Risk Factors for Stress Fractures in Female Track-and-Field Athletes: A Retrospective Analysis

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Abstract: The incidence and nature of stress fractures and the relationship of potential risk factors to stress-fracture history were investigated retrospectively in a group of 53 female competitive track-and-field athletes. Forty-five stress fractures, diagnosed by clinical findings and bone scan, radiograph, or CT scan, were reported in 22 women. Tibial fractures were the most common (33%). There was no significant difference in bone mineral density at the lumbar spine and tibia/fibula or in percentage body fat and total lean mass when comparing the groups with and without a stress-fracture history. Athletes with a past stress fracture were significantly older at menarche and were more likely to have experienced a history of menstrual disturbance (p < 0.05). Analysis of dietary behavior found that athletes with stress fractures scored significantly higher on the EAT-40 test and were more likely to engage in restrictive eating patterns and dieting. Multiple logistic regression showed that athletes with a history of oligomenorrhea were six times more likely to have sustained a stress fracture in the past, while those who were careful about their weight were eight times more likely. Prevention and treatment of stress fractures in female athletes should include a thorough assessment of menstrual characteristics and dietary patterns. **Key Words:** Stress fractures—Menstrual status—Exercise. *Clin J Sport Med* 1995;5(4):229–35.

Stress fractures are a common overuse injury sustained by athletes. A multiplicity of potential risk factors for this injury have been proposed, including low bone density, menstrual disturbances, dietary intake, biomechanical features, and body composition (2,7,10,15,20,28,37). While these factors have been comprehensively assessed in cross-sectional and prospective studies in the military, results from military personnel cannot be generalized to athletes, given differences in training, footwear, and initial fitness levels. Therefore, it is imperative to investigate risk factors for stress fractures specifically in athletes. Since men and women are biologically dissimilar, different factors may be operating to influence stress-fracture risk for each sex.

One athletic group that would seem to be at particularly high risk of developing stress fractures is track-and-field athletes (14,18). Thus, it is surprising that so few studies have investigated risk factors for the development of stress fractures in this population. The aims of this study were to investigate the prevalence and nature of stress fractures in a group of female competitive track-and-field athletes and to relate these stress fractures to selected bone density, menstrual, body composition, and dietary risk factors.

METHOD

Study Design

Retrospective analysis was conducted of risk factors for stress fractures in a female cohort.

Subjects

Fifty-four female track-and-field athletes ranging in age from 17 to 26 years agreed to participate in this study. One woman was later excluded when it was found that she had taken hormone-replacement therapy. Women were recruited from registered state athletics clubs and were competing at the club, state, or national level in any event, except throwing and walking. All metropolitan-based, accredited Levels 2 and 3 track-and-field coaches (n = 53) were sent a letter that outlined the study and requested names of athletes suitable for inclusion in the study. Fifty-six athletes were then contacted by telephone; two declined to participate, citing study or work commitments. The mean (±SE) age of the subjects was 20.5 (±0.3) years, and their mean height and weight were 167.4 (±0.8) cm and 59.0 (±0.8) kg, respectively.

It was not possible to obtain a random sample of eligible track-and-field athletes for this study. However, subjects were recruited from a number of different clubs and trained under many different coaches, at different venues, and with different training regimens. Although the exact proportion of all eligible subjects that our sample represents cannot be calculated, available figures suggest that our sample makes up ~15% of all state-registered female track-and-field athletes aged ≥18. This percentage would be considerably higher if our inclusion criteria were taken into consideration.

Procedure

This study was undertaken with approval from the Human Experimentation Ethics Committees of LaTrobe University and the Royal Melbourne Hospital. All subjects gave written informed consent before participation in the study. Each subject completed a questionnaire on age, training, age at menarche, menstrual history, stress fracture history, and dietary habits.

Stress fracture history

Stress fracture history was obtained from a self-reported questionnaire. For this study, stress fractures were defined as fractures that were diagnosed by a physician based on history and physical examination and confirmed by positive isotope bone scan, radiography, or computerized tomography. For each fracture, athletes provided information regarding the location of the stress fracture and method of diagnosis. Stress fracture history could be clarified by review of medical records in some, but not all cases.

Menstrual characteristics

Amenorrhea was defined as three or fewer menses per year, oligomenorrhea as four to eight menses per year, and eumenorrhea as nine or more menses per year. Women were questioned as to the number of years in each menstrual category since menarche. This information was used to calculate a menstrual index (MI) based on the work of Grimston et al. (16). This index quantifies the average number of menstrual cycles per year since menarche. A menstrual index <10.5 indicates a history of menstrual disturbance. The equation used to derive the menstrual index is

$$MI = \frac{\begin{array}{c}10.5 \text{ (no. of years E)} + \\ 6 \text{ (no. of years O)} + 1.5 \text{ (no. of years A)}\end{array}}{\text{current age} - \text{age at menarche}}$$

A menstrual disturbance ratio was also calculated for each female athlete by dividing the number of years with fewer than nine menses per year by the total number of years since menarche. A higher ratio indicated a greater proportion of menstrual years with fewer than nine menses.

Dietary habits

Food attitudes and dieting behavior were assessed through questionnaire. Subjects were asked whether they considered themselves careful about their weight, whether they restricted their diet in order to maintain a desirable weight, whether they had ever dieted for >1 month to lose weight, and the number of times they weighed themselves per month.

Fifty subjects completed the EAT-40, an eating attitudes test designed and validated by Garner and Garfinkel (11). This test has 40 questions relating to three factors—dieting, bulimia and food preoccupation, and oral control—and is useful for identifying women with abnormal weight and eating concerns. A score of ≥30 is considered the cutoff for anorexic tendencies (11). To encourage honesty, identification numbers were used on tests, and questions were separate from answer sheets. Subjects were assured of confidentiality. The tests were completed in private, and the answers were placed in an envelope on completion.

Bone mineral density

Bone mineral density (BMD) was measured non-invasively using dual energy x-ray absorptiometry (DXA; Hologic QDR 1000W densitometer; Hologic Inc., Waltham, MA, U.S.A.). DXA acquisition and analysis were performed using the standard whole-body protocol (Version 5.47) with subjects positioned supine on the scanning table. Regional measurements obtained from the whole-body protocol correlate well with measurements obtained from specific regional scans (23,29). In children and young adults, there was a strong linear association (r = 0.97) between lumbar spine BMD measured by whole-body software and that measured by spine software (23). The measurements used were lumbar spine BMD, lower-limb BMD (average of left and right lower limbs, including femur, tibia/fibula, and foot), and tibia/fibula BMD (average of left and right tibias and fibulas). Short-term *in vivo* precision studies were conducted using 15 normal subjects.

Each subject underwent three consecutive total body scans with repositioning between each scan. The average coefficient of variation (CV) was 1.3% for lumbar spine BMD, 0.7% for lower-limb BMD, and 1.4% for tibia/fibula BMD.

Body composition

Height and weight were measured, and body mass index was calculated. Total body fat mass, percentage body fat, and total lean mass were obtained by DXA using the whole body protocol. The average CV for these measurements was 1.2% for total body fat mass and 0.4% for total body lean mass.

Statistical Analysis

All statistics were performed with the Statistical Package for the Social Sciences. For continuous variables, comparisons were made between athletes with and without a history of stress fracture using the independent *t* test or the Mann–Whitney U test with one- or two-tailed significance levels of p < 0.05, decided a priori. An association between a history of stress fracture and other categorical variables was evaluated using a chi-square test or Fisher's exact test. Selected independent variables that were significantly different between stress fracture and nonstress fracture groups on univariate tests were entered into a forward stepwise multiple logistic regression.

RESULTS

The number of women competing in the different track-and-field events is shown in Table 1. The athletes who competed in more than one event were categorized according to their specified best event. The majority of women (37.7%) were classified as middle-distance runners.

Subjects were questioned as to their level of competition in the year preceding the study. Thirty-two athletes (60.4%) qualified for the Australian national championships, with 20 (37.7%) competing in a national final. Over two-thirds of athletes (37, or 67.9%) competed in the highest state-level competition. On average, subjects spent 12 (±5.5) h per week training for athletics. The mean distance run per week was 40.7 (±28.1) km, and the mean number of hours spent running, including interval and hill training, was 8.0 (±4.0) h. There was wide variation in the type and amount of training by athletes depending on their specialty event.

A total of 45 stress fractures was reported in 22 (41.5%) women. Eleven of them (20.8%) had a history of multiple stress fractures. The average time interval from diagnosis of the stress fracture to the present study (concurrent stress fractures were considered as one episode) was 25.7 (±18.2) months. The distribution of the number and percentage of athletes in each event who reported a history of stress fractures is shown in Table 1. Hurdlers and distance runners appeared to be at greatest risk of sustaining a stress fracture, with rates of 87.5% and 60.0%, respectively.

The most common sites for stress fractures were the tibia (33%), the tarsal navicular (20%), and the metatarsals (20%). Overall, stress fractures in the bones of the foot were more common than those in the tibia. Other regions where stress fractures occurred were the femur (11%), fibula (7%), and pelvis (7%).

The means (±SE) of the measured variables for all athletes and for the subgroups with and without a stress-fracture history are shown in Table 2. The results of unpaired *t* tests or Mann–Whitney U tests comparing the group with a history of stress fracture and the group without such a history are also presented in Table 2. There were no statistically significant differences (p > 0.05) between the groups in terms of age, hours spent training per week, age at commencement of competition, or body composition.

Bone mineral density at the lumbar spine, lower limb, and tibia/fibula for the stress-fracture group was lower than for the non-stress-fracture group, but the differences were not statistically significant. Women with a history of stress fracture reached menarche at a later age than those without a history of stress fracture. The stress-fracture group also had a significantly lower menstrual index, a higher menstrual disturbance ratio, and more years of amenorrhea and oligomenorrhea.

TABLE 1. *Number of athletes in each event with and without a history of stress fractures (SF)*

Event	Number of stress fractures						Number (%) of athletes with SF
	0	1	2	3	4	8	
Sprints (100, 200, 400m)	4	1	0	1	0	0	2 (33.3%)
Middle distance (800, 1,500m)	15	2	3	0	0	0	5 (25.0%)
Distance (3-, 5-, 10-km marathon)	4	2	1	2	0	1	6 (60.0%)
Hurdles	1	6	0	0	1	0	7 (87.5%)
Jumps (long, triple, high)	4	0	0	1	0	0	1 (20.0%)
Multi (heptathlon)	3	0	1	0	0	0	1 (25.0%)
Total	31	11	5	4	1	1	22 (41.5%)

TABLE 2. *Characteristics of all athletes and subgroups according to stress fracture (SF) history*[a]

Characteristics	All athletes (n = 53)		No SF (n = 31)		SF (n = 22)	
Age	20.5	(0.3)	20.3	(0.4)	20.8	(0.4)
Age commenced competition	11.4	(0.7)	11.7	(1.0)	10.9	(1.0)
Hours spent training per week	12.0	(0.8)	11.4	(0.9)	12.8	(1.3)
Body composition						
Body mass index	21.1	(0.2)	21.0	(0.3)	21.1	(0.4)
Body fat %	17.4	(0.4)	17.7	(0.5)	17.0	(0.8)
Total body lean mass (kg)	46.1	(0.5)	46.3	(0.7)	45.9	(0.8)
Bone mineral density (BMD)						
Lumbar spine BMD (g/cm^2)	1.093	(0.020)	1.109	(0.020)	1.070	(0.037)
Lower-limb BMD (g/cm^2)	1.140	(0.011)	1.144	(0.077)	1.134	(0.014)
Tibia/fibula BMD (g/cm^2)	1.115	(0.010)	1.124	(0.015)	1.102	(0.015)
Menstrual history						
Age at menarche	14.3	(0.2)	14.0	(0.2)	14.8	(0.4)[b]
Menstrual index	8.5	(0.3)	8.7	(0.4)	7.7	(0.5)[b]
Menstrual disturbance ratio	0.25	(0.05)	0.19	(0.01)	0.35	(0.01)[b]
Years of <9 menses per year	1.6	(0.3)	1.1	(0.4)	2.3	(0.6)[b]
Longest duration without menses (months)	5.1	(1.1)	4.5	(1.1)	6.0	(2.1)
Dietary factors						
Number of times weighed self per month	6.4	(1.2)	6.4	(1.6)	6.5	(1.6)
EAT-40 score	16.6	(1.9)	15.2	(2.6)	18.7	(3.0)[b]

[a] Results are given as the mean ± SE.
[b] $p < 0.05$.

Athletes with stress fractures had a tendency to weigh themselves more often per month and had a significantly higher score on the EAT-40 ($p < 0.05$). This finding indicates a greater preoccupation with weight control among the female athletes with stress fractures. Using a cutoff score of 30, seven (14.0%) athletes were considered to have traits indicative of anorexia nervosa. Only two of these athletes had a history of stress fracture. There was no difference in scores on the EAT-40 comparing different event groups ($p > 0.05$).

The analyses of the categorical variables are shown in Table 3. Women with a history of stress fracture were significantly more likely to have a history of oligomenorrhea, to be careful about their weight, and to engage in dieting for >1 month at a time. There were no significant differences between the two groups in the frequency of amenorrhea, duration of amenorrhea for >6 months, menarche after 14 years of age, or dietary restriction to maintain weight.

Age at menarche, menstrual index, a history of oligomenorrhea, EAT-40 score, and a history of dieting and carefulness about weight were entered into a forward stepwise multiple logistic regression. Results showed that a history of oligomenorrhea and carefulness about weight were significant, independent predictors of stress-fracture history ($\beta = 1.82$, SE = 0.77, p = 0.02 and $\beta = 2.09$, SE = 0.95, p = 0.03, respectively). Those who had a history of oligomenorrhea were six times more likely to have sustained a stress fracture in the past than those with no history of oligomenorrhea. Similarly, those who were careful about their weight were eight times more likely to have a history of stress fracture than those who did not pay attention to their body weight.

DISCUSSION

Female track-and-field athletes are a group of physically active individuals who appear to sustain

TABLE 3. *Characteristics of all athletes and subgroups according to stress fracture (SF) history*

Characteristics	All athletes (n = 53)	No SF (n = 31)	SF (n = 22)
Menstrual history			
History of amenorrhea	17 (32.7%)	9 (29.0%)	8 (38.1%)
History of oligomenorrhea	16 (30.8%)	6 (19.4%)	10 (47.6%)[a]
Menarche at >14 years of age	27 (50.9%)	13 (41.9%)	14 (63.6%)
Duration of amenorrhea >6 months	13 (25.0%)	9 (29.0%)	4 (19.1%)
Dietary			
Careful about weight	35 (66.0%)	17 (54.8%)	18 (81.8%)[a]
Restricts diet to maintain weight	21 (39.6%)	10 (32.3%)	11 (50.0%)
Dieted to lose weight	23 (43.4%)	10 (32.3%)	13 (59.1%)[a]

[a] $p < 0.05$.

a large number of stress fractures. In this study, almost half of the women reported a history of one or more stress fractures. However, this figure may overestimate the true incidence due to the voluntary nature of subject recruitment. The results of other surveys investigating the incidence of stress fractures in female athletes have varied depending on the type of athletes who participated and the definition of stress fracture employed. In runners, figures have ranged from 13.2% (4) to 37.0% (2) and in ballet dancers from 22.0% (10) to 45.0% (35). In a recent 2-year prospective study of collegiate athletes from a variety of sports, the incidence of stress fractures was highest in female track-and-field athletes, with an annual incidence rate of 31% (18). This finding suggests that track and field is a sport where stress fractures are highly likely to occur.

In the present study, stress fractures were commonly found in the tibia, navicular, and metatarsals. The site distribution of stress fractures in female athletes has not been well documented since many larger case series do not provide the breakdown of figures by gender. Differences in method of data collection, definition of stress fracture, number of cases, and type of sports represented may all influence the reported distributions.

In series involving a variety of sportswomen, tibial stress fractures were the most common, constituting between 44.3% and 63% of total stress fractures (2,17,25). Generally, navicular stress fractures accounted for a small proportion (<5%). However, Matheson et al. (25) reported a high percentage (19.4%) of tarsal fractures, the majority of which were navicular fractures (personal communication). No previous study has reported the distribution of stress fractures in female track-and-field athletes covering the broad spectrum of events included in this study. Benazzo et al. (3) reviewed a series of 45 stress fractures in track-and-field athletes, although men and women were not considered separately. In this study, 28% of the fractures were located at the navicular and 26% at the tibia, a finding similar to the present study. Our results suggest that female track-and-field athletes are at high risk of navicular stress fracture. This finding may relate to the demands of the sport, where training often occurs on hard, artificial surfaces and calls for speed and plyometric and jumping activities.

A number of risk factors have been suggested for stress fractures in female athletes. We measured several variables relating to bone density, body composition, training, diet, and menstrual function. There was no difference in age, current number of hours spent training per week, or body composition when comparing the groups with and without a history of stress fracture. The amount and nature of past training or the training regimen before the development of a stress fracture were not analyzed. It is possible that the training program was modified following fracture. Body mass index, percentage

body fat, and total lean mass were similar in both groups. This finding confirms the results of other studies that have failed to find associations between anthropometric characteristics and stress fractures (20,22,35). However, in our study, it is possible that the body composition of the athletes changed over time, and thus the measurements may not give a true indication of their status preceding the stress fracture.

Since osteoporotic women with low bone density suffer insufficiency fractures, it has been surmised that low bone density may predispose to stress fractures in young athletes. In addition, it has been consistently shown that athletes with menstrual disturbances and estrogen deficiency have reduced bone mass at the lumbar spine (6,9,24,32,36) and, in a minority of cases, at peripheral lower-limb sites (19,27). Low bone density has been shown to hasten the accumulation and progression of bone microdamage leading to a fracture (8,30,31).

In the present study, mean bone mineral density was lower in those with a history of stress fracture, although it was not statistically significant. The results of similar retrospective analyses investigating bone density in female athletes have been conflicting. Frusztajer et al. (10) and Carbon et al. (7) both reported nonsignificant deficits of ~4.0% at the lumbar spine, which corresponds to the results of the present study. The only study to find a significant reduction, of 8.5%, at the lumbar spine was Myburgh et al. (28). It should be noted that their sample also included male athletes. One particularly disparate result was that from Grimston et al. (15) in a small sample of 14 runners. A significant increase in bone density of 8.2% at the lumbar spine was found in six runners with past stress fractures. The authors postulated that these contradictory results may have been due to the higher ground-reaction forces that were measured in these athletes.

Since stress fractures occur mostly in lower-limb weight-bearing bones, bone density measured at these sites may be more clinically relevant. Frusztajer et al. (10) found no difference in bone density at the first metatarsal measured in ballet dancers with and without stress fractures. In our study, there was no difference in the measurement of total lower limb or tibia/fibula bone density between the two groups. Grimston et al. (15) reported a nonsignificant increase of 9.7% at the tibia in those runners with stress fractures. It is apparent that the role of bone density in stress-fracture development is not yet clear, and aspects of bone structure other than bone density may also play a part. This possibility was indicated in a prospective study of male military recruits, in whom tibial bone width and area moment of inertia, but not bone density, were negatively correlated with the incidence of stress fractures in the tibia and femur (13,26). No research of this nature has been conducted in athletes.

The possible effects of menstrual factors on stress-fracture development are thought to be me-

diated through the influence of reduced levels of reproductive hormones on bone remodeling and bone density, perhaps lowering the threshold for overload. Athletes with a stress-fracture history were significantly older at menarche than those without such a history, supporting the findings of some previous studies (7,34,35). Stress-fracture subjects were also more likely to have experienced menstrual irregularity at some stage since menarche, which agrees with the findings of some studies (2,7,15,20,21,22,24,28,35), but not others (5,10,34). Our results showed that a history of oligomenorrhea was an independent predictor of a history of stress fracture.

Restrictive dietary patterns and eating disorders may alter nutrient intake, ovarian function, and body composition and thus influence stress-fracture development. The results of the EAT-40 in our subjects showed scores similar to those recorded in other female competitive athletes (33) and university students (11,12). As a group, the athletes were within the normal range, although athletes with stress fractures had a significantly higher score compared with those without stress fractures. Two other studies, using abbreviated versions of the EAT-40 in ballet dancers (10,35), did not find significant differences between groups with and without stress fracture. Frusztajer et al. (10) found a significantly higher incidence of eating disorders, diagnosed by DSM-111-R criteria (1), in 10 ballet dancers with stress fractures. Dancers may well represent a population separate from track-and-field athletes, and results may not be applicable to other sports. Responses to simple questions regarding eating behaviors supported the results of the EAT-40. In multivariate analysis, carefulness about weight was an independent predictor of a history of stress fracture.

The limitations of this study relate to its retrospective nature and to self-reporting of stress-fracture diagnosis. It is recognized that the measurements were taken at varying times after the stress fracture. Parameters such as bone density may have changed since the stress fracture, and current measurements may not reflect their status at or immediately before injury. However, given that >20% of women had multiple stress-fracture episodes, it is apparent that risk factors must still be in operation. Self-reporting of stress-fracture diagnosis may have resulted in misclassification of some subjects, since it was not possible to confirm bone scan and radiographic findings. Prospective studies in large groups of athletes are necessary to assess the temporal relationship between risk factors and stress fractures.

CONCLUSION

In conclusion, this study found a high prevalence of stress fractures, particularly navicular stress fractures, in a group of female track-and-field athletes. Athletes with a history of stress fracture were more likely to have commenced menarche later and to have a history of menstrual disturbance. Dieting and restrictive eating patterns were more common in those with stress fractures. Bone mineral density, body composition, and present training load did not differ between women with and without a history of stress fracture. In clinical practice, prevention or treatment of stress fractures should include a detailed assessment of menstrual and dietary factors.

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