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Timing of Stress Fractures in Soldiers During the First 6 Career Months: A Retrospective Cohort Study

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Context: Stress fractures (SFs) are injuries that can result from beginning new or higher-volume physical training regimens. The pattern of clinical presentation of SFs over time after individuals start a new or more demanding physical training regimen is not well defined in the medical literature.

Objective: To report trends in the clinical presentation of SFs over the first 6 months of soldiers' time in the service.

Design: Retrospective cohort study.

Setting: This study was conducted using medical encounter and personnel data from US Army soldiers during the first 6 months of their career.

Patients or Other Participants: United States Army soldiers beginning their careers from 2005 to 2014 (N = 701 027).

Main Outcome Measure(s): Weekly SF numbers and incidence were calculated overall, as well as by sex, over the first 6 months of military service.

Results: Stress fracture diagnoses (n = 14 155) increased steeply in weeks 3 and 4, with a peak in the overall incidence during weeks 5 to 8. Although the clinical incidence of SFs generally decreased after 8 weeks, incident lower extremity SFs continued to present for more than 20 weeks. The hazard ratio for SFs among women compared with men was 4.14 (95% CI = 4.01, 4.27).

Conclusions: Across the 6-month study period, women showed a more than 4 times greater hazard for SFs than men. The results also suggest that health care providers should be particularly vigilant for SFs within 3 weeks of beginning of a new or higher-intensity exercise regimen. The incidence of SFs may continue to climb for several weeks. Even as the SF incidence declines, these injuries may continue to appear clinically several months after a change in activity or training.

Key Words: overuse injuries, bone injuries, military athletes, tactical athletes

Key Points

- Medical encounters for lower extremity stress fractures began to increase steeply 3 weeks after soldiers began a novel training regimen, with peak rates seen in weeks 5 through 8.
- Although stress fracture rates decreased after the peak period, incident lower extremity stress fractures were seen for more than 20 weeks after the soldiers' careers began.
- Women showed a more than 4 times greater hazard of an incident stress fracture compared with men during the 6-month study period.

Stress fractures occur in populations that suddenly increase participation in repetitive physical activities, such as athletes at the beginning of a new sporting season and military recruits entering initial military training.[1–10] Stress fractures are thought to occur when repetitive loading of bone results in microscopic fatigue damage that may accumulate with continued loading in the absence of adequate time for bone tissue self-repair.[11] The tibia is reportedly the most common site of stress fracture in athletes and military personnel, followed by other bones of the lower extremities, including the fibula, metatarsals, femur, and pelvis.[1,12] Although men beginning a new training regimen experience rates of stress fracture as high as 7% to 10%,[13] female endurance athletes and military service members have a higher risk than their male counterparts, with reports of stress fracture rates as high as 20% in active female populations.[1,14] During the first 10 weeks of military training, a time of greater than customary physical activity for most recruits, the risk of stress fracture has been reported to be 4 times greater in women than in men.[15]

Although stress fracture is an injury of concern in those beginning a new training regimen,[2,7,9,15–23] the clinical presentation of stress fractures over time in a population beginning a new or more demanding physical training regimen is not well defined in the medical literature. For new soldiers, the first 10 weeks of a career are typically the "basic training" phase, with more advanced military training in the subsequent weeks and months. After those varying periods of training, soldiers transition into the physical and operational training activities of their first permanent station unit. This transition into military life may represent a change in lower extremity loading and impact activities that could contribute to stress fractures. Clinicians may understand the risk of stress fractures and be able to offer anecdotal evidence as to the timing of stress fractures seen in their various clinical populations. However, data are not readily available in the peer-reviewed literature in which researchers described the trend over time of the clinical presentation of stress fracture injuries after initiation of novel, higher-intensity, or longer-duration exercise regimens.

The US Army, which transforms recruits into soldiers through the process of initial military training, represents a large population of individuals who are susceptible to stress fractures due to beginning a novel or higher-volume training regimen. Studying this population allows for characterization of the timing and location of stress fractures in individuals at high risk of injury due to a change or increase in physical training. Therefore, the purpose of our study was to describe the overall and weekly incidences of lower extremity stress fracture injuries over the first 6 months of soldiers' service in the US Army.

METHODS

We conducted a retrospective cohort study using data from the Total Army Injury and Health Outcomes Database (TAIHOD). The TAIHOD is a data repository that includes medical encounter data and personnel data on all active-duty US Army soldiers and exists for the purpose of conducting epidemiologic research in Army personnel.[24] The dataset for this retrospective cohort study was constructed using demographic and service-time data from soldiers' personnel records and diagnosis codes from medical encounter data. Personnel data came from the Defense Manpower Data Center and medical encounter data came from the Military Health System Medical Repository. This study was approved by the Institutional Review Board of the US Army Research Institute of Environmental Medicine.

Participants

The population studied was US Army soldiers who entered into active duty from January 1, 2005, through December 31, 2014 (N = 701 027). The entire population was examined, and stress fracture cases were identified from medical encounter data to establish the weekly proportion of soldiers who were diagnosed with stress fractures. Incident stress fractures were identified using International Classification of Diseases Ninth Revision (ICD-9; https://www.cdc.gov/nchs/icd/icd9.htm) codes. For outpatient visits, an *incident case* was defined as an initial ICD-9 code from the following list: 733.93 (stress fracture of tibia or fibula), 733.94 (stress fracture of metatarsals), 733.95 (stress fracture of other bone), 733.96 (stress fracture of femoral neck), 733.97 (stress fracture of shaft of femur), 733.98 (stress fracture of pelvis), 733.99 (other stress fracture), 733.14 (pathologic fracture of neck of femur), 733.15 (pathologic fracture of other part of femur), and 733.16 (pathologic fracture of tibia or fibula). Each case was followed up with a second code from the list at least 14 but no more than 90 days from the service date of the initial code. Pathologic fracture codes were used because staff from medical treatment facilities may have become accustomed to using those codes before the availability of stress fracture codes and continued to use those codes.[15,25] Given that pathologic fractures are unlikely in this population, the inclusion of these codes helps to capture stress fractures and is unlikely to confound the data.[15,25] These methods and the use of these diagnosis codes are similar to those of previous studies.[12,15,24–27] By using this method with these types of data, we were able to confirm the injury after the initial differential diagnosis because it can take weeks to confirm stress fractures using imaging modalities,[28] and follow-up care will continue for weeks or months after a stress fracture is identified. For inpatient visits, a single entry from the ICD-9 codes listed earlier was sufficient for a case to be defined as *incident*, as confirmation of the injury necessitated more involved inpatient management. Stress fracture diagnoses were sorted by location according to the specificity allowed by the ICD-9 codes. The location designations were tibial and fibular, metatarsal, femoral neck, femoral shaft, pelvic, and unspecified or other. The category of *unspecified or other* is based on stress fracture diagnosis codes that did not specify a location or indicated "other" bone in the code. The location of the stress fracture was derived using the second coding (confirming diagnosis), except in the case of inpatient diagnosis of stress fracture, for which only a single code was present.

Quantitative and Qualitative Assessments

Because the bulk of stress fractures occur at the beginning of soldiers' careers, as they acclimate to initial military training and unit physical training, we examined the first 6 months of service in weekly increments to determine stress fracture numbers and incidence. Overall weekly incidences of stress fractures were calculated for all soldiers and separately for males and females. The *incidence* was defined by the proportion of soldiers in the Army with a clinical diagnosis of a stress fracture within the respective week of their career. The *timing of the stress fracture* was determined based on the number of weeks that the soldier had served on active duty; injuries were tallied based on the week of service with respect to the first day of a soldier's active-duty service. To determine the weekly incidence proportion for stress fractures, the total number of soldiers experiencing a stress fracture diagnosis during a given week of service was divided by the total number of soldiers in the Army during that career week. The number of soldiers in the denominator was based on the actual count of soldiers in the Army during the specific week of service. Any soldiers who left the Army before that week were not included in the calculation of weekly incidence. The resulting proportion was then multiplied by 1000 to calculate the weekly epidemiologic incidence of stress fractures per 1000 soldiers.[29] The temporal presentation of stress fracture injuries was examined using a graphical representation of stress fracture numbers and incidence proportions. Stress fracture numbers by region and by year were also tabulated. In addition to the descriptive statistics on the incidence of stress fractures, we calculated a hazard ratio (HR) by comparing the hazard for incident lower extremity stress fractures in women compared with men and produced survival curves.

RESULTS

Data from a total of N = 701 027 soldiers (n = 586 412 [83.7%] male, n = 114 615 [16.3%] female) were assessed over the 10-year study period. Within the first 6 months of soldiers' time in the Army, 14 155 incident lower extremity stress fractures were identified. The demographic characteristics of soldiers in this study are provided in Table 1.

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Table 1. Participant Characteristics[a]

Characteristic	Stress Fracture Status	
	Cases (n = 14 155)	Noncases (n = 686 872)
Sex, No. (%)		
Male	8042 (56.8)	578 370 (84.2)
Female	6113 (43.2)	108 502 (15.8)
Age, mean ± SD	21.8 ± 3.5	21.1 ± 3.2
Minimum, maximum	17, 34	17, 34
Body mass index, mean ± SD	23.9 ± 3.4	24.7 ± 3.5
Minimum, maximum	17.76, 33.5	18.0, 34.4

[a] Demographic variables are provided for soldiers who sustained a stress fracture during the first 6 months of their military career (Cases) compared with those who did not (Noncases).

The incidence of stress fractures and the 95% CI for soldiers in the first 6 months of service were 20.19 (95% CI = 19.86, 20.52) per 1000 soldiers, with men having an incidence of 13.71 (95% CI = 13.42, 14.01) per 1000 and women having an incidence of 53.33 (95% CI = 52.03, 54.64) per 1000. The weekly numbers and incidences of stress fractures are shown in Figure 1 (incidence and confidence bounds are available in the Appendix). Higher overall and weekly incidences of stress fractures were seen in women, but a higher raw number of stress fractures were seen in men (Figure 1 and Table 1). Women had a 4 times greater hazard of developing an incident stress fracture than men over the first 6 months of service, with an HR of 4.14 (95% CI = 4.01, 4.27). Survival curves were also produced (Figure 2). The location-specific diagnoses for stress fractures are presented in Table 2. The annual numbers and incidences of stress fractures during the study period are provided in Table 3.

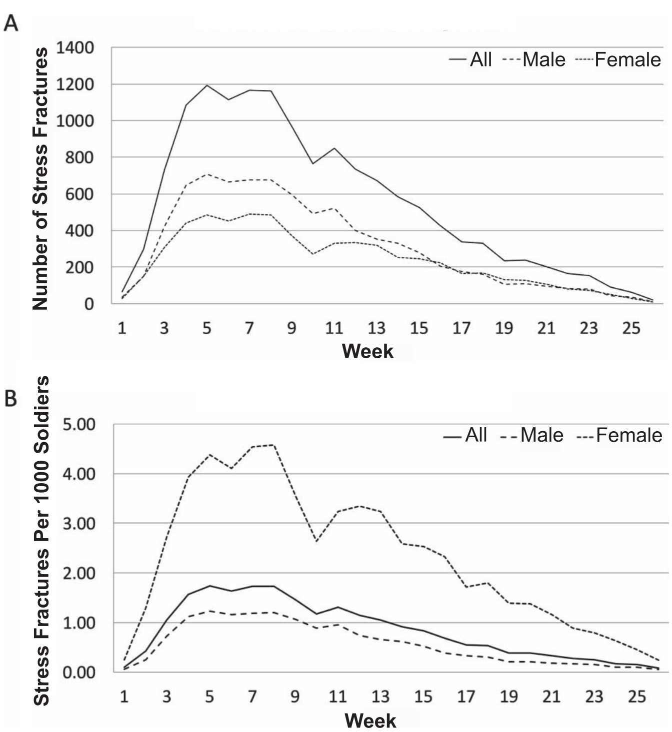

Figure 1. Weekly numbers and incidence of stress fractures (per 1000 soldiers) over the first 26 weeks (6 months) of service in the Army. A, Represents the number of stress fractures per week of service; B, represents the weekly incidence. Numbers and incidences are depicted for all soldiers (solid line) and separately for male (dashed line) and female (dotted line) soldiers.

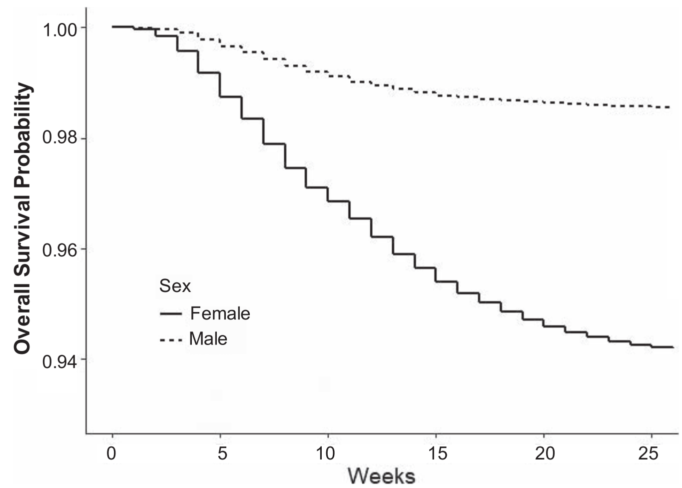

Figure 2. Survival curve for incident lower extremity stress fractures over the 6-month study period. The hazard ratio for lower extremity stress fractures in women versus men was 4.14, with 95% CI = 4.01, 4.27.

Although stress fracture diagnosis occurred during weeks 1 and 2 of soldiers' careers, stress fracture diagnoses began to increase steeply beginning in week 3. The stress fracture incidence peaked from the fifth through eighth weeks (Figure 1) of service, with the highest point estimates of incidence observed during the seventh and eighth weeks. The point estimates in weeks 7 to 8 were 1.73 to 1.74 (95% CI = 1.63, 1.84) per 1000 soldiers overall, 1.19 to 1.20 (95% CI = 1.10, 1.29) per 1000 men, and 4.54 to 4.58 (95% CI = 4.14, 4.98) per 1000 women. A decline was seen in diagnoses during weeks 9 and 10, with a spike in diagnoses occurring in week 11. Stress fracture diagnoses steadily decreased over the remainder of the 6-month period.

DISCUSSION

Stress fracture diagnoses began to increase steeply during the third and fourth weeks after entry into the Army, with the peak weekly incidences of medical encounters for stress fractures seen from the fifth through eighth weeks of service. These first several weeks of a soldier's career represent the period of basic combat training, during which physical training and military-specific activities may be novel or of greater frequency than before entry into the service. It appears that the weekly incidence of clinically recorded stress fractures steadily increased over the first 8 weeks of this period. Although the weekly incidence of

Table 2. Incident Stress Fractures During the First 6 Months of Service in the Army for All Soldiers, 2005–2014

Location of Fracture	No. (%) of Stress Fractures		
	Total (n = 14 155)	Males (n = 8042)	Females (n = 6113)
Tibia or fibula	3978 (28.1)	2805 (34.9)	1173 (19.2)
Metatarsal	1429 (10.1)	1109 (13.8)	320 (5.2)
Femoral shaft	466 (3.3)	290 (3.6)	176 (2.9)
Femoral neck	1432 (10.1)	737 (9.2)	695 (11.4)
Pelvis	1331 (9.4)	295 (3.7)	1036 (16.9)
Unspecified or other	5519 (39.0)	2806 (34.9)	2713 (44.8)

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Table 3. Yearly Stress Fracture Incidence Over the Study Period, 2005–2014[a]

Year	Total Cases	Total Denominator	Total Incidence	Male Cases	Male Denominator	Male Incidence	Female Cases	Female Denominator	Female Incidence
2005	1671	65 475	25.52	886	54 398	16.29	785	11 077	70.87
2006	1605	74 484	21.55	949	61 729	15.37	656	12 755	51.43
2007	1735	71 275	24.34	1020	59 462	17.15	715	11 812	60.53
2008	1428	78 854	18.11	849	65 837	12.90	547	12 811	42.70
2009	1515	72 304	20.95	834	60 605	13.76	681	11 698	58.22
2010	1445	75 361	19.17	884	63 154	14.00	561	12 207	45.96
2011	1497	64 865	23.08	850	54 348	15.64	647	10 517	61.52
2012	982	65 512	14.99	564	55 363	10.19	418	10 149	41.19
2013	1250	73 214	17.07	627	61 418	10.21	623	11 796	52.81
2014	1027	59 683	17.21	558	49 979	11.16	469	9 703	48.34

[a] The total number of incident stress fractures and incidence per 1000 soldiers is provided, as well as the number and incidence per 1000 male and 1000 female soldiers.

stress fractures decreased beyond the 8th week of service, it is important to note that incident stress fractures were still seen beyond the 20th week of service. This initial, approximately 10-week period of basic combat training is largely standardized for soldiers. Beyond 10 weeks, soldiers may enter Advanced Initial Training or other military training programs, and that phase of training can vary greatly, from a few weeks to several months, depending on the soldier's military occupational specialty. After initial military training, soldiers typically transition into the physical and operational training activities of their first permanent station unit. Whereas the bulk of stress fractures are seen during basic combat training, these data showed that bone stress injuries can occur beyond that period and even when soldiers are no longer trainees.

After the peak of clinical encounters for incident stress fractures around week 8, a steep decrease occurred for the next 2 weeks, followed by another increase around the 11th week of service. This second spike in clinical encounters was likely due to a reluctance to report an injury at the end of initial basic training periods (9th to 10th weeks), for which the motivation to endure pain and graduate from the basic training environment may be high, although this remains to be demonstrated through direct evidence. This type of underreporting of injuries to avoid duty restrictions that could negatively affect job performance has been previously discussed in soldiers.[30] After graduation from the basic phase of training, soldiers may report injuries that have failed to show symptomatic improvement with a short period of relative rest as they continue to more specific military occupational training. This trend holds clinical importance because it shows that people developing stress fractures, with the gradual onset of pain, may feel that they are able to endure the symptoms to achieve a short-term physical goal. The closing of training periods may also include culminating events that add greater physical stress at the end of training and further stimulate the development of stress injuries in at-risk individuals. This observation was supported by a study[7] of stress fractures in Royal Marine recruits that showed greater numbers of stress fractures around the time of the more physically demanding training events and that the peak numbers of stress fractures coincided with those events when they were rescheduled to a different time in training. No data in this study involved reporting patterns or the physical activity of soldiers at the time of injury, but these explanations are plausible given supporting evidence elsewhere in the medical literature.[7,30] Potential underreporting of pain associated with stress fractures is an important factor to consider in people who are susceptible to stress fractures, such as military personnel or endurance athletes, when they are close to a training goal or athletic competition.

These data suggested that a heightened awareness of stress fractures as a differential diagnosis for individuals with lower extremity pain may be warranted around the third week of entry into a new training program, even though smaller numbers of individuals may present with stress fractures earlier than the third week. The period of the greatest increase and highest incidence of lower extremity stress fractures appeared 3 to 8 weeks after beginning a regimen of novel or increased (or both) weight-bearing and impact activities in this military population. The number and incidence of stress fractures decreased over time after the peak period but extended into the sixth month (20+ weeks) of service. This finding indicated that some people may develop stress fractures more slowly, perhaps based on intrinsic physiologic factors, and present as cases after a longer exposure period.

The reasons for the development of stress fractures in as little as 2 to 3 weeks into training are unclear, given that this leaves little time from the start of training to move along the stress fracture etiologic pathway. The pathophysiology of stress fractures has been suggested to arise from heightened repetitive loading of bone tissue, which includes generation of bone fatigue damage, increased bone remodeling that targets this damage for removal, resultant porosity, and a positive feedback cycle of damage, repair, and porosity until fracture.[11] It is highly unlikely that these physiological processes would be completed in 1 to 2 weeks of training, and therefore, it is plausible that soldiers diagnosed with stress fractures early in training may have self-selected to begin physical training before arrival at basic training to prepare for the physical challenges ahead. These hypotheses remain to be tested, and the results could have important implications for recommendations related to the timing of physical preparation before military entry or athletic competition.

The higher incidence of stress fracture in women seen in our study was consistent with the findings of researchers who used similar data to examine the stress fracture incidence in basic trainees[15,25] and was also consistent with the summary findings of a systematic review[31] in which the investigators reported a generally higher incidence of stress fractures in female military members and athletes. Across

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the 6-month study period, women showed a greater than 4 times the hazard for developing a stress fracture than men (HR = 4.14; 95% CI = 4.01, 4.27), which is consistent with the findings from previous studies[15,25] in which researchers used medical encounter data to compare stress fractures between male and female soldiers during basic training. The yearly incidence rate of stress fractures (Table 3) varied slightly over the study period in a pattern similar to the fluctuations demonstrated in an earlier examination[21] of stress fracture rates in service members. Many explanations are possible for the yearly variations stemming from recruitment policies and the recruit population, policy variations, or world events that alter unit training or unit mission. Overall, the incidence of stress fractures in women was higher than in men from year to year across the 10 years of this study, with women showing a 4 times greater hazard for incident stress fractures than men.

Consistent with the increased hazard of stress fracture in women compared with men, the survival curves (Figure 2) displayed a much steeper effect of these injuries in female soldiers than in male soldiers. This highlights the effect of these injuries in the potential for lost training and duty days in women versus men during the first 26 weeks of their careers. Although women showed a higher incidence of clinical presentation of stress fractures in this study, men accounted for more incident stress fractures than women due to the much higher percentage of men (83.7%) in the Army than women (16.3%). From the perspective of screening or differentially diagnosing these injuries, it is beneficial for clinicians to understand that the incidence of stress fractures was substantially higher in women than men. However, from the perspective of the effect of this injury within the Army, it must be noted that men presented clinically with these injuries in higher numbers than women. That is an important point to consider in this heavily male population and may be a consideration for clinicians serving other populations that may be skewed in distribution of the sexes.

Here, we highlight several limitations of our work. The investigation was conducted using medical encounter data, yet providers or medical coders may have committed coding errors. Any errors in coding should be rare, randomly distributed, and not a significant source of bias. Due to the lack of clinical notes, elements of the diagnosis such as clinical examination findings and imaging results are not available. Therefore, the diagnostic criteria used by providers were not known. It is also probable that diagnostic criteria and follow-up varied among providers. That reflects clinical practice for this musculoskeletal condition and should not significantly affect the overall results. The largest individual diagnostic category in the study was *unspecified or other*, which has also been reported by earlier researchers[12] using this type of data. This category likely represents less common stress fractures of bones such as the tarsals, patella, or sesamoids, as well as coding of stress fracture as a general injury diagnosis on the part of providers or coders who selected a nonspecific stress fracture code in the electronic medical records system. We included the category of *unspecified or other* in the location-specific categories to thoroughly present the data to readers. Because the diagnoses were obtained from clinical encounter data, these results should not be assumed to offer empirical evidence on the timing of physiological processes underlying stress fractures. Clinical presentation is often due to multiple factors, such as patients' pain tolerance and motivation, which can vary among individuals and may not reliably coincide with the stages of pathophysiology. That variation does not detract from the significance of our findings regarding the timing of clinical presentation of stress fractures, as patients present clinically at various phases of pathophysiology for musculoskeletal stress injuries. Providers can still gain an understanding of the timing of the clinical presentation of stress fractures in general from the results of this study. Despite these limitations, the large study size and the inclusion of data from the entire US Army over a 10-year period provide a useful depiction of the clinical presentation patterns of lower extremity stress fractures in an adult population beginning a novel or higher-intensity physical training program.

These results can be used to guide future prospective clinical and physiological research examining bone health and stress fracture pathophysiology. Specifically, large-scale cohort studies during initiation of physical training in soldiers, in which bone metabolism and microarchitecture are studied, can help elucidate the physiological process underlying the clinical presentation of stress fractures and help identify potential preventive measures. The findings may also be used to educate clinicians who care for military members or other populations of individuals who will begin a period of increased physical activity, particularly involving loading of the lower extremities. Understanding the timing of the clinical presentation of stress fractures and other injuries may aid in planning for medical support to at-risk populations.

CONCLUSIONS

The clinical incidence of lower extremity stress fractures increased substantially at approximately 3 weeks after beginning US Army military training and increased for up to 8 weeks into training. Although the clinical incidence of stress fracture tended to decrease beyond 8 weeks, incident stress fractures continued to present for 20 or more weeks after military entry. These observations may help guide military health care providers in terms of clinical practice for suspicion of stress fracture in service members and could also have implications for sports medicine practitioners caring for members of the general public who have begun a novel physical training regimen.

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Appendix. Incident Stress Fracture Diagnoses During the First 26 Weeks of Military Service

Week	No.	Rate[a] (95% CI)
1	66	0.09 (0.07, 0.12)
2	296	0.42 (0.38, 0.47)
3	731	1.05 (0.98, 1.13)
4	1086	1.57 (1.48, 1.66)
5	1192	1.74 (1.64, 1.84)
6	1115	1.64 (1.54, 1.73)
7	1164	1.73 (1.63, 1.82)
8	1160	1.74 (1.64, 1.84)
9	965	1.46 (1.37, 1.55)
10	764	1.17 (1.08, 1.25)
11	850	1.31 (1.22, 1.40)
12	735	1.14 (1.06, 1.22)
13	671	1.05 (0.97, 1.13)
14	582	0.92 (0.84, 0.99)
15	524	0.83 (0.76, 0.91)
16	427	0.69 (0.62, 0.75)
17	337	0.54 (0.49, 0.60)
18	329	0.53 (0.48, 0.59)
19	235	0.38 (0.33, 0.43)
20	237	0.39 (0.34, 0.44)
21	201	0.33 (0.29, 0.38)
22	163	0.27 (0.23, 0.31)
23	152	0.25 (0.21, 0.30)
24	91	0.17 (0.14, 0.21)
25	62	0.16 (0.12, 0.20)
26	20	0.08 (0.05, 0.12)

[a] Incidence proportion per 1000 soldiers.

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