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The Incidence and Distribution of Stress Fractures in Competitive Track and Field Athletes

A Twelve-Month Prospective Study*

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ABSTRACT

The incidence and distribution of stress fractures were evaluated prospectively over 12 months in 53 female and 58 male competitive track and field athletes (age range, 17 to 26 years). Twenty athletes sustained 26 stress fractures for an overall incidence rate of 21.1%. The incidence was 0.70 for the number of stress fractures per 1000 hours of training. No differences were observed between male and female rates ($P > 0.05$). Twenty-six stress fractures composed 20% of the 130 musculoskeletal injuries sustained during the study. Although there was no difference in stress fracture incidence among athletes competing in different events ($P > 0.05$), sprints, hurdles, and jumps were associated with a significantly greater number of foot fractures; middle- and long-distance running were associated with a greater number of long bone and pelvic fractures ($P < 0.05$). Overall, the most common sites of bone injuries were the tibia with 12 injuries (46%), followed by the navicular with 4 injuries (15%), and the fibula with 3 injuries (12%). The high incidence of stress fractures in our study suggests that risk factors in track and field athletes should be identified.

Stress fractures are common injuries among athletes and represent a major disruption to training and competition. Previous studies are mostly case series that provide information about the relative frequency and distribution of stress fractures, but these case series have little value in estimating the incidence of stress fractures in a population. Although stress fractures may account for up to 15% of the injuries seen at sports medicine clinics,[7,23,38,41] it has not been well established what proportion of the athletic population (e.g., track and field, football) incurs stress fractures. In addition, little research directly compares the incidence rates between male and female athletes, despite anecdotal observations suggesting that women are at an increased risk of stress fracture.[12]

Track and field competition encompasses a variety of events, including sprints, hurdles, jumps, and middle- and long-distance running. These activities may place the athlete at risk of injury by subjecting the skeleton to repeated high mechanical loads, which result from ground reaction forces and muscular contraction. However, because training differs in activity, duration, and intensity, athletes in different events may be exposed to varying degrees of risk of stress fracture. The site of stress fracture development may also be influenced by the type of training.

The aims of this study were to 1) document the annual incidence of stress fracture prospectively in a group of competitive track and field athletes, 2) establish what proportion of the musculoskeletal injuries are stress fractures, 3) compare the incidence and site distribution of stress fractures between male and female track and field competitors, and 4) compare the incidence and site distribution of stress fractures within the different events.

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MATERIALS AND METHODS

Subjects

Subjects, who were recruited from Victoria, were registered track and field athletes who competed at either club, state, or Australian national levels in all track and field events except throwing or walking. Fifty-three Level 2 and 3 registered state coaches were sent a letter that outlined the study and requested names of athletes for inclusion in the study.[3] State athletes who ranked among the top 50 national track and field competitors were also sent a letter.[2]

Athletes were included in the study if they met the following criteria: 1) they trained at least three times per week when uninjured; 2) their age range was from 17 to 26 years; 3) they had no past (<12 months) or present use of anabolic steroids or human growth hormone; 4) they had no history of disease or medication likely to influence bone density; and 5) if they were female athletes, they had reached menarche.

We contacted coaches and athletes and followed up by letter and telephone. Fifty-three female and 58 male athletes were enrolled in the study. Table 1 shows participant characteristics, such as age, height, weight, body mass index, and training in the 12 months preceding the study.

The following track and field athletes and events were represented in our study: 19 sprinters (100, 200, and 400 m), 40 middle-distance runners (800 and 1500 m), 21 long-distance runners (3 km and marathon), 16 hurdlers, 10 jumpers (long, triple, and high jumps), and 5 multievent athletes (heptathlon and decathlon). Because the athletic ability of the subjects varied, we ascertained their level of competition in the year preceding the study. Thirty-two of 53 female athletes (60.4%) and 47 of 58 male athletes (81%) qualified for the Australian national championships; 20 women (37.7%) and 28 men (48.3%) competed in the national finals. More than two thirds of the athletes, 36 women (67.9%) and 42 men (72.4%), competed in the highest state-level competition.

Forty-three of the 111 study participants (38.7%), 22 female (41.5%) and 21 male athletes (36.2%), reported a previous history of one or more stress fracture as diagnosed with clinical assessment and either isotope bone scan, CT scan, or radiograph. Among these athletes, 11 women (50.0%) and 7 men (33.3%) had a past history of multiple stress fractures.

TABLE 1
Descriptive and Training Variables (Mean ± SD) in Female and Male Athletes

Characteristics	Women (N = 53)	Men (N = 58)
Age (years)	20.5 (2.2)	20.3 (2.0)
Height (cm)	167.4 (6.1)	179.3 (6.1)
Weight (kg)	59.0 (5.6)	70.3 (7.8)
Body mass index	21.1 (1.8)	21.8 (1.7)
Total training/week[a] (hrs)	12.0 (5.5)	12.6 (4.1)
Running training/week[a] (hrs)	8.0 (4.0)	9.7 (3.9)
Distance run/week[a] (km)	40.7 (28.1)	53.7 (41.3)

[a] Totals recorded in the year preceding the study.

Procedures

This study was undertaken after approval from the Human Experimentation Ethics Committees of La Trobe University and the Royal Melbourne Hospital. All subjects gave written informed consent before participation.

Stress fracture diagnosis. During the 12-month study, subjects were closely monitored for signs and symptoms suggesting a stress fracture. Athletes were requested to report any symptoms of pain lasting more than 1 week, and they were questioned by one of the researchers (KLB) monthly. Athletes with musculoskeletal pain were assessed by a sports physician. The main symptom of a stress fracture is pain, typically associated with exercise and relieved by rest.[32] Clinical signs of a stress fracture include localized bony tenderness, swelling of the overlying soft tissue, and pain on loading the affected bone.[19,32] Athletes with suspected stress fractures underwent technetium-99m triple-phase isotope bone scans. If the scans showed a focal area of increased uptake, a CT scan was performed, when possible, to confirm the diagnosis.

The diagnosis of a stress fracture on a bone scan or CT scan was made using a blinded protocol. A radiologist and a sports physician were given anonymous scans, which included those of the participants in the study. For each scan, they received information on the site of pain reported by the patient.

Each assessor independently interpreted the scans on the following criteria. Bone scans were categorized as having no increased uptake, decreased uptake, or increased uptake of the isotope at the site of pain. If increased uptake was noted, the pattern of uptake was categorized as either focal ovoid, focal linear, or diffuse. Bone scans were considered diagnostic of a stress fracture if there was focal increased uptake at the site of pain that was ovoid in shape.[1,21,45] The CT scans were similarly assessed; they were considered diagnostic of a stress fracture if they showed signs of a linear cortical defect, focal cortical lucency, periosteal new bone, cortical bridging, or focal sclerosis.[35,46] Using these criteria, the diagnosis of a stress fracture was made if both assessors agreed. Because there were no discrepancies, a third opinion was not required.

Total injuries. At the conclusion of the study, subjects were questioned by one researcher (KLB) about injuries sustained during the 12-month study. An injury was defined as any musculoskeletal pain or injury that resulted from athletic training and caused alteration of normal training in mode, duration, intensity, or frequency for 1 week or more. A similar definition was used by Blair et al.[6] and Lysholm and Wiklander.[30] Further information for each injury included month, anatomic location, mechanism of injury, and, if assessed by a health professional, diagnosis.

Training. The same researcher (KLB) conducted a structured interview at the conclusion of the study to obtain information about training during the preceding 12 months. Subjects were questioned on their average number of hours per week of athletic training and on the number of weeks they went without training because of injury, illness, or planned rest. This information enabled calculation of the incidence of stress fracture per 1000 hours of training.

Statistical Analysis

All statistics were performed with the Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois). For continuous variables, comparisons were made using the Mann-Whitney U-test. Differences among categoric variables were evaluated using a chi-square test or Fisher's exact test. A two-tailed significance level of $P < 0.05$ was set.

RESULTS

Stress Fractures

Seven women and 9 men of the 111 total study participants were excluded from the final analysis, representing an overall attrition rate of 14.4%. Six participants left the project because of study or work commitments, nine retired from athletics or did not train during the year, and one relocated overseas. Of the remaining 95 athletes, 10 (21.7%) women and 10 (20.4%) men sustained at least one stress fracture during the study. There was no significant difference between male and female incidence rates (chi-square [1] = 0.03, $P > 0.05$). The combined overall incidence rate of stress fractures for male and female athletes was 21.1%.

A total of 26 stress fractures resulted; female and male athletes sustained 14 and 12 injuries, respectively. Although six of these fractures were not imaged with CT scanning because of scheduling difficulties, stress fractures of these three subjects were included in the results because the injuries were imaged on isotope bone scans and fulfilled the study criteria. Two female and one male athletes had concurrent stress fractures, and two athletes sustained stress fractures in different locations on separate occasions. Sixty percent of the male and female competitors who sustained stress fractures also had a history of one or more stress fracture. Fifty percent of stress fractures (13) occurred during the winter, 15% (4) during the precompetition phase, and 35% (9) during the summer. Stress fractures occurred in equal numbers on the left and right sides of the body.

Overall, the incidence of stress fracture per 1000 hours of training was 0.70. Women sustained 0.86 stress fractures per 1000 training hours and men sustained a rate of 0.54. With those incidence rates, it appears that women are at a slightly increased risk of stress fracture compared with men when the same amount of training is considered. However, a Mann-Whitney U-test revealed that the difference was not statistically significant (U = 1105, P = 0.82).

Table 2 shows the number of athletes with stress fractures and the number of stress fractures in each event. The percentage of athletes who sustained stress fractures in each event is illustrated in Figure 1; multievent athletes were not included in the data because of the limited number of competitors. With the data of men and women combined, long-distance runners had the highest percentage of athletes (6 of 19) with stress fractures, 31.6%. Eight of 35 middle-distance runners (22.9%) and 2 of 11 hurdlers (18.2%) were next at the most risk. Male athletes with stress fractures were distributed evenly across the different events. No female athlete sustained a stress fracture in sprints or jumps, but four of nine long-distance runners, a significant number, sustained stress fractures (44.4%).

Because the numbers in each separate event were too small to analyze statistically, athletes were combined into two event groups based on similarity of training techniques and activities. Sprinters, hurdlers, jumpers, and multievent athletes (Group I), who tend to train with more interval and plyometric activities, were compared with middle- and long-distance runners (Group II). Although chi-square analysis revealed no significant difference ($P >$ 0.05) in the percentage of athletes sustaining stress fractures in the two event groups, women in the middle- and long-distance running group showed a trend of having a greater percentage of athletes with stress fractures than the sprinting, hurdling, and jumping group (Table 3).

Figure 2 shows the site distribution of all stress fractures. Overall, the tibia was the most common site of stress fracture with 12 injuries (46%), followed by the navicular bone with 4 injuries (15%) and the fibula with 3 injuries (12%). For women, the majority of the 14 stress

TABLE 2
Number of Athletes and Stress Fractures in Each Event[a]

Category	Sprints	Mid-Dist	Distance	Hurdles	Jumps	Multi	Total
No. of subjects							
All athletes	16	35	19	11	10	4	95
Women	5	17	9	6	5	4	46
Men	11	18	10	5	5	0	49
No. of stress fractures							
All athletes	4	9	9	2	1	1	26
Women	0	5	7	1	0	1	14
Men	4	4	2	1	1	0	12
No. of athletes with stress fractures							
All athletes	2	8	6	2	1	1	20
Women	0	4	4	1	0	1	10
Men	2	4	2	1	1	0	10

[a] Mid-Dist, middle distance; Multi, multiple events.

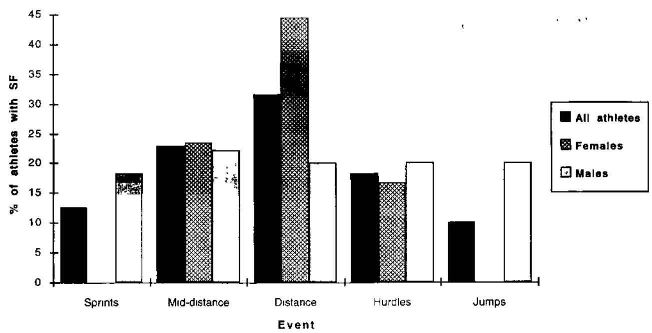

Figure 1. Percentage of athletes with stress fractures in each event.

TABLE 3
Chi-Square Analysis Comparing Incidence of Stress Fractures

Variables	Group I[a] N (%)	Group II[b] N (%)	Chi-square	P value
All athletes				
Stress fracture	6 (15)	14 (26)	1.75	0.19
No stress fracture	35 (85)	40 (74)		
Females				
Stress fracture	2 (10)	8 (44)	2.87	0.09
No stress fracture	18 (90)	18 (56)		
Males				
Stress fracture	4 (19)	6 (21)	0.02	0.85
No stress fracture	17 (81)	22 (79)		

[a] Group I, sprints, hurdles, jumps, and multievents.
[b] Group II, middle and long distance events.

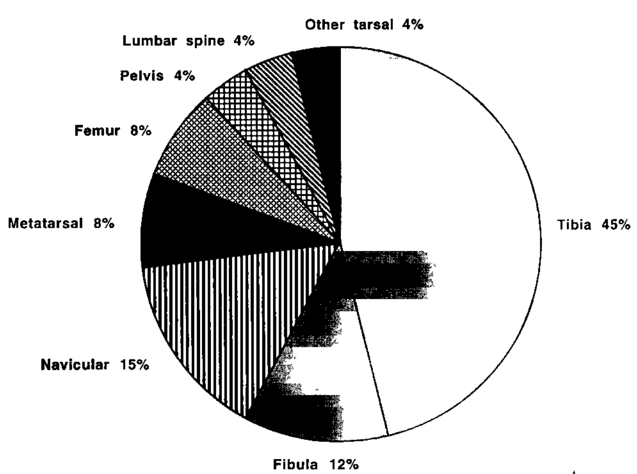

Figure 2. Site distribution of stress fractures in all athletes.

fractures were located in the tibia, 7 (50%); the femur, 2 (14%); and the metatarsals, 2 (14%). The most common sites of injury for men, who sustained 12 stress fractures overall, were the tibia, 5 (42%); navicular bone, 3 (25%); and fibula, 3 (25%). Pelvic, femoral, or metatarsal stress fractures were found only in the women athletes; fibular fractures were found only in the men.

To test whether there were any differences in the site distribution of stress fractures according to athletic event, stress fractures were divided into two groups. Athletes in Stress Fracture Group I had tibial, fibular, femoral, and pelvic stress fractures; Stress Fracture Group II had metatarsal and tarsal stress fractures. The groupings allowed comparison of the incidence of foot fractures with fractures occurring proximally. Event Group I (sprinters, hurdlers, jumpers, multievent athletes) had a significantly greater percentage of foot fractures; Event Group II (middle- and long-distance runners) had a greater percentage of long bone and pelvic fractures (chi-square [1] = 9.11, $P < 0.01$) (Fig. 3).

Total Injuries

During the study, 72 (75.8%) athletes, 32 (69.6%) women and 40 (81.6%) men, sustained one or more musculoskeletal injuries that were sufficient to alter their usual training for at least 1 week. Among the 130 musculoskeletal injuries, women sustained 57 and men sustained 73. Stress fractures composed 20% of the injuries; 14 (24.6%) in women and 12 (16.4%) in men. The difference among male and female athletes was not statistically significant (chi-square [1] = 1.32, $P > 0.05$). When only the 83 lower-limb overuse injuries were considered, lower-limb stress fractures composed 28.9% of the injuries, with female and male athletes representing 34.2% and 24.4%, respectively. This difference between male and female athletes was not statistically significant (chi-square [1]) = 0.96, $P > 0.05$).

Training

During the 12-month study, athletes averaged 11.3 hours per week training, averaging 10.6 hours per week in summer and 11.9 hours per week in winter. The training included 8.6 hours of running, with an average weekly distance of 45.2 km. No significant differences resulted between the men and women for any of these training parameters ($P > 0.05$).

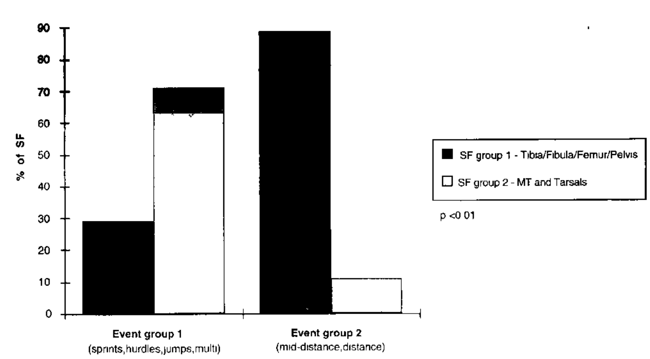

Figure 3. Percentages of stress fractures in different skeletal regions occurring in different events.

DISCUSSION

The results of this prospective study show a high annual incidence of stress fractures in male and female competitive track and field athletes. Interestingly, we observed a high incidence of history of stress fracture in those who sustained fractures. This finding may indicate the persistence of certain risk factors, such as abnormal biomechanics, excessive training, or low bone density.[16,32,36] Only two other studies have prospectively evaluated the incidence of stress fractures in track or running athletes.[24,51] Johnson et al.[24] reported the approximate annual incidence of 19% in collegiate track athletes, a figure similar to the 21% incidence found in the present study. However, their percentage may be an overestimation because the numerator in the calculation was the number of stress fractures, not the number of athletes with stress fractures. For comparison, the incidence rate in the present study would become 27% if calculated similarly.

Zernicke et al.[51] found a 20% annual incidence of tibial stress fractures over 2 years in female collegiate cross-country runners. Although not given, we presume that the incidence of the stress fractures at all the sites would be even greater. It is possible that the incidence rate found in the present study is affected by the potential for recruitment bias because a nonrandom sample was used and many athletes had previous stress fractures. However, our results and other prospective studies indicate that track and field athletes are at high risk of developing stress fractures.

Retrospective studies investigating the incidence or prevalence of stress fracture in runners have yielded less consistent results.[4,9,11,18] This finding may stem from differences in study methods, in particular, the population sampled, the duration of observation, the definition of stress fracture, and the response rate of athletes to the questionnaire. The lowest incidence, 3.7%, was found by Goldberg and Pecora,[18] who reviewed the clinical records of collegiate track athletes. However, their figure may underestimate the incidence of stress fractures because it is possible that not all collegiate track athletes with stress fractures attended the clinics in question, and the population at risk was only estimated. The highest prevalence, 37%, was reported in female collegiate long-distance runners who were surveyed by questionnaire.[4] This figure may be inflated because it represents a history of stress fracture and, of the 1000 athletes questioned, only 241 (24%) responded. These factors may have introduced considerable ascertainment bias because athletes who have an interest or a concern in the topic of the questionnaire are more likely to respond. Cameron et al.[11] surveyed 886 Australian state- and national-level sprinters and middle- and long-distance runners, with a response rate of 62% (549 respondents). Their prevalence rates for history of stress fracture for male and female track and field competitors were 28% and 26.6%, respectively. This is similar to the values of 20.5% (8 men) and 25.8% (8 women) found in the present study if these three running events are combined. Overall, retrospective surveys are less likely to provide accurate incidence data because they rely on 1) athletes to respond to a survey, 2) accurate patient recall, and 3) diagnoses that lack physician verification.[48]

Although it is common to calculate injury incidence using the number of athletes at risk as the denominator, this method may not be the best because it does not allow comparison of incidence rates among different sports. Expressing incidence per training exposure, such as the number of training hours, may be more accurate because this format considers the amount of exposure irrespective of sport or training.[48] To our knowledge, our study is the first to express stress fracture incidence in this manner. We found a relatively high incidence of stress fracture per 1000 hours of training. Because no other studies have this information on stress fractures, it is impossible to compare the relative risk of sustaining a stress fracture in different sports.

Because track and field has several different events, it is unlikely that the risk of stress fracture will be uniform across events. Although the number of athletes in each event was relatively small in this study, our results did not show a significant difference in the rate of stress fractures between the combined group of sprinters, hurdlers, jumpers, and multievent athletes compared with the group of middle- and long-distance runners. This supports the findings of Cameron et al.[11] who found no difference in prevalence rates between sprinters and middle- and long-distance runners.

Stress fracture development is a function of the number of loading cycles and the amount of applied force.[10,29] Although the high-intensity speed training performed by sprinters, hurdlers, and jumpers increases the ground reaction forces applied to bone,[15,20,37] the endurance training of long-distance runners increases the number of bone loading cycles. This may explain the similar stress fracture incidence among athletes in these events.

Our results showed that stress fractures made up 20% of the musculoskeletal injuries (26) sustained by track and field athletes. Numerous case series have provided the relative incidence of stress fractures expressed as a percentage of injuries in runners seen in sports medicine clinics.[7,13,23,38,41,50] However, it is difficult to compare incidence results among studies because of differences in patient demographics, including sex, age, and level of sports participation.[49] These differences are reflected in the large variation in results where values range between 0.7% and 15.6%. Our value of 20% appears to be somewhat higher than other studies. This may be related to our strict definition of injury, which would have reduced the total number of injuries, thereby increasing the proportion attributed to stress fractures. In addition, our athletes were encouraged to notify a sports physician at the first sign of any bony pain, which may have resulted in a higher detection rate of stress fractures.

Anecdotal evidence suggests that women may sustain a disproportionately higher number of stress fractures. This disproportion has been shown in military populations where women, undergoing identical training programs as their male counterparts, had an increased risk of stress fracture ranging from 1.2 to 10 times that of male recruits.[8,25,42,43] Even when the training regimen was structured to decrease skeletal loading, women had a higher incidence of stress fracture.[26,44] The most likely reason for the higher risk of stress fracture is a lower initial fitness level, but other suggested factors include higher body fat, lower bone density, endocrine factors, and biomechanical variances.[34,43]

Whether female athletes are also at an increased risk of stress fracture is unclear. Studies in athletes are more difficult than observation of the military population because external factors known to influence stress fracture incidence, such as training, footwear, and surface cannot be as tightly controlled. Reviews of the clinical records of patients seen at sports medicine centers have shown that stress fractures in female athletes compared with male athletes make up more of the total injuries.[13,31] Although a similar trend was noted in our findings, the difference was not statistically significant. Few studies have made direct comparisons of the incidence of stress fractures in female and male athletic populations. An increased risk of injury in female athletes, ranging from 1.5 to 3.5 times, has been reported[9,18,24,40,51]; however, some studies had inadequate methodological details. When either the number of injured athletes or the number of stress fractures per 1000 training hours were compared, we found men and women to be equally at risk. Our finding concurs with another Australian study involving track athletes.[11] The discrepancy in results may reflect the influence of certain risk factors such as diet, menstrual history, and bone density.[36] Differences in these risk factors among athletic populations may be an explanation for differences in stress fracture risk. Our results suggest that sex, per se, does not affect the risk of developing a stress fracture in Australian track and field athletes.

The finding that the tibia was the most common site of stress fracture concurs with that of many other studies.[14,17–19,22,24,32,33,39] Similar to the Benazzo et al.[5] study on track and field athletes, we also found a high incidence of navicular bone stress fractures. The small number of navicular bone fractures in other studies may, in part, be due to underdiagnosis resulting from vague patient symptoms,[27,47] radiologic subtlety,[28] and the athletic population studied. Repetitive jumping has been considered an etiologic factor in navicular stress fractures.[47] In the literature, the majority of these stress fractures occur in track and field athletes.[5,17,27] Therefore, it is not surprising that in our study, the group of sprinters, hurdlers, jumpers, and multievent athletes sustained more metatarsal and navicular bone stress fractures than the group of middle- and long-distance runners.

Significant sex differences have been noted in the site distribution of stress fractures.[22,24,38] Our results agree with other studies that suggest women develop more metatarsal[22,38] and pelvic[22] stress fractures and fewer fibular fractures[22] than men. Although Johnson et al.[24] found a higher incidence of navicular bone stress fractures in women, this was not apparent in the present study. Factors other than sex may also influence the site distribution of stress fractures, including the mechanical loads placed on the skeletal system by the sport, the age of the athletes,[32] and the level of competition.[22] These factors may explain the variation in study results.

CONCLUSIONS

This study is one of a small number of prospective studies investigating the incidence of stress fractures in a defined population of athletes. It is the first study to calculate the incidence of stress fractures using the amount of training as the denominator. The results showed that track and field athletes have a high annual rate of stress fracture, as expressed as the number of injured athletes and as the number of stress fractures per 1000 training hours. Men and women were equally at risk. Stress fractures composed a large proportion of the musculoskeletal injuries with no significant effect because of the sex of the athlete. Events involving high-intensity loading such as sprints, jumps, and hurdles were not associated with a greater rate of stress fracture than middle- and long-distance running. However, these events were associated with a greater number of foot fractures; middle- and long-distance running were associated with a greater number of long bone and pelvic fractures. Overall, the tibia was the most commonly injured bone, but a relatively high proportion of navicular bone stress fractures was also sustained. Because track and field is a sport where stress fractures are common, attention should be paid to the risk factors in the prevention and treatment of these injuries.

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