

Stress Fracture Sites Related to Underlying Bone Health in Athletic Females

Robert G. Marx, MD, MSc, Deborah Saint-Phard, MD, Lisa R. Callahan, MD, Jaime Chu, and Jo A. Hannafin, MD, PhD

Women's Sports Medicine Center, Hospital for Special Surgery, New York, New York, U.S.A.

Objective: The study tested the hypothesis that females who sustain stress fractures of cancellous bone have decreased bone density.

Design: A retrospective, controlled, cross-sectional study.

Setting: The setting of the study was a tertiary care center for Women's Sports Medicine.

Patients: 20 female patients under the age of 40 who had suffered a stress fracture and who had a positive diagnostic study (radiograph, bone scan, or magnetic resonance imaging) were included in the study.

Interventions: Patients who had a positive diagnostic study (radiograph, bone scan, or magnetic resonance imaging) for the diagnosis of stress fracture also underwent dual energy X-ray absorptiometry (DEXA) scans.

Main Outcome Measure: Bone density measured by the

DEXA scan, as defined by the World Health Organization criteria for osteopenia (greater than one standard deviation from the standard age-matched control).

Results: 8 of 9 patients with cancellous stress fractures had DEXA scans indicating osteopenia while only 3 of 11 patients with stress fractures of cortical bone had a scan indicating osteopenia ($p = 0.01$).

Conclusions: A cancellous stress fracture in a female may be a warning sign of early onset osteopenia. We recommend that young females who have documented stress fractures of cancellous bone or cortical bone (with risk factors for osteopenia) undergo bone density evaluation.

Key Words: Fracture—Stress—Female—Bone Density.

Clin J Sport Med 2001;11:73–76.

INTRODUCTION

It has long been recognized that moderate exercise is a positive factor in bone health. However, exercise-related injury to bone may occur, frequently in the form of stress fractures.^{1–3} In the female athlete, stress fractures have been reported in a wide variety of sports, especially running, gymnastics, and track and field.^{4–6} The most commonly described sites for stress fracture are cortical ones, including the shaft of tubular bones such as the tibia, the metatarsals, and less commonly, the femoral shaft. Stress fractures have also been described in areas of cancellous bone, such as the femoral neck, pelvis, and sacrum. At our center, we began to question whether an association existed between location of stress fracture (i.e., cortical or cancellous) in the female athlete and underlying bone health. This query grew in part from our familiarity with the female athlete triad, a term recently coined to describe the association of disordered eating, amenorrhea, and osteoporosis in young athletic women.^{7–13}

In the athlete suffering from disordered eating, includ-

ing low calcium intake, the menstrual cycle abnormalities are one of the first changes. These lead to low estrogen levels and subsequent changes in bone mineral density.^{14,15} This premature bone loss is likely related to decreased estrogen levels and may not be reversible.⁸ Postmenopausal osteoporosis, which is also related to decreased estrogen, affects primarily areas of cancellous bone, as opposed to cortical bone. We hypothesized that patients who were suffering stress fractures of cancellous bone had a lower bone mineral density than those suffering stress fractures of cortical bone, and we began obtaining dual energy X-ray absorptiometry (DEXA) scans¹⁶ for these patients.

METHODS

We retrospectively identified all patients who were seen at our Women's Sports Medicine Center with a diagnosis of stress fracture. To ensure that the study was specific for stress fractures, only patients who had a positive diagnostic study (radiograph, bone scan, or magnetic resonance imaging [MRI]) as well as a DEXA scan were included.¹⁷ Chart review, carried out over a 2-month period, indicated that patients with stress fractures were generally referred for DEXA scan if they were deemed to be at high risk of osteopenia. Patients were believed to be at high risk if they had a history of multiple stress frac-

Received December 20, 2000; accepted February 14, 2001.

Address correspondence and reprint requests to Deborah Saint-Phard, MD, Women's Sports Medicine Center, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, U.S.A. E-mail: saintphardd@hss.edu

tures, a known restrictive eating pattern or eating disorder, abnormal menses, and/or very low apparent body fat. However, the decision to order the DEXA scan was based on the clinical judgement of the treating physician. The majority of our patients have the DEXA scan performed at our institution, although some have it done elsewhere.

Patients with metabolic bone disease were excluded because their stress fractures were considered to be pathologic fractures. Patients who were older than 40 years of age were excluded *a priori* to eliminate the potential confounding effect of age-related bone loss.

An abnormal DEXA scan was defined as per the World Health Organization criteria for osteopenia, which is greater than 1 SD (standard deviation) below the mean for young adult women.¹⁸ We considered a DEXA scan that indicates osteopenia in either the lumbar spine or the femoral neck to be abnormal since these are both important sites of cancellous bone. We compared the proportions of abnormal DEXA scans in the cortical and cancellous groups with the Fisher exact test. Patient variables studied included the type of bone involved (cortical or cancellous), age, age at menarche, menstrual history, activity level, body mass index, nutritional history, history of oral contraceptive use, smoking, alcohol use, and calcium intake and supplementation. It was impossible to define if the activities involved high impact for all cases, although most patients involved in vigorous or intense activity included some impact loading. These were compared with Student *t*-test for continuous variables and the Fisher exact test for ordinal variables.

RESULTS

Over a 4-year period, 65 patients were diagnosed with stress fractures at the Women's Sports Medicine Center. Of these, three had metabolic bone disease and were therefore excluded from the study. Eighteen patients were excluded because they had a clinical diagnosis of stress fracture without a confirmatory imaging study, and therefore it is possible that their symptoms were due to a muscle strain, stress reaction, or ligament sprain. Seven patients were excluded because they were 40 years of age or greater (mean 49.0 years, range 40–65 years). Of the remaining 37 patients, 17 did not undergo DEXA scans and were also excluded from further study. Of these 17 patients, 6 had cancellous stress fractures, while 11 had cortical stress fractures. These patients did not undergo DEXA scanning because either the treating physician did not believe them to be at high risk for osteopenia or the patient refused the study.

We studied 9 patients with stress fractures of cancellous bone and 11 patients with cortical stress fractures. The cortical fractures consisted of three metatarsal fractures, one femoral shaft fracture, and seven tibial shaft fractures. The cancellous fractures consisted of four medial femoral neck fractures, one calcaneal fracture, three pubic rami fractures, and one sacral fracture. The time frame from diagnosis to DEXA scan was less than 3 months in all cases. Fifteen of the DEXA scans were

performed at our institution and five at other locations. Eight patients with cancellous fractures had DEXA scans that indicated osteopenia while only three of the patients with stress fractures of cortical bone had a scans indicating osteopenia ($p = 0.01$) (Table 1). Six patients were osteopenic in both areas, three in the lumbar spine only and two in the hip only. The *t*- and *z*-score values were very similar since the patients were young overall. The mean *t*- and *z*-scores among the cortical group were -0.62 and -0.48 for spine and -0.22 and -0.12 for hip, respectively. The mean *t*- and *z*-scores for the cancellous group were -0.84 and -0.71 for spine and -1.17 and -1.00 for hip, respectively.

The age and age at menarche were both similar between the two groups. The age of the patients in the cancellous fracture group was 29.9 years (range 25–37) compared with 28.7 years (range 16–39) in the cortical group ($p = 0.70$). The age at menarche of the patients in the cancellous fracture group was 13.9 years (range 12–16) compared with 14.4 years (range 12–17) in the cortical group ($p = 0.50$). Body mass index was 21.3 (range 17.2–26.4) for the cortical group compared with 20.4 (range 17.7–23.4) for the cancellous group ($p = 0.38$).

Activity was graded as inactive, light (walking, gardening), moderate (moderate exercise three times per week), vigorous (vigorous exercise 3–5 times per week), and intense (competitive or vigorous training 5–7 times per week). The activity history of the two groups was similar (Table 2). There were a greater number of individuals with a history of restrictive eating or an eating disorder in the cancellous fracture group than in the cortical group (Table 3). Oral contraceptive use was similar in the two groups as was menstrual history (Tables 4 and 5).

There was only one patient in the study who smoked (cancellous group), while there were six who consumed alcohol (all in the cortical group). All fractures studied healed with activity restriction. Femoral neck stress fractures (all were on the compression side of the neck) were treated with a period of nonweight-bearing ambulation, followed by progressive weight-bearing when radiographic evidence of fracture healing was present.

DISCUSSION

This cross-sectional study examined the association between stress fractures of cancellous bone in females less than 40 years of age and early onset osteopenia as measured by DEXA scan. Stress fractures of cancellous bone were associated with early onset osteopenia ($p = 0.01$).

Patients with stress fractures of cortical bone were chosen as our control group for two reasons. First, the patients had to have had a DEXA scan to determine whether osteopenia was present or not. There was a very limited number of young, healthy females who have had DEXA scans for other reasons and who could have served as a control group. The second reason that we used these patients as our control group was that they are relatively well matched to the cases because they exer-

TABLE 1. DEXA result for patients with cortical and cancellous stress fractures*

	Cortical stress fracture	Cancellous stress fracture
Positive DEXA	3	8
Negative DEXA	8	1

* $p = 0.01$, Fisher exact test.
DEXA, dual energy X-ray absorptiometry.

TABLE 2. Activity history for patients with cortical and cancellous stress fractures

	Cortical stress fracture	Cancellous stress fracture
Inactive	0	0
Light activity (walking, gardening)	0	0
Moderate activity (moderate exercise 3 times per week)	2	1
Vigorous activity (vigorous exercise 3–5 times per week)	3	4
Intense activity (competitive vigorous sports training 5–7 times per week)	6	4

TABLE 3. Nutritional history for patients with cortical and cancellous stress fractures*

	Cortical stress fracture	Cancellous stress fracture
Unknown	2	1
Normal dietary habits	7	1
Restrictive eating or history of an eating disorder	2	7

* $p = 0.02$, Fisher exact test.

TABLE 4. Oral contraceptive use for patients with cortical and cancellous stress fractures

	Cortical stress fracture	Cancellous stress fracture
Current OC user	3	4
Never used OC	6	3
Previous OC user	2	2

OC, oral contraceptive.

TABLE 5. Menstrual history for patients with cortical and cancellous stress fractures

	Cortical stress fracture	Cancellous stress fracture
Unknown	0	1
Eumenorrheic (menses <38 days apart)	6	1
Irregular menses (menses 38–90 days apart)	3	4
Amenorrheic (menses >90 days apart)	2	3

cise sufficiently to also suffer overuse injury. Therefore, by using patients with stress fractures of cortical bone as our control group, we may have controlled for certain patient variables associated with the lifestyle of these patients.

The only patient variable that was significantly associated with stress fractures of cancellous bone was a history of an eating disorder or a pattern of restrictive eating. It is possible that the patients who suffered the cancellous injuries had inferior bone mass in part due to chronic malnutrition. However, there were three patients for whom the dietary history was not recorded, and it is possible that the observed association was spurious in nature. Nevertheless, the abnormal dietary habits of this patient population fit the paradigm of the female athlete triad.

Limitations of this study include the fact that it is retrospective in nature and therefore it was not possible to include all patients who presented with stress fractures. Only patients who had a bone density study as well as an imaging study documenting the stress fracture were reviewed. This led to the exclusion of 17 patients who had stress fractures documented by X-ray, bone scan, or MRI but who did not undergo DEXA. It is possible that the DEXA results of these patients would have altered our results. Additionally, patient variables were determined by chart review, and despite our standard history taking forms for these patients, the accuracy of this information is also limited. Lastly, the number of patients included in the study is quite small.

CONCLUSIONS

In summary, a cancellous stress fracture in a female may be a warning sign of early onset osteopenia. We are undertaking a prospective evaluation of bone density including all patients presenting with stress fractures of cortical and cancellous bone to further study this issue. In this study we are collecting detailed information on menstrual history, activity, nutrition, and health-related quality of life.

Currently, based on this evidence, we recommend that females under 40 years of age who have documented stress fractures of cancellous bone or stress fractures of cortical bone with risk factors for osteopenia undergo bone density evaluation.

If the diagnosis of osteopenia is made, we recommend a multidisciplinary approach. Treatment must take into account evaluation for metabolic bone disease, calcium intake, and menstrual history. Certain patients may also benefit from oral contraceptives should oligomenorrhea or amenorrhea persist despite a normal endocrine profile and restriction of activity. In view of the potential irreversibility of bone loss, prompt identification of early onset osteopenia may contribute to reducing future morbidity in such individuals.

Acknowledgment: Dr. Marx was supported by an American Academy of Orthopaedic Surgeons Health Services Research Fellowship and a Royal College of Physicians and Surgeons of

Canada Detweiler Travelling Fellowship. This project was supported by a philanthropic gift from Ms. Marcia Kapp.

REFERENCES

1. Barrow GW, Saha S. Menstrual irregularity and stress fractures in collegiate female distance runners. *Am J Sports Med* 1988;16:209–216.
2. Bennell KL, Brukner PD. Epidemiology and site specificity of stress fractures. *Clin Sports Med* 1997;16:179–196.
3. Bennell KL, Malcolm SA, Thomas SA, et al. Risk factors for stress fractures in female track-and-field athletes: a retrospective analysis. *Clin J Sport Med* 1995;5:229–235.
4. Bennell KL, Malcolm SA, Thomas SA, et al. Risk factors for stress fractures in track and field athletes. A twelve-month prospective study. *Am J Sports Med* 1996;24:810–818.
5. Dixon M, Fricker P. Injuries to elite gymnasts over 10 yr. *Med Sci Sports Exerc* 1993;25:1322–1329.
6. Marcus R, Cann C, Madvig P, et al. Menstrual function and bone mass in elite women distance runners. Endocrine and metabolic features. *Ann Intern Med* 1985;102:158–163.
7. Cann CE, Martin MC, Genant HK, et al. Decreased spinal mineral content in amenorrheic women. *JAMA* 1984;251:626–629.
8. Drinkwater BL, Bruemner B, Chesnut CH. Menstrual history as a determinant of current bone density in young athletes. *JAMA* 1990;263:545–548.
9. Drinkwater BL, Nilson K, Chesnut CH, et al. Bone mineral content of amenorrheic and eumenorrheic athletes. *N Engl J Med* 1984;311:277–281.
10. Drinkwater BL, Nilson K, Ott S, et al. Bone mineral density after resumption of menses in amenorrheic athletes. *JAMA* 1986;256:380–382.
11. Frusztajer NT, Dhuper S, Warren MP, et al. Nutrition and the incidence of stress fractures in ballet dancers. *Am J Clin Nutr* 1990;51:779–783.
12. Lindberg JS, Fears WB, Hunt MM, et al. Exercise-induced amenorrhea and bone density. *Ann Intern Med* 1984;101:647–648.
13. Rigotti NA, Nussbaum SR, Herzog DB, et al. Osteoporosis in women with anorexia nervosa. *N Engl J Med* 1984;311:1601–1606.
14. Cann CE, Martin MC, Jaffe RB. Duration of amenorrhea affects rate of bone loss in women runners: implications for therapy. *Med Sci Sports Exerc* 1985;17:214.
15. Nattiv A, Armsey TD, Jr. Stress injury to bone in the female athlete. *Clin Sports Med* 1997;16:197–224.
16. Beck TJ, Ruff CB, Mourtada FA, et al. Dual-energy X-ray absorptiometry derived structural geometry for stress fracture prediction in male U.S. Marine Corps recruits. *J Bone Miner Res* 1996;11:645–653.
17. Deutsch AL, Coel MN, Mink JH. Imaging of stress injuries to bone. Radiography, scintigraphy, and MR imaging. *Clin Sports Med* 1997;16:275–290.
18. World Health Organization. *Assessment of Fracture Risk and Its Application for Screening for Postmenopausal Osteoporosis*. Technical Report 843. 1994.