater BMI (>95th percentile) had a 4-fold higher incidence of ankle sprain than normal-weight male athletes, although the same was not observed in female athletes.[44]

Male cadets with higher levels of physical conditioning, as indicated by better raw scores in push-up, sit-up, and run time testing, were more likely to sustain an ankle sprain. Currently, there is no consensus in the literature regarding surrogate measures of physical fitness and ankle injury. Some previous studies have reported an increased incidence of training injury in military service members with lower cardiorespiratory fitness,[35,36,38] citing earlier muscle fatigue and delayed neuromuscular response to inversion ankle stresses as potential causes. Similarly, Willems et al[61] showed increased incidence of ankle sprain in men with slower running speed and decreased cardiovascular endurance. Conversely, Milgrom et al[46] showed no difference in 2-km run time between military recruits with and without ankle sprain. In our study, we believe that the increased incidence of ankle sprain associated with higher levels of physical conditioning may be best explained by an increased exposure to at-risk activities. As well, higher conditioned athletes may compete more aggressively and engage in more risk-taking behavior during organized athletics.[18]

Level of competition has been implicated as a risk factor for ankle sprain, and several prospective studies have recorded athlete-exposure data.[3,6,19,43,45] We found that intercollegiate athletes had a nearly 7-fold increased rate of ankle sprain compared with intramural athletes when IRs were calculated by 1000 person-years. However, when controlling for athlete-exposures, ankle sprain IRs were comparable between intramural and intercollegiate athletes. Prior ankle sprain incidence studies concerning level of competition were split, with a report of an increased incidence in intercollegiate versus high school athletes[32] and another that did not find a difference.[12] Two studies have shown an increased risk of severe sports injuries in lower skill soccer players than in their higher skill counterparts.[15,52] We believe that other factors may more adequately predict the higher ankle sprain IR such as number of athlete-exposures, high match exposure,[4] low training-to-match ratio,[18] and limited warm-up or stretch period.[18,19,51]

To our knowledge, this is the first study to document the relative risk of ankle sprain incurred by participation in over 20 different intercollegiate sports within a single cohort. Male intercollegiate athletes in basketball, rugby, lacrosse, and soccer had the highest IR of ankle sprain, whereas the female sports that had the highest ankle sprain IR were cheerleading, soccer, basketball, and volleyball. Traditionally, an increased ankle sprain IR has been observed in soccer, basketball, and football.[12,23] In these higher risk sports, athletes frequently encounter contact with other players and often perform running, jumping, and sharp cutting movements,[15,23,26,40] which expose the ankle to increased angular and rotational strain. In our analysis, the ankle sprain IR was less than 1.7 per 1000 athlete-exposures in all sports. These results are comparable, although higher in all sports except football[31] and women's basketball,[12] to previous studies of intercollegiate athletes. However, the incidence in certain sports may still be underestimated. The assessment of athlete-exposure included both on- and off-field/court training to include less risk-prone sessions such as weight lifting and running. This is of particular importance in explaining the relatively lower ankle sprain IR in men's football, as these less-risk athlete exposures comprise approximately one third of football athlete-exposures in the present study.

The epidemiology of syndesmotic ankle sprain is variably described with reported IRs from 1% to 18% of all ankle sprains.[20,25,32] Previous studies[22,32,50] have described a higher incidence of syndesmotic ankle sprain

during football, hockey, wrestling, rugby, and lacrosse, with a contact external rotation injury being the most commonly reported mechanism.[50] In the current study, 5.0% of all ankle sprains were classified as syndesmotic ligaments, with at least 80.6% occurring during sports activity and 67.8% occurring during intercollegiate athletics. Syndesmotic ankle sprain occurred most commonly during intercollegiate football, although soccer and wrestling were associated with the highest IRs per 1000 athlete-exposures. Furthermore, syndesmotic ankle sprains resulted in an average time loss of 9.82 days (range, 3-21 days), which was higher than time lost to either lateral or medial ankle sprains. While this is lower than time lost to injury reported in previous studies (range, 13.4-55 days),[28,32,50,58] this may be a function of limited time-loss reporting as only 16 of 31 syndesmotic injuries had available time-loss data.

The greatest strength of this study is the large number of athletes (greater than 10 000 person-years at risk) and the corresponding athlete-exposure data that were captured within the closed health care system and annotated in the CIITS database. As a result of this closed cohort, our study can more adequately assess the true incidence of ankle sprain. The authors acknowledge the limitations inherent to any large database study. First, because of limited patient history, we could not fully exclude all subjects with ankle sprain sustained prior to matriculation at USMA. Recurrent sprains during the study period were not included in the calculation of incidence, and any individuals with prior recorded sprain during attendance at USMA were excluded at the onset of this study. Second, multiple providers evaluated and coded the patient encounters, which may decrease the accuracy of the diagnosis of ankle sprain. Despite these limitations, the data from this closed longitudinal cohort study represent true measures of the incidence of ankle sprain and can guide strategies for risk reduction and injury prevention in at-risk groups.

The USMA represents an endemic population for ankle sprain, with IRs nearly 10-fold higher than those reported in the general population. Higher height and weight in men, increased BMI in men, increased physical conditioning in males, and exposure to selected sports were all risk factors for ankle sprain. The intercollegiate sports of basketball, cheerleading, rugby, lacrosse, and soccer have the highest rates of ankle sprain.

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REFERENCES

1. Agel J, Arendt EA, Bershadsky B. Anterior cruciate ligament injury in National Collegiate Athletic Association basketball and soccer: a 13-year review. *Am J Sports Med*. 2005;33(4):524-530.
2. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data review of the literature. *Am J Sports Med*. 1995;23:694-701.
3. Arnason A, Gudmundson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports*. 1996;6:40-45.
4. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med*. 2004;32(1S):5S-16S.
5. Barker HB, Beynnon BD, Renström PA. Ankle injury risk factors in sports. *Sports Med*. 1997;23(2):69-74.
6. Barrett JR, Tanji JL, Drake C, Fuller D, Kawasaki RI, Fenton RM. High versus low-top shoes for the prevention of ankle sprains in basketball players: a prospective randomized study. *Am J Sports Med*. 1993;21:582-585.
7. Baumhauer JF, Alosa DM, Renström AF, Trevino S, Beynnon B. A prospective study of ankle injury risk factors. *Am J Sports Med*. 1995;23(5):564-570.
8. Bell NS, Mangione TW, Hemenway D, Amoroso PJ, Jones BH. Higher injury rates among female army trainees: a function of gender? *Am J Prev Med*. 2000;18(3 Suppl):141-146.
9. Belmont PJ Jr, Shawen SB, Mason KT, Sladicka SJ. Incidence and outcomes of anterior cruciate ligament reconstructions among US Army aviators. *Aviat Space Environ Med*. 1999;70:316-320.
10. Beynnon BD, Murphy DF, Alosa DM. Predictive factors for lateral ankle sprains: a literature review. *J Athl Train*. 2002;37(4):376-380.
11. Beynnon BD, Renström PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. *J Orthop Res*. 2001;19:213-220.
12. Beynnon BD, Vacek PM, Murphy D, Alosa D, Paller D. First-time inversion ankle ligament trauma: the effects of sex, level of competition, and sport on the incidence of injury. *Am J Sports Med*. 2005;33(10):1485-1491.
13. Bjordal JM, Arnøy F, Hannestad B, Strand T. Epidemiology of anterior cruciate ligament injuries in soccer. *Am J Sports Med*. 1997;25:341-345.
14. Bridgman SA, Clement D, Downing A, Walley G, Phair I, Maffulli N. Population based epidemiology of ankle sprains attending accident and emergency units in the West Midlands of England, and a survey of UK practice for severe ankle sprains. *Emerg Med J*. 2003;20:508-510.
15. Chomiak J, Junge A, Peterson L, Dvorak J. Severe injuries in football players: influencing factors. *Am J Sports Med*. 2000;28:S58-S68.
16. Cox JS, Lenz HW. Women midshipmen in sports. *Am J Sports Med*. 1984;12:241-243.
17. deLoes M, Dahlstedt LJ, Thomee R. A 7-year study on risks and costs of knee ainjuries in male and female youth participants in 12 sports. *Scand J Med Sci Sports*. 2000;10:90-97.
18. Dvorak J, Junge A, Chomiak J, et al. Risk factor analysis for injuries in football players: possibilities for a prevention program. *Am J Sports Med*. 2000;28(5):S69-S74.
19. Ekstrand J, Gillquist J, Moller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med*. 1983;11:63-67.
20. Fallat L, Grimm DJ, Saracco JA. Sprained ankle syndrome: prevalence and analysis of 639 acute injuries. *J Foot Ankle Surg*. 1998;37:280-285.
21. Faude O, Junge A, Kindermann W, Dvorak J. Risk factors for injuries in elite female soccer players. *Br J Sports Med*. 2006;40(9):785-790.
22. Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med*. 2005;33:183-187.

23. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sports Med*. 2007;37(1): 73-94.
24. Garrick JG. The frequency of injury, mechanism of injury, and epidemiology of ankle sprains. *Am J Sports Med*. 1977;5:241-242.
25. Gerber JP, Williams GN, Scoville CR, Arciero RA, Taylor DC. Persistent disability with ankle sprains: a prospective examination of an athletic population. *Foot Ankle Int*. 1998;19(10):653-660.
26. Giza E, Fuller C, Junge A, Dvorak J. Mechanisms of foot and ankle injuries in soccer. *Am J Sports Med*. 2003;31:550-554.
27. Gomez JE, Ross SK, Calmbach WL, Kimmel RB, Schmidt DR, Dhanda R. Body fatness and increased injury rates in high school football lineman. *Clin J Sport Med*. 1998;8(2):115-120.
28. Guise ER. Rotational ligamentous injuries to the ankle in football. *Am J Sports Med*. 1976;4:1-6.
29. Gwinn DE, Wilckens JH, McDevitt ER, Ross G, Kao TC. The relative incidence of anterior cruciate ligament injury in med and women at the United States Naval Academy. *Am J Sports Med*. 2000;28:98-102.
30. Holmer P, Sondergaard L, Konradsen L, Nielsen PT, Jorgensen LN. Epidemiology of sprains in the lateral ankle and foot. *Foot Ankle Int*. 1994;15(2):72-74.
31. 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.
32. Hopkinson WJ, St Pierre P, Ryan JB, Wheeler JH. Syndesmotic sprains of the ankle. *Foot Ankle*. 1990;10:325-330.
33. Hosea TM, Carey CC, Harrer MF. The gender issue: epidemiology of ankle injuries in athletes who participate in basketball. *Clin Orthop Relat Res*. 2000;372:45-49.
34. Jackson DW, Ashley RL, Powell JW. Ankle sprains in young athletes: relation of severity and disability. *Clin Orthop*. 1974;101:201-215.
35. Jones BH, Bovee MW, Harris JM, Cowan DN. Intrinsic risk factors for exercise-related injuries among male and female army trainees. *Am J Sports Med*. 1993;21(5):705-710.
36. Jones BH, Knapik JJ. Physical training and exercise-related injuries: surveillance, research and injury prevention in military populations. *Sports Med*. 1999;27(2):111-125.
37. Kannus P, Renstrom P. Treatment for acute tears of lateral ligaments of the ankle. *J Bone Joint Surg Am*. 1991;73(2):305-312.
38. Knapik JJ, Shapr MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH. Risk factors for training-related injures among men and women in basic combat training. *Med Sci Sports Med Exerc*. 2001;33(6):946-954.
39. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. *J Athl Train*. 2006;41(2):207-215.
40. Kofotolis ND, Kellis E, Vlachopoulos SP. Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. *Am J Sports Med*. 2007;35(3):458-466.
41. Lauder TD, Baker SP, Smith GS, Lincoln AE. Sports and physical training in injury hospitalizations in the Army. *Am J Prev Med*. 2000;18(3S):118-128.
42. Leininger RE, Knox CL, Comstock RD. Epidemiology of 1.6 million pediatric soccer-related injuries presenting to US emergency departments from 1990-2003. *Am J Sports Med*. 2007;35:288-293.
43. McGuine TA, Greene JJ, Best T, Leverson G. Balance as a predictor of ankle injuries in high school basketball players. *Clin J Sport Med*. 2000;10(4):239-244.
44. McHugh MP, Tyler TF, Tetro DT, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school athletes: the role of hip strength and balance ability. *Am J Sports Med*. 2006;34: 464-470.
45. McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: injury rate and risk factors. *Br J Sports Med*. 2001;35: 103-108.
46. Milgrom C, Shlamkovitch N, Finestone A, et al. Risk factors for lateral ankle sprain: a prospective study among military recruits. *Foot Ankle*. 1991;12(1):26-30.
47. Mountcastle SB, Posner M, Kragh JF Jr, Taylor DC. Gender differences in anterior cruciate ligament injury vary with activity: epidemiology of anterior cruciate ligament injuries in a young, athletic population. *Am J Sports Med*. 2007;35(10):1635-1642.
48. Murphy DF, Connolly DA, Beynnon BD. Risk factors for lower extremity injury: a review of the literature. *Br J Sports Med*. 2003;36: 13-29.
49. NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*. Bethesda, MD: National Heart, Lung, and Blood Institute; 1998.
50. Nussbaum ED, Hosea TM, Sieler SD, Incremona BR, Kessler DE. Prospective evaluation of syndesmotic ankle sprains without diastasis. *Am J Sports Med*. 2001;29:31-35.
51. Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: clustered randomized controlled trial. *BMJ*. 2005;330(7489):449.
52. Petersen L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups. *Am J Sports Med*. 2000;28(5):S51-S57.
53. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995-1997 seasons. *J Athl Train*. 1999;34: 277-284.
54. Powell JW, Barber-Foss KD. Sex-related injury patterns among selected high school sports. *Am J Sports Med*. 2000;28:385-391.
55. Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy*. 2007;23(12):1320-1325.
56. Soboroff SH, Pappius EM, Komaroff AL. Benefits, risks, and costs of alternative approaches to the evaluation and treatment of severe ankle sprains. *Clin Orthop*. 1984;183:160-168.
57. Stevenson J, Webster J, Johnson R, Beynnon B. Gender differences in knee injury epidemiology among competitive alpine ski racers. *Iowa Orthop J*. 1998;18:64-66.
58. Taylor DC, Englehardt DL, Bassett FH 3rd. Syndesmotic sprains of the ankle: influence of heterotopic ossification. *Am J Sports Med*. 1992;20:146-150.
59. 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.
60. Watson AW. Ankle sprains in players of the field games Gaelic football and hurling. *J Sports Med Phys Fitness*. 1999;39:66-70.
61. Willems TM, Witvrouw E, Delbaere K, Mahieu N, De Bourdeauduij I, De Clercq D. Intrinsic risk factors for inversion ankle sprains in male subjects: a prospective study. *Am J Sports Med*. 2005;33(3): 415-423.
62. Yeung MS, Chan KM, So CH, Yuan WY. An epidemiological survey on ankle sprain. *Br J Sports Med*. 1994;28(2):112-116.