Epidemiology of Lower Extremity Stress Fractures in the United States Military

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ABSTRACT Purpose: To comprehensively quantify established risk factors for the development of lower extremity stress fractures within a contemporary U.S. military cohort. Methods: Using the Defense Medical Epidemiological Database, all U.S. service members diagnosed with tibia/fibula, metatarsal, other bone, femoral neck, and femoral shaft stress fractures were identified based on International Classification of Diseases, 9th Revision, Clinical Modification code from 2009 to 2012. Incidence rates (IRs) and adjusted IRs controlling for sex, race, age, rank, and branch of service were obtained with multivariate Poisson regression analysis. Results: Between 2009 and 2012, 31,758 lower extremity stress fractures occurred among 5,580,875 person-years, for an unadjusted IR of 5.69 per 1,000 person-years. Tibial/fibular (40%) involvement was the most common. Bimodal age distribution revealed that service members under 20 years old (23.06; 95% confidence interval [CI] 22.52, 23.55) or ≥40 (6.86; 95% CI 6.65, 7.07) had greatest risk. Females were at higher risk for total lower extremity (3.11; 95% CI, 3.03, 3.18). White service members were also more at risk than Black service members ($p < 0.0001$). The majority of stress fractures (77.5%) occurred in junior enlisted service members, with the Army and Marines most at risk. Conclusion: This investigation elucidates several nonmodifiable risk factors for stress fractures in the military and may inform screening measures to reduce this significant source of disability.

INTRODUCTION

The Prussian military physician Breithaupt documented the first cases of "march foot" among soldiers after prolonged tactical movements in 1855.[1] In the modern era, stress fractures have continued to plague competitive athletes and military recruits, especially at the beginning of military service.[2–4] Yet despite increased awareness and improved diagnosis,[5] stress fractures remain an important source of disability in the contemporary military.[6] The presence of a stress fracture during basic training was the single most powerful predictor of military discharge, with a four-fold higher risk than those who complete training without injury.[7]

The underlying pathophysiology of stress fractures occurs when the rate of repetitive microtrauma exceeds that of osseous remodeling.[8] This often develops during basic training, field exercises, and combat deployments, largely as a result of marked increases in exposure and/or intensity of endurance, impact physical activity. The prevention of lower extremity stress fractures remains a long-standing problem in the military, and it represents a significant socioeconomic burden due to the significant cost of treatment and time lost to injury. The purpose of the current investigation was to broadly describe and enumerate the epidemiological trends and nonmodifiable risk factors associated with lower extremity stress fractures in an active military population within the United States. Based on existing data, the authors hypothesized that younger age, female sex, junior military status, and service in ground military forces would be associated with significantly increased risk of lower extremity stress fractures.[2,3,9,10]

METHODS

This study was approved by the institutional review board as a comparative prognostic study of prospectively gathered data to evaluate the demographic and occupational risk factors for lower extremity stress fracture in the U.S. military. The Defense Medical Epidemiology Database (DMED) is a military repository that accounts for every ambulatory or inpatient medical encounter by an active duty U.S. Army, Navy, Air Force, or Marine service member treated at a military treatment facility or civilian medical center. This robust epidemiological tool collects corresponding International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes related to a patient clinical encounter, and is derived from the diagnosis data entered into the electronic health record by a provider or physician extender well-versed in overuse musculoskeletal injuries. In association with the Defense Manpower Data Center, the DMED maintains up-to-date demographic and military service information on each service member, while integrating clinical and coding data

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from the Armed Forces Health Longitudinal Technology Application and its predecessor Composite Health Care System II. At the time of database entry, an ICD-9-CM code for a given patient encounter may be described as "new" for first-time diagnosis, or "chronic" for ongoing treatment or continuing medical care. As in the current study, this permits selection of only first-time diagnoses within each year to ensure accuracy of incidence reporting.

Using this framework, the DMED was queried for all unique occurrences between 2009 and 2012 for the following ICD-9-CM codes: 733.93 (stress fracture of tibia/fibula), 733.94 (stress fracture of metatarsals), 733.95 (stress fracture of other bone), 733.96 (stress fracture of femoral neck), and 733.97 (stress fracture of femoral shaft). Extracted data were further categorized by sex, race, age, rank, and branch of service. Race was classified according to broad self-reported categories, including White, Black, or Other race. Age was stratified according to the following 5-year age groups: less than 20 years, 20 to 24 years, 25 to 29 years, 30 to 34 years, 35 to 39 years, and 40 years or greater. Military rank was categorized as junior enlisted (grade E1–E4), senior enlisted (grade E5–E9), junior officer (grade O1–O3), and senior officer (grade O4–O10). Branch of service categories used were Army, Navy, Air Force, and Marine Corps.

Statistical Methods

Calculations were performed using SAS software, version 9.4 (SAS Institute, Cary, North Carolina) with the assistance of a biostatistician. Incidence rates (IRs) were expressed per 1,000 person-years for lower extremity stress fractures, along with 95% confidence intervals (CIs) for total and itemized diagnostic codes. To estimate incidence, one exposure year was defined as one year that the service member was in the U.S. Armed Forces. The calculations were adjusted to control for sex, race, age, rank, branch of military service, and calendar year utilizing multivariate Poisson regression to calculate the adjusted IRs, along with 95% CIs and adjusted incidence rate ratios (IRR). The referent category was selected on the basis of lowest IR within each category.

RESULTS

Between 2009 and 2012, 31,758 lower extremity stress fractures occurred among an at-risk military population of 5,580,875 service members, resulting in an unadjusted IR of 5.69 per 1,000 person-years. The annual IR for total lower extremity stress fractures ranged from 5.39 in 2010 to 6.27 in 2009, with the greatest change occurring between 2009 and 2010 with a decrease of 14% (Table I). During this timeframe, 40% of stress fractures involved tibia/fibula (IR 2.26), 16% occurred in the metatarsals (IR 0.92), 9% involved the femoral neck (IR 0.49), and 6% occurred at the femoral shaft (IR 0.34), whereas 30% of stress fractures involved other unspecified bones (IR 1.68).

TABLE I. Epidemiology of Lower Extremity Stress Fractures, 2009–2012

Year	Total Stress Fractures	Unadjusted IR (95% CI)	Total Femoral Neck Stress Fractures	Unadjusted (R	Total Number of Tibial Stress Fractures	Unadjusted IR (95% CI)	Total Number of Metatarsal Stress Fractures	Unadjusted IR (95% CI)	Total Number of Other Stress Fractures	Unadjusted IR (95% CI)	Total Number of Femoral Shaft Stress Fractures	Unadjusted IR (95% CI)
2009	8,787	6.27 (6.13,6.40)	703	0.50 (0.47,0.54)	3,345	2.38 (2.31,2.47)	1,419	1.01 (0.96,1.07)	2,929	2.09 (2.01,2.17)	391	0.28 (0.25,0.31)
2010	7,637	5.39 (5.27,5.51)	686	0.48 (0.45,0.52)	3,138	2.21 (2.14,2.29)	1,168	0.82 (0.78,0.87)	2,229	1.57 (1.51,1.64)	416	0.29 (0.27,0.32)
2011	7,945	5.61 (5.49,5.74)	700	0.49 (0.46,0.53)	3,097	2.19 (2.11,2.27)	1,332	0.94 (0.89,0.99)	2,207	1.56 (1.50,1.63)	609	0.43 (0.40,0.47)
2012	7,389	5.48 (5.36,5.61)	631	0.47 (0.43,0.51)	3,050	2.27 (2.19,2.35)	1,233	0.92 (0.87,0.97)	2,013	1.50 (1.43,1.56)	462	0.34 (0.31,0.37)

TABLE II. Epidemiology of Lower Extremity Stress Fractures According to Demographic Risk Factors

	Total Stress Fractures (*n*)	Person-Years	Unadjusted IR (95% CI)	Adjusted Rate Ratio (95% CI)	*p*-Value	Total Femoral Neck Stress Fractures	Person-Years
Age (Years)							
<20	7,678	332,989	23.06 (22.52, 23.55)	3.14 (3.05,3.23)	<0.0001	607	332,989
20–24	10,498	1,793,604	5.85 (5.74,5.97)	1	—	1,057	1,793,604
25–29	5,217	1,375,667	3.79 (3.69,3.90)	1.15 (1.11,1.19)	<0.0001	465	1,375,667
30–34	2,472	849,958	2.91 (2.80,3.03)	1.47 (1.40,1.54)	<0.0001	180	849,958
35–39	1,798	631,292	2.85 (2.72,2.98)	2.01 (1.90,2.13)	<0.0001	118	631,292
≥40	4,095	597,365	6.86 (6.65,7.07)	6.4 (6.12,6.70)	<0.0001	293	597,365
Gender							
Male	21,811	4,796,084	4.55 (4.49,4.61)	1	—	1,403	4,796,084
Female	9,947	784,791	12.67 (12.41,12.91)	3.11 (3.03, 3.18)	<0.0001	1,317	784,791
Race							
White	23,587	3,880,001	6.08 (6.00,6.16)	1.51 (1.46,1.55)	<0.0001	2,087	3,880,001
Other	3,316	752,015	4.41 (4.26,4.56)	1.17 (1.12,1.22)	<0.0001	220	752,015
Black	4,855	948,859	5.12 (4.98,5.26)	1	—	413	948,859
Military Rank							
Junior Enlisted	24,606	2,455,430	10.02 (9.90,10.15)	18.54 (16.97,20.26)	<0.0001	2,410	2,455,430
Senior Enlisted	5,009	2,188,822	2.29 (2.23,2.35)	3.2 (2.94,3.49)	<0.0001	192	2,188,822
Junior Officer	1,526	571,508	2.67 (2.54,2.80)	3.89 (3.53,4.29)	<0.0001	79	571,508
Senior Officer	617	365,115	1.69 (1.54,1.80)	1	—	39	365,115
Military Service							
Army	18,487	2,192,307	8.43 (8.31,8.56)	2.56 (2.47,2.65)	<0.0001	1,917	2,192,307
Navy	3,798	1,280,459	2.97 (2.87,3.06)	1	—	173	1,280,459
Marines	5,319	799,587	6.65 (6.47,6.83)	1.9 (1.82,1.98)	<0.0001	464	799,587
Air Force	4,154	1,308,522	3.17 (3.07,3.27)	1.09 (1.04,1.13)	0.0003	166	1,308,522

Age

After adjusting for other variables, a bimodal distribution by age was identified for all stress fractures and individual subtypes (Table II). When compared to individuals 20 to 24 years old, the adjusted rate ratios for total stress fractures were highest among those service members less than 20 years old (IRR 3.14; 95% CI 3.05, 3.23) and among the 40 years or greater age group (IRR 6.4; 95% CI 6.12, 6.70).

Sex

When compared with males, females had significantly higher overall rates of lower extremity stress fractures (IRR 3.11; 95% CI 3.03, 3.18), demonstrating higher rates of fractures involving the femoral neck (IRR 7.13; 95% CI 6.60, 7.71), femoral shaft (IRR 2.73; 95% CI 2.46, 3.03), tibial/fibular (IRR 2.30; 95% CI 2.21, 2.40), metatarsal (IRR 2.67; 95% CI 2.51, 2.85), and all other stress fractures (IRR 3.86; 95% CI 3.69, 4.03).

Race

The unadjusted IR for lower extremity stress fractures was 6.08 per 1,000 person-years among White service members, as compared to Black service members (5.21), and those of Other race category (4.41). Using Black race as a referent category, White service members had a significantly increased risk of sustaining all lower extremity stress fractures (IRR 1.51; 95% CI 1.46, 1.55). Similarly, White service members were also at significantly higher risk for femoral neck (IRR 1.88; 95% CI 1.68, 2.09), femoral shaft (IRR 1.67; 95%CI 1.17, 1.57), tibial/fibular (IRR 1.18; 95% CI 1.12, 1.23), metatarsal (IRR 2.11; 95% CI 1.93, 2.31), and other stress fractures (IRR 1.67; 95% CI 1.58, 1.77) when compared to those of Black race.

Rank and Branch of Service

The majority of fractures (77.5%) occurred in junior enlisted service members (IRR 18.54; 95% CI 16.97, 20.26), with at least a two-fold greater unadjusted IR than any other rank group. The Army had the highest incidence of total (IRR 5.11; 95% CI 4.96, 5.27), femoral neck (IRR 6.19; 95% CI 5.27, 7.26), tibial/fibular (IRR 1.84; 95% CI 1.75, 1.94), and unspecified (IRR 4.47; 95% CI 4.14, 4.83) lower extremity stress fractures, whereas the Marines had the highest IR of metatarsal stress fractures (IRR 2.43; 95% CI 2.21, 2.67).

DISCUSSION

The current study sought to calculate the IRs of lower extremity stress fractures and to identify demographic risk factors within a large-scale contemporary U.S. military population. Given the elevated risk among physically active patients, military cohorts have been ideal for previous investigations of the epidemiology, natural history, and morbidity

TABLE II. (continued)

Unadjusted IR (95% CI)	Adjusted Rate Ratio (95% CI)	*p*-Value	Total Tibial Stress Fractures	Person-Years	Unadjusted IR (95% CI)	Adjusted Rate Ratio (95% CI)	*p*-Value
1.82 (1.68,1.97)	2.22 (2.01,2.45)	<0.0001	3,001	332,989	9.01 (8.70,9.34)	3.07 (2.93,3.22)	<0.0001
0.59 (0.55,0.63)	1	—	4,311	1,793,604	2.4 (2.33,2.48)	1	—
0.34 (0.31,0.37)	1.09 (0.98,1.22)	0.1296	2,080	1,375,667	1.51 (1.45,1.58)	1.14 (1.08,1.20)	<0.0001
0.21 (0.18,0.25)	1.3 (1.11,1.54)	0.0015	1,004	849,958	1.18 (1.10,1.26)	1.52 (1.41,1.64)	<0.0001
0.19 (0.16,0.22)	1.82 (1.49,2.22)	<0.0001	662	631,292	1.05 (0.97,1.13)	1.92 (1.75,2.10)	<0.0001
0.49 (0.44,0.55)	6.69 (5.75,7.78)	<0.0001	1,572	597,365	2.63 (2.50,2.76)	6.61 (6.15,7.12)	<0.0001
0.29 (0.28,0.31)	1	—	9,279	4,796,084	1.93 (1.90,1.97)	1	—
1.68 (1.59,1.77)	7.13 (6.60, 7.71)	<0.0001	3,351	784,791	4.27 (4.13,4.41)	2.3 (2.21, 2.40)	<0.0001
0.54 (0.52,0.56)	1.88 (1.68, 2.09)	<0.0001	8,909	3,880,001	2.3 (2.25,2.34)	1.18 (1.12, 1.23)	<0.0001
0.29 (0.26,0.33)	1.11 (0.94,1.31)	0.2174	1,497	752,015	1.99 (1.89,2.09)	1.08 (1.01, 1.15)	0.0275
0.44 (0.40,0.48)	1	—	2,224	948,859	2.34 (2.25,2.44)	1	—
0.98 (0.94,1.02)	29.76 (21.23,41.72)	<0.0001	9,929	2,455,430	4.04 (3.97,4.12)	30.76 (25.97,36.44)	<0.0001
0.09 (0.08,0.10)	2.11 (1.49,2.99)	<0.0001	1,999	2,188,822	0.91 (0.87,0.95)	4.84 (4.11,5.72)	<0.0001
0.14 (0.11,0.17)	3.04 (2.05,4.49)	<0.0001	547	571,508	0.96 (0.88,1.04)	5.63 (4.69,6.75)	<0.0001
0.11 (0.08,0.15)	1	—	155	365,115	0.42 (0.36,0.50)	1	—
0.87 (0.84,0.91)	6.19 (5.27,7.26)	<0.0001	6,934	2,192,307	3.16 (3.09,3.24)	1.84 (1.75, 1.94)	<0.0001
0.14 (0.12,0.16)	1	—	1,964	1,280,459	1.53 (1.47,1.60)	1	—
0.58 (0.53,0.64)	4.28 (3.57,5.12)	<0.0001	1,993	799,587	2.49 (2.38,2.60)	1.34 (1.26, 1.43)	<0.0001
0.13 (0.11,0.15)	1.06 (0.86,1.32)	0.5788	1,739	1,308,522	1.33 (1.27,1.39)	0.91 (0.86,0.98)	0.0067

of these overuse injuries.[11] This investigation reflects an at-risk population of over 5 million American service members across a 4-year timeframe, which is among the largest known epidemiological analysis for stress-related injury to date. Across a broad tri-service U.S. military population, an average of six individuals will sustain a lower extremity stress fracture for every 1,000 service members each year. Furthermore, age, sex, race, military rank, and military branch of service were significantly associated with the IR of lower extremity stress fractures.

Many previous studies evaluating the incidence of stress fractures have disproportionately focused on short periods of temporal surveillance or isolated military subsets.[2,4,7,12–15] These investigations have typically characterized injuries at individual centers and selected intervals for intense physical activity such as military basic training, in large due to the relatively high incidence of stress fractures associated with this unique environment. However, this methodology fails to account for other service members with stress fractures and may underestimate the cumulative burden of stress-related, lower extremity injuries throughout the military population. The total IR of stress fracture is variably reported and may occur in up to 31%.[12,15–17] Cosman et al[2] evaluated 755 male and 136 female U.S. Military Academy cadets, and reported that 5.7% of males and 19.1% of females had at least one stress fracture over a period of 4 years. Of 614,606 basic training recruits, Knapik et al[12] documented an IR of 6.9 and 26.1 among men and women, respectively, over a 10-year period between 1997 and 2007. In a study of 1,296 randomly selected male Marine recruits followed during boot camp, stress fractures occurred in 4.0%.[10] In 2011, Wentz et al[18] summarized the results of 11 military studies, including case-control retrospective and prospective cohorts within the United States, Israeli, and Finnish militaries, and documented an overall incidence of 3% in males and 9.2% in females.[19] Some studies, however, have shown much higher IRs, with an overall incidence of stress fracture in up to 31%.[14]

This investigation demonstrates that tibial or fibular stress fractures (IR 2.26; 40%) had the highest relative IR by anatomic location among a contemporary military cohort, followed by the metatarsals (IR 0.92; 16%), femoral neck (IR 0.49; 9%), and femoral shaft (IR 0.34; 6%), respectively. In addition, 30% of all stress fractures involved other bones of the lower extremity (IR 1.68), underscoring the diversity and prevalence of stress fractures in other, “atypical” locations such as the calcaneus or patella. In their, series, Cosman et al[2] identified that the metatarsals (58%) and tibia (29%) were the most common sites for stress fracture among U.S. military cadets of both sexes, and over 50% of all stress fractures occurred within 3 months of matriculation. The prevalence among Israeli Defense Force basic trainees skewed more heavily toward tibial involvement (76.8%), followed by metatarsal (14.3%), femur (7.9%), tarsal (0.8%), and other bones.[14] This anatomic predilection likely occurs as a result of the repetitive deformation with mechanical bending and tensile loads during periods of increased impact activity in service members, such as during initial military training. However, certain biologic and anthropomorphic risk factors may also predispose certain individuals to stress fractures, particularly those of the tibia and femoral neck.[2,20]

Female sex has been repeatedly associated with a higher risk of stress fracture, especially within military cohorts.[3,9,21–23] Even when controlling for physical demands, sport, and activity exposure, this difference among the sexes has been reported in active, athletic cohorts.[2,6] The current study demonstrated that female military service members had an over three-fold higher IR of all lower extremity stress fractures and seven times greater rate of femoral neck stress fracture than their male counterparts. Numerous inherent anatomic, physiologic, and endocrinological factors have been suggested for women, including bony morphology (size, thinner cortex, narrower bone width, and wider pelvis), lower bone mineral density, early muscular fatigue, diminished relative cardiorespiratory fitness, fundamental gait or neuromuscular differences, dietary deficiencies, and/or menstrual disturbances.[2,12,24]

Although younger patients (18–24 years old) account for nearly two-thirds of all stress fractures, increasing chronological age was associated with increasing IRs in the current study. Patients aged 40 years or older had the highest IR of overall lower extremity stress fractures and of all individual subtypes, except for those involving the femoral shaft. This bimodal distribution likely reflects two separate phenomena. First, younger service members and new recruits are exposed to significant increases in both frequency and intensity of impact and other at-risk, load-bearing activities during regimented military training (e.g., basic combat training). Conversely, older service members may be at heightened risk of stress fracture due to cumulative microtrauma, declining bone mass density, and decreased osteoblastic activity and/or remodeling potential, all of which compromise fundamental mechanical properties during further, repetitive stress loading.

In addition to other hereditary predispositions, race and ethnicity have been consistently correlated with risk of stress injury, osteoporosis, and fragility fractures, most notably non-black and Caucasian white race. Several authors have posited that individuals of Black race may have comparatively increased bone mineral density and differences in inherent bone geometry that contribute to increased mechanical strength and act as a protective factor to stress injuries.[12,19,21,25] Although the exact underlying mechanism has not been elucidated, the current investigation supports a higher risk for all lower extremity stress fractures among white service members, with an IR up to 110% higher than that of black service members.

The greatest strength of this study is the large number of active duty service members who receive care in the closed military health care system and whose data were captured within the DMED. Multiple limitations must be acknowledged within this database registry. First, there are no predetermined diagnostic criteria or available musculoskeletal imaging to confirm the diagnostic accuracy of the treating medical provider. Since the dataset is constructed on patient-driven clinic visits, one can presume that the data are reflective of symptomatic complaints in the context of musculoskeletal imaging findings. Second, the framework of the ICD-9 coding scheme during the period of study does permit the ability to evaluate specific lower extremity stress fractures by distinct anatomic locations. Similarly, the unspecified stress fracture of other bone code (733.95) may have encompassed more rare subtypes not included within this framework (e.g., calcaneus, talus, tarsal navicular, patella, sesamoid), and this may affect interpretation of temporal and other epidemiological trends of these stress fractures. Third, the risk factors and demographic categories available for analysis are also not exhaustive and are limited by those entered into the DMED; thus, it is difficult to accurately evaluate patients of mixed race, or those who chose not to specify their race. Fourth, we were unable to assess the relative disease burden with identified stress fractures and correlate de-identified data with time lost to injury and ultimate clinical outcomes.

Despite these limitations, this investigation provides a broad and robust epidemiological analysis of the burden and risk factors for lower extremity stress fracture in a contemporary military cohort of over 5.58 million service members. Although there have been several attempts to mitigate the risk of stress fracture within the military through alterations in physical training, further preventative measures are warranted. With the identification of specific high-risk demographic subgroups within the U.S. military, future studies may target other modifiable risk factors to decrease the risk of primary or recurrent stress fracture. Although it is not feasible to expect that all lower extremity stress fractures can be obviated with preventative measures, this data may serve to benchmark current rates of overuse stress injuries and guide further interventions. Previously, improved prevention of displaced femoral neck stress fractures in military has been observed with increased physician education and effective prevention algorithms.[20] Subsequent research may seek to more systematically evaluate the impact of lower extremity stress fracture on mid- to long-term military retention and healthcare resource utilization. In addition, further stratified analysis of at-risk demographics identified in this study and specific military occupational specialties will be even more essential to protect these service members during intensive, high impact training.

CONCLUSION

Statistically significant risk factors for lower extremity stress fractures identified in this study were female sex, age groups ≥40 and ≤20, non-Black race, junior enlisted rank, and Army or Marine branch of service. Female sex had its greatest influence on femoral neck stress fractures, while junior enlisted status had its most profound effect on tibia/fibula and "other" stress fractures. This investigation elucidates several nonmodifiable risk factors for stress fractures in the military and may inform screening measures to reduce this significant source of lower extremity disability among high-risk cohorts.

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