0363-5465/101/2929-0498$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 29, No. 4
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Stress Fractures of the Sacrum

An Atypical Cause of Low Back Pain in the Female Athlete

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ABSTRACT

Low back pain is a common finding in an athletically active premenopausal female population. We describe an unusual cause of persistent low back/sacroiliac pain: a fatigue-type sacral stress fracture. Plain radiographs, bone scans, computed tomography, and magnetic resonance imaging studies were obtained in the female athletes to determine the nature of the pathologic abnormality. The most significant risk factor for fatigue-type sacral stress fractures was an increase in impact activity due to a more vigorous exercise program. Potential risk factors such as abnormal menstrual history, dietary deficiencies, and low bone mineral density were examined. The clinical course was protracted, with an average 6.6 months of prolonged low back pain before resolution of symptoms. Sacral fatigue-type stress fractures did not preclude the athletes from returning to their previous level of participation once healing had occurred.

Occasional low back pain and discomfort in the sacroiliac region is a common finding in an athletically active premenopausal female population. This is often caused by a lumbar sprain or paraspinal strain and responds to symptomatic treatment. We describe an atypical cause of low back/sacroiliac pain in female athletes: a fatigue-type stress fracture of the sacrum.

MATERIALS AND METHODS

We report on eight female athletes ranging in age from 19 to 45 years old. All patients were initially evaluated with a thorough history and physical examination by the athletic training and sports medicine staff at a Division I collegiate institution; five were varsity athletes and three were private patients. All patients had vague nonlocalized low back, buttock, or hip discomfort that eventually localized to the sacroiliac region. The patients had failed to respond as expected to an initial treatment of limited activity, nonsteroidal antiinflammatory medication, and ambulatory assistance devices as deemed necessary. Because of persistent symptoms, plain radiographs were obtained in all patients along with subsequent technetium bone scans. Bone scan images were further refined in one case using a nuclear medicine imaging SPECT system. These images more precisely pinpointed the site of injury. Investigational CT and MRI scans of the involved areas were obtained whenever possible to further localize and define the pathologic lesion.

Bone density determination was performed in six of the eight patients using quantitative CT, dual-energy x-ray absorptiometry scans, or both. Quantitative CT measures vertebral trabecular bone density as hydroxyapatite equivalents expressed in milligrams per milliliter. Patients with values above 110 mg/ml rarely have vertebral deformities, whereas patients with values below 65 mg/ml nearly all have radiographic evidence of vertebral osteoporosis.[6] As a consequence, the density of 110 mg/ml is referred to as the fracture threshold below which insufficiency fractures are more prevalent.

Bone density evaluations of the lumbar spine and femoral neck by dual-energy x-ray absorptiometry are generally reported in terms of standard deviations from the mean young adult and age-matched control values. Values of 1 to 2.5 SD below the mean are defined as osteopenia, while values greater than 2.5 SD below the mean are defined as osteoporosis. The risk for fracture increases with age and with each standard deviation below the young adult mean. Below 2 SD, the fracture risk increases exponentially.[23] A value of 0.800 g/cm^2 with a dual-energy x-ray absorptiometry scan corresponds to the 110 mg/ml fracture threshold seen with quantitative CT.

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No author or related institution has received any financial benefit from research in this study.

Menstrual and dietary histories were obtained from all patients. There are four recognized methods to determine a patient's food consumption. Weighed food intake is the most accurate, but it is time-consuming and requires equipment and a motivated patient. Twenty-four hour diet recall and food frequency questionnaires have built-in errors because both depend on recall and patients tend to overemphasize healthy choices. The food diary method was used in this study and is the most accurate for active ambulatory adults.[7,19] Athletes recorded all food intake with estimated quantities for 3 days. Diets were analyzed using a nutrition computer program to determine average daily intake.

Ideal body weight and body frame type were determined using height and wrist circumference measurements. One hundred pounds were given for the first 5 feet, 5 additional pounds for each inch above 5 feet, and plus or minus 10% for a heavy or light frame. Daily caloric needs were determined using the U.S. Department of Agriculture method of 20 Kcal/pound of ideal body weight for moderately active or active adults. To this were added daily activity calories from standard activity lists.[19] The athlete's recorded average daily caloric intake was then compared with their calculated caloric need. The recommended calorie distributions of protein (15%) and carbohydrate (60%) were used in this comparison.

Case 1

A 21-year-old female soccer player experienced pain in the left sacroiliac region after a varsity soccer game. There was no obvious acute injury, but her practice schedule had increased significantly over the previous 2 weeks because of the fall double practice sessions. Point tenderness was found over the left sacrum and left sacroiliac joint, with mild discomfort at the extreme of left hip extension and left lateral flexion and rotation of the lumbosacral spine.

Twelve days of treatment including rest, physical therapy, and nonsteroidal antiinflammatory drugs yielded no improvement. Radiographs taken 2 weeks after injury were normal (Fig. 1), but a bone scan revealed increased technetium uptake in the midlateral aspect of the left sacrum at the level of the left sacroiliac joint (Fig. 2). An investigational MRI scan ordered 3 weeks after the onset of symptoms confirmed bone marrow edema with an area of bony sclerosis within the same region of the sacrum (Fig. 3). A bone scan done 1 year later for right-sided sacral pain showed no right-sided uptake and complete resolution of the left sacral problem (Fig. 4).

This patient had a history of a metatarsal stress fracture in high school and bilateral tibial stress fractures within the past 12 months. She had been oligomenorrheic and amenorrheic as a teenager, took oral contraceptives for a time in college, but discontinued them with resultant amenorrhea for 4 to 5 months before the present problem. Her diet was found to be deficient; she ingested only 52% of her estimated caloric need, 42% of recommended protein, 66% of calculated carbohydrates, and nearly no dietary calcium. Her quantitative CT bone mineral density of 142.2 mg/ml of hydroxyapatite equivalent was within normal range and well above the 110 mg/ml fracture threshold.

Initial treatment consisted of 4 to 6 weeks of nonweightbearing for which she was minimally compliant. She was also given nutritional counseling, calcium supplementation, and began hormone replacement therapy. At 2 months after the diagnosis pain was still present with sitting. By 9 months she reported performing at 80% of her previous activity level, but she still had pain with jogging. Full activity and pain-free return to varsity level collegiate soccer was achieved at 1 year after diagnosis.

Figure 1. Anteroposterior radiograph of the pelvis in case 1, performed 2 weeks after onset of pain, shows normal anatomy.

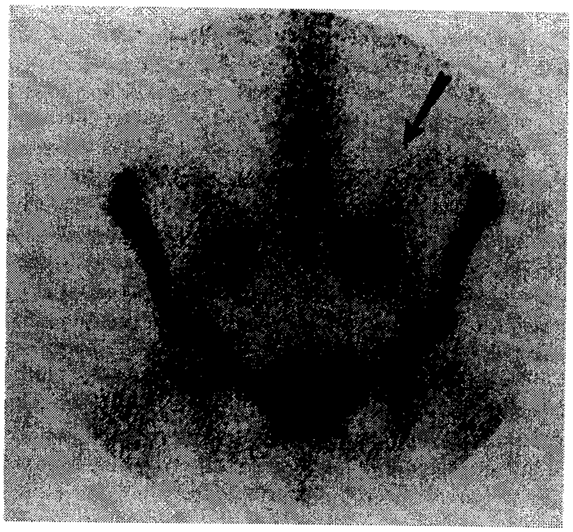

Figure 2. Anterior view bone scan of the pelvis in case 1, performed 2.3 weeks after onset of pain, reveals increased uptake in the midlateral aspect of the left sacrum at the level of the sacroiliac joint (arrow).

Figure 3. Short T1-weighted inversion recovery MRI of the pelvis in case 1, performed 3 weeks after onset of symptoms, demonstrates left sacral bone marrow edema with an interior area of bony sclerosis (arrows).

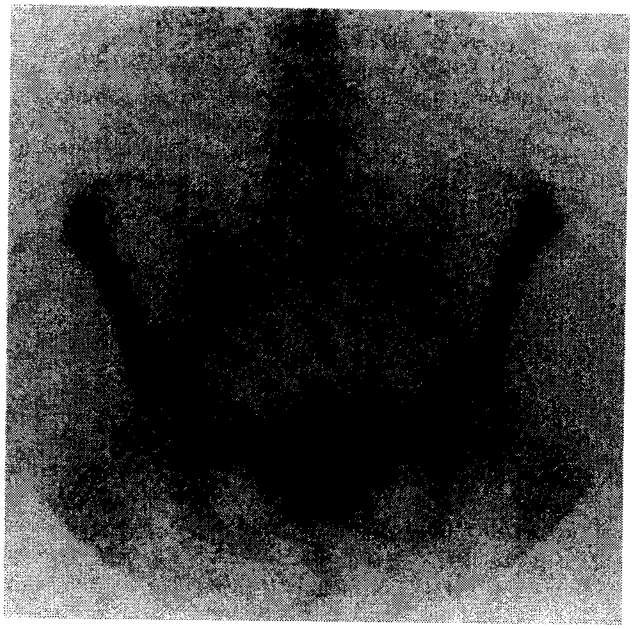

Figure 4. Anterior view bone scan of the pelvis in case 1, performed 1 year after onset of pain, shows normal anatomy.

Case 2

A 20-year-old female varsity basketball player initially experienced generalized low back pain while sitting during final examinations. The pain resolved over a 2-week holiday break but returned within 3 days during double practice sessions in January. Physical findings were nonspecific, with paralumbar muscle spasm and increased low back pain with hip flexion and hyperextension.

She had some initial improvement with physical therapy and nonsteroidal antiinflammatory drugs, but by the 3rd week her pain had localized to the left sacroiliac joint and adjacent sacrum. Radiographs taken 4 weeks after injury were normal except for minimal degenerative spurring of the left inferior sacroiliac joint. A bone scan performed on the same day revealed a moderate-sized focus of increased tracer within the inferior aspect of the left sacroiliac joint. A research CT performed 5 weeks after injury demonstrated an irregular oblique line of increased attenuation coursing through the superior portion of the left sacral ala to the left first sacral neural foramen (Fig. 5). The radiologist believed this was strongly suggestive of impacted trabeculae, typical of a microtrabecular fracture or stress fracture. There was no evidence of cortical fracture or displacement. An MRI scan obtained at 9 weeks revealed a sclerotic fracture line in the same region with adjacent bone marrow edema.

The patient's menstrual history was normal since menarche and there were no prior stress fractures. Nutritionally, she averaged 71% of total caloric needs, 108% of recommended protein, 45% of calculated carbohydrates, and 128% of needed calcium. Bone mineral density determination by quantitative CT was 0.5 SD above normal at 167 mg/ml.

Two months after diagnosis, she no longer experienced constant pain. By 4 months she reported being at 20% of her former activity level with pain principally with menses and prolonged sitting. Full return to activity and varsity level basketball was achieved at 9 months without pain.

Case 3

A 45-year-old female recreational runner was seen with left-sided groin and left lower back pain for approximately 6 weeks. The pain had gradually increased until all activity was discontinued except walking with a cane. In the 6 months before injury she had increased her weekly mileage from 15 to 20 miles running on a short-banked indoor track.

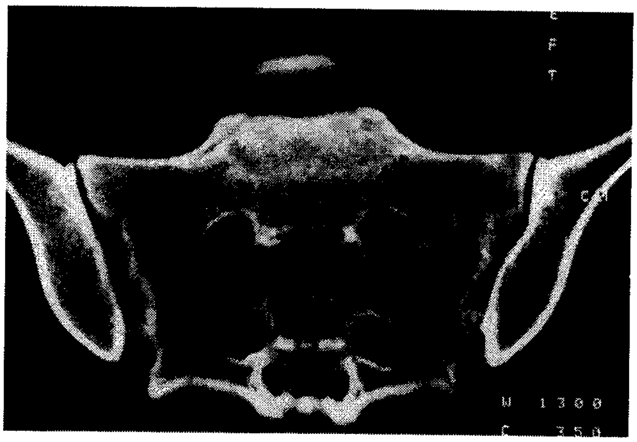

Figure 5. A coronal image CT scan of the pelvis in case 2, performed 5 weeks after injury, reveals an irregular oblique line of increased attenuation coursing through the superior portions of the left sacral ala (arrow).

Plain radiographs obtained at 5.4 weeks after onset of pain showed increased sclerosis in the left sacrum and sacroiliac joint as well as a suspicious area of sclerosis in the left inferior pubic ramus (Fig. 6). A bone scan done 2 days later revealed intense focal uptake of both the mid left sacroiliac joint area and the left inferior pubic ramus. An investigational MRI performed at 3 months after injury was read as consistent with a stress fracture of the sacrum (Fig. 7). A serpiginous area of low signal was demonstrated within the left sacrum parallel to the sacroiliac joint, and an ill-defined area of low signal was noted in the adjacent marrow.

A CT scan done 4 months after injury showed patchy sclerosis with several more discrete sclerotic lines within the left sacrum (Fig. 8). In addition, a well-defined fracture line with periosteal thickening of callus formation was seen in the left inferior pubic ramus. A follow-up CT scan done 4 months later showed resolution of all sclerotic foci in the left sacral ala and evidence of the healed inferior pubic ramus fracture.

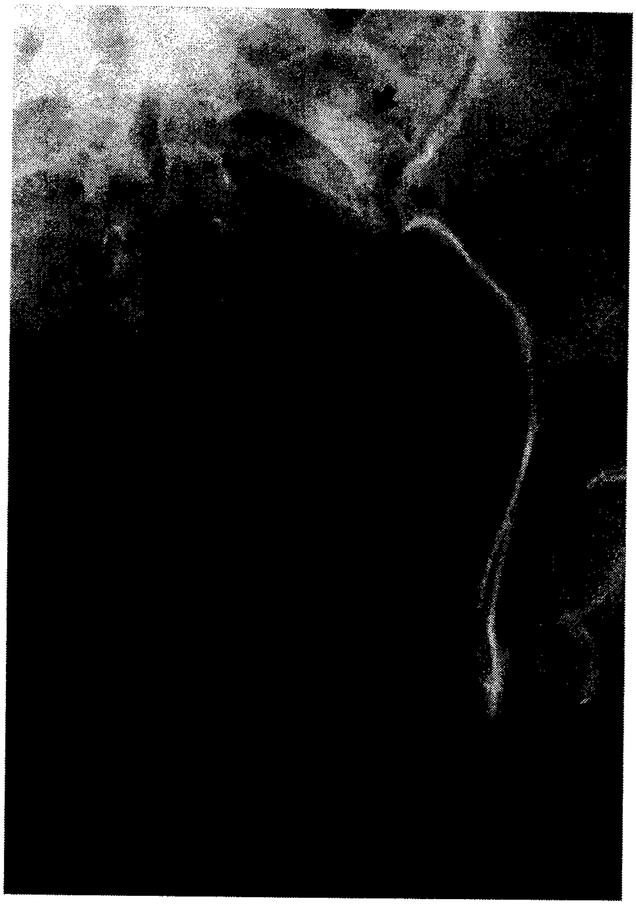

Figure 6. Outlet view radiograph of the pelvis in case 3, performed 5.4 weeks after the onset of symptoms, shows increased sclerosis of the left sacroiliac joint (arrows, top), adjacent sacrum, and left inferior pubic ramus (arrows, bottom).

Figure 7. A T1-weighted coronal MRI of the pelvis in case 3, performed 3 months after onset of pain, reveals an irregular line of sclerosis in the left sacrum parallel to the sacroiliac joint (arrows).

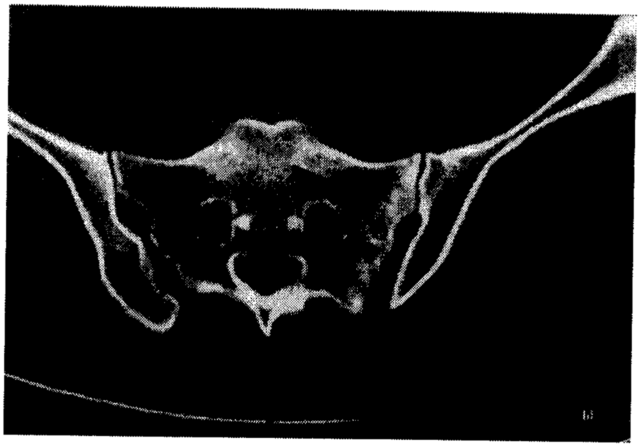

Figure 8. A coronal CT scan of the pelvis in case 3, performed 4 months after injury, demonstrates patchy sclerosis in the left sacrum parallel to the sacroiliac joint (arrows).

The patient's menstrual history was normal since menarche and she was nulliparous. Three-day diet analysis indicated a vegetarian diet averaging 62% of her total calculated caloric need, 50% of recommended protein, 65% of needed carbohydrate, and 63% of her calcium requirement.

A quantitative CT study revealed a bone density of 84.8 mg/ml, which was significantly below the average for her age and well below the fracture threshold. Based on this and a normal estrogen level, a 4-month trial was initiated with a daily calcitonin injection (100 IU), oral calcium (1500 mg), and vitamin D (400 IU). Repeat quantitative CT at 4 months was unchanged, but a dual-energy x-ray absorptiometry scan for comparison suggested normal bone mineral density of 1.13 g/cm^2. One year later the same discrepancy existed between the quantitative CT and dual-energy x-ray absorptiometry scans. This discrepancy may relate to the quantitative CT being more sensitive for cortical bone and the dual-energy x-ray absorptiometry being more sensitive for trabecular bone mineral.[14]

The patient's clinical course was protracted. At 9 months she reported her activity to be 25% of her previous level with persistent pain while standing, bending, and lifting. She was pain-free by 14 months but had given up running in favor of a walking program.

Case 4

A 22-year-old female varsity cross-country runner complained of left lateral hip pain that radiated down the left leg. Over the following week of continued running the pain localized to the left sacroiliac area. This athlete began training 3 months before injury after a 4-year hiatus from running. One week before the symptoms began, she had increased her mileage from 6 or 7 miles per day to 8 or 9 miles per day.

Radiographs were normal. A bone scan taken 3 days later revealed increased activity in the left sacroiliac joint and adjacent sacral ala. An investigational MRI and CT scan done 5 weeks after injury showed a sclerotic fracture line, adjacent marrow edema, and sclerosis, all consistent with the diagnosis of a left sacral stress fracture.

During high school, she had discontinued distance running because of constant foot pain, which in retrospect was most likely one or more undiagnosed stress fractures. This problem may have been a direct consequence of 6 years of anorexia/bulimia, severe weight loss, and amenorrhea. At age 19 she delivered a very premature infant that did not survive, and at age 21 she gave birth to a full-term infant. The baby was breast fed for 8 months, during which time she was amenorrheic. Two months later she began running, leading to the present injury.

Diet evaluation showed a vegetarian diet averaging 69% of total caloric needs, 49% of recommended protein, 53% of calculated carbohydrate, and 81% of needed calcium. Her weight was 9% below her ideal body weight. A quantitative CT study revealed a bone density 0.5 SD below the mean for her age at 141.2 mg/ml, but well above the 110 mg/ml fracture threshold.

The patient was told to curtail all activity and the use of crutches was advised but not consistently used. Four and one-half months after diagnosis, her pain persisted with weather changes, sitting, and walking up or down hills. She was nearly pain-free by 9 months, but she had not attempted running and blamed persistent aching on her third pregnancy.

Case 5

A 41-year-old woman began a low-fat diet and a 2-miles-per-day jogging program after a 10-year break from running and a 15 to 20 pound weight gain. Four weeks later she began experiencing left gluteal pain. She kept running another month before seeking medical attention. Radiographs were normal and examination was suggestive of left sciatica. A supervised physical therapy program was begun and resulted in some initial improvement.

Four months later, when she was still jogging, she was again evaluated because of worsening pain even with activities of daily living. A bone scan showed increased tracer uptake in the region of the left inferior sacroiliac joint. A research MRI demonstrated bone marrow edema in the left sacrum with an internal sclerotic line and a lesser amount of edema in the adjacent ilium.

The patient's menstrual cycles had been normal since menarche and she had never been pregnant. At the time of diagnosis, she was estimated to be 38 pounds overweight. The 3-day self-reported diet indicated she was receiving 83% of her total caloric need, 88% of recommended protein, 89% of calculated carbohydrates, and 109% of needed calcium. A quantitative CT bone mineral analysis revealed a density of 153.6 mg/ml, 0.1 SD above the mean for her age.

At 2 months after diagnosis she had only intermittent pain and had begun a walking program. Five months into treatment she was pain-free, walking 30 to 40 minutes 5 days per week plus participating in low-impact aerobics three to four times per week. She personally decided not to return to jogging for fear of recurrent symptoms.

Case 6

A 19-year-old female recreational athlete and university mascot complained of pain for approximately 2 months in the right sacroiliac and buttock area. There was no history of trauma, but she jogged 6 miles per day 6 to 7 days a week along with jumping activities as a mascot. There were no radiating symptoms. On examination she had full active and passive range of motion of the back, Faber's test was positive on the right, and passive right hip extension elicited pain in the right sacroiliac joint. Radiographs were normal, and the diagnosis of right-sided chronic sacroiliac joint sprain was offered. After a brief period of supervised therapy, she returned to her out-of-town university to continue a home stretching and strengthening program.

The patient was seen again at 9 weeks and at 6 months after the initial evaluation. During this time, she experienced some pain-free intervals but was feeling worse by the 6-month visit. Her activities at that time included intramural soccer four times a week, running, ice skating, and roller blading. Her lumbar motion was significantly reduced in all directions, and her neurologic examination was normal. Repeat radiographs revealed increased sclerosis at the right sacroiliac joint. A subsequent bone scan showed a moderate area of diffuse increased uptake within the right sacroiliac joint that correlated with the area of sclerosis seen on plain radiographs. A research MRI confirmed the presence of trabecular bone edema and bony sclerosis in the superior region of the right sacrum.

Analysis of a self-reported 3-day diet revealed the patient to mainly follow a vegetarian diet. Compared with calculated needs, the patient averaged 60% of total required calories, 55% of calculated carbohydrates, 64% of recommended protein, and 98% of the daily calcium requirement. Her menses were monthly since menarche and she had never used oral contraceptives. A bone density analysis was not performed on this patient.

Relief of her right sacral symptoms was achieved 2 months after diagnosis with relative rest. By 13 months after diagnosis, she was participating at 50% of her prior activity level. Further attempt to return to full activity was complicated by the onset of left-sided back pain with radiculopathy. An MRI revealed a left-sided L5/S1 herniated disc.

Case 7

A 20-year-old female varsity cross-country and distance track athlete was seen with a 4-day history of pain in the right buttocks and sacroiliac joint area. The pain began during practice and rapidly progressed to pain with walking and bending. Symptoms seemed to abate with rest and a week's course of nonsteroidal antiinflammatory medication but rapidly returned with the next attempt at running. Although initially treated as a low back strain, the patient's failure to respond to treatment and subsequent localization of pain to the right sacrum raised the possibility of a sacral stress fracture.

Plain radiographs were normal, but the bone scan with SPECT images done 2 weeks after the onset of symptoms demonstrated intense uptake in the right sacroiliac joint and sacral ala (Fig. 9). A research MRI obtained 7 weeks after injury verified the problem by demonstrating an oblique sclerotic fracture line with adjacent marrow edema in the right sacrum (Fig. 10).

The patient had a history of two tibial stress fractures in high school, a left tibial stress fracture her sophomore year in college, and a right femoral shaft stress fracture 6 months before the current injury. Her menses had been regular except for 6 months of amenorrhea during high school sports. Her recent training involved running 40 to 45 miles per week. This level had been achieved fairly rapidly over the previous 2 months after recovery from the femoral stress fracture.

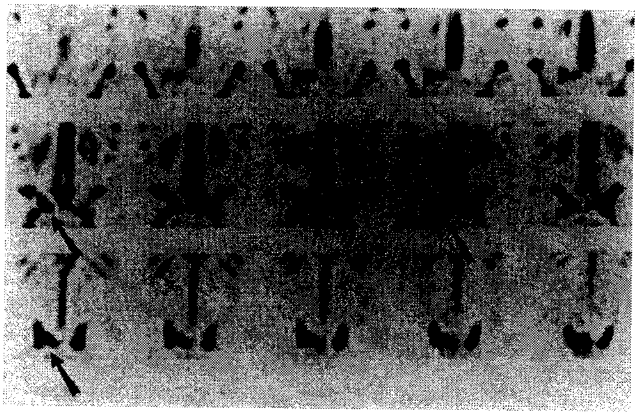

Figure 9. Coronal SPECT bone scan of the pelvis in case 7, performed 2 weeks after the onset of symptoms, demonstrates intense tracer uptake in the right sacroiliac joint and sacral ala (arrows).

Figure 10. A T1-weighted coronal MRI of the pelvis in case 7, performed 7 weeks after onset of symptoms, reveals bone marrow edema in the right sacrum with central bony sclerosis (arrows).

The 3-day diet analysis showed that the athlete was receiving 77% of her protein requirement, but only 56% of the carbohydrate needs. Calcium intake was 100% of the recommended daily allowance for the past 8 months because of supplemental calcium tablets, but before that time her intake had only been one-third the recommended daily allowance.

A dual-energy x-ray absorptiometry scan was performed to evaluate bone mineral density. The left hip reading was 0.911 g/cm^2, which was 94% of age-matched controls but 0.45 SD below the mean. The average lumbar spine reading was 0.888 g/cm^2, which was 87% of age-matched controls and 1.22 SD below the mean for her age. The latter numbers were still above but close to the fracture threshold of 0.800 g/cm^2.

Treatment consisted of improving her diet, maintaining the 1500 mg of calcium daily, adding 400 IU of vitamin D daily, and restricting activities to those of daily living. By 5 weeks she was pain-free. At 5 months she was able to return to full activity.

Case 8

A 21-year-old female varsity cross-country athlete was seen with a 3-day history of left hip pain that radiated to the proximal lateral left thigh and ischial tuberosity. Pain began during a race 2 months into her fall season. By the following day she had pain while walking or sitting. Physical findings included pain to palpation directly over the left sacrum and marked exacerbation of symptoms with single-legged weightbearing on the left leg. Initial treatment failed to relieve symptoms.

Radiographs and a bone scan were performed 2 weeks after the onset of symptoms. Radiographs were normal, but the bone scan showed increased activity in the left sacrum and sacroiliac joint. This was interpreted by the radiologist as being consistent with a stress fracture of the sacrum. Magnetic resonance imaging and CT scans were

TABLE 1
Clinical Data for Athletes with Stress Fractures of the Sacrum

Case	Age	Sport	Onset of symptoms to diagnosis (weeks)	Studies[a] (positive or negative)
1	21	Varsity soccer	2	Radiograph (−) Bone scan (+) MRI (+) CT scan (+) QCT (−)[a]
2	20	Varsity basketball	5.5	Radiograph (−) Bone scan (+) CT scan (+) MRI (+) QCT (−)
3	45	Recreational jogger	6	Radiograph (+) Bone scan (+) MRI (+) CT scan (+) QCT (+) DXA scan (−)[b]
4	22	Varsity cross-country	0.5	Radiograph (−) Bone scan (+) MRI (+) CT scan (+) QCT (−)
5	41	Recreational jogger	20	Radiograph (−) Bone scan (+) MRI (+) CT scan (−) QCT (−)
6	19	Recreational jogger, intramural soccer and ice hockey, university mascot	26	Radiograph (−), 2nd radiograph (+) Bone scan (+) MRI (+) CT scan (−)
7	20	Varsity cross-country/track	2	Radiograph (−) Bone scan (+) SPECT scan (+) MRI (+) DXA scan (−)
8	21	Varsity cross-country/track	2	Radiograph (−) Bone scan (+)

[a] QCT, quantitative computerized tomography; DXA, dual-energy x-ray absorptiometry.
[b] Calcitonin injections (100 IU) were given daily for the first 4 months after diagnosis.

not ordered because of our experience with the other seven cases.

The athlete had a history of two stress fractures of the left femur 2 and 4 years before the present injury. After the second stress fracture, she was found to have been oligomenorrheic for a number of years, averaging 6 to 9 menses per year. Estradiol levels drawn 14 days apart were 17 and 35 pg/ml. Because of these low estradiol values, she was started on oral contraceptive pills and had been taking them a full year before the current sacral injury. Diet inquiry revealed a low-fat, low-cholesterol diet devoid of red meat.

Initial treatment consisted of dietary counseling, calcium supplementation, and partial weightbearing with crutches. By 3 weeks after diagnosis she was pain-free with activities of daily living, and her examination was negative. Over the subsequent 2 weeks she progressed from water running to riding a stationary bicycle without problem. At 5 weeks after diagnosis she had begun jogging, and by 10 weeks she was running at her preinjury level without pain.

RESULTS

The results for these cases are summarized in Table 1. Table 2 summarizes various parameters that may predispose an athlete to sacral stress fractures and influence the rate of healing. All eight cases of sacral stress fractures were in premenopausal women ages 19 to 45 years old. Bone density determinations were obtained in six of eight cases; all were above the fracture threshold of 110 mg/ml using quantitative CT or 0.800 g/cm^2 for the dual-energy x-ray absorptiometry scan except for one 45-year-old recreational jogger (case 3). Her quantitative CT reading was low at 84.8 mg/ml, but several subsequent dual-energy x-ray absorptiometry scans were normal.

The average time to becoming pain-free in all eight cases was 6.6 months, while the average time to achieve

TABLE 1
Continued

Fracture location	Treatment (months)	Course (No. of months after diagnosis)
Left mid sacrum	Relative rest with nonweightbearing conditioning (1–2), progressive activity (10), nutritional counseling, calcium supplementation, oral contraceptive pills	Mild pain relief (2), 80% activity (9), pain-free full sport (12)
Left superior sacral ala	Relative rest with pain-free, nonweightbearing conditioning and stretching (1–2), progressive activity (7), nutritional counseling	Mild pain relief (2), 20% activity (4), pain-free full sport (9)
Body of left sacrum parallel to sacroiliac joint, inferior pubic ramus	Cane with activities of daily living only (5), progressive activity (9), nutritional counseling, calcium supplementation, vitamin D, calcitonin injections[b]	Mild pain and 25% activity (9), pain-free walking program (14)
Left superior sacral ala	Crutches (0.5), relative rest (4), progressive activity (5), nutritional counseling	Intermittent pain (4.5), pain-free (9), not jogging because of pregnancy rest
Left sacrum with a lesser amount of bone marrow edema in the left ilium	No impacting activity and relative rest (2), progressive activity (11)	Intermittent pain (2), pain-free walking and low-impact aerobics (5)
Right superior sacral ala	Relative rest (2), progressive activity (11), nutritional counseling	No pain (2), 50% activity (13) because of L5-S1 herniated disc, left side
Right sacral ala	Relative rest (2), progressive activity (3–4), nutritional counseling, continued calcium supplementation, vitamin D	Pain-free (1), full activity (5)
Left sacrum	Partial weightbearing (0.75), progressive activity (1.75), nutritional counseling, calcium supplementation, continue oral contraceptive pills	Pain-free (0.75), full activity (2.5)

approximately the same preinjury activity level was 8 months in six of the eight cases. The other two athletes were unable to return to their sport because of a pregnancy (case 4) and a herniated disc (case 6).

The most consistent risk factor was a rapid increase in level of activity (six of eight cases). Three of the athletes were vegetarians and two others avoided red meat. One woman had a prolonged problem with anorexia/bulimia in high school (case 4), and a second athlete was suspected of having similar problems but never admitted to this on questioning (case 1). Both women had had years of amenorrhea/oligomenorrhea off and on dating back to high school. Five of the athletes (cases 1, 3, 4, 7, and 8) had had prior stress fractures and one had had a stress fracture of the inferior pubic ramus along with the sacral stress fracture (case 3).

A 3-day diet analysis was performed for seven athletes using a nutrition computer program. Caloric needs were determined using standard methods making allowances for height, body build, and activity level. Based on these calculations, only two women of the seven were obtaining adequate protein and carbohydrates (cases 2 and 5). Two women had calcium-deficient diets (cases 1 and 3), and two others had past histories of calcium deficiency (cases 4 and 7).

Interestingly, the three athletes with the best overall diets (cases 2, 5, and 7) had the best bone mineral density, fewer other risk factors, and were able to return to full pain-free activity 3 to 9 months earlier than the other women.

DISCUSSION

Stress fractures are a well-documented complication of mechanical overload of bone in both the athletic and military populations.[3,15,16,22] Stress fractures can be characterized as either insufficiency-type fractures or fatigue-type fractures. Insufficiency stress fractures occur under

TABLE 2
Potential Risk Factors for Sacral Stress Fractures Found in Each Patient

Factor	Case number (Age)							
	1 (21)	2 (20)	3 (45)	4 (22)	5 (41)	6 (19)	7 (20)	8 (21)
Sport	Varsity soccer	Varsity basketball	Recreational jogger	Varsity cross country	Recreational jogger	Jogger, intramural sports, mascot	Varsity cross country	Varsity cross country[a]
Rapid increase in training	+		+	+	+	+	+	
History of prior stress fractures	+		+	+			+	+
History of amenorrhea/ oligomenorrhea	+			+			+	+
History of prior eating disorder	?[b]			+				
Vegetarian diet			+	+		+		
Avoids red meat	+		+	+		+		+
QCT[c] bone density (±SD for age)	142.4 (−0.2)	167.0 (+0.5)	84.8 (−2.0)	141.2 (−0.5)	153.6 (+0.1)			
DXA[d] bone density (% age-matched controls)			Hip: 0.857 (91%) L1–L4: 1.13 (95%)				Hip: 0.911 (94%) L1–L4: 0.888 (87%)	
Calcium (% RDA)	<40	128	63	81	109	98	100	
Protein (% calculated need)	42	108	50	49	88	64	77	
Carbohydrate (% calculated need)	66	45	65	53	89	55	56	

[a] Formal dietary analysis not completed.
[b] Suspected of having an eating disorder.
[c] QCT, quantitative computed tomography scan. Expressed in milligrams per milliliter.
[d] DXA, dual-energy x-ray absorptiometry scan. Expressed in grams per square centimeter.

normal stress in abnormal bone (that is, osteoporosis/ osteomalacia), and their occurrence in the pelvis and sacral region, particularly in the elderly female population, has been previously reported.[8–11,17,18]

Fatigue-type stress fractures occur in normal bone from mechanical overload. Repetitive microtrauma concentrated across the specific bony site induces attempted adaptive remodeling of the bone (Wolf's law). Cyclic stress creates an increased rate of osteoclastic (resorptive) activity, followed by osteoblastic (building) activity of new bone.[3,22] If adequate rest or time is not present to allow for new bone to accumulate, subsequent weakening and fracture of the involved bone will occur. Isolated cases of fatigue-type sacral stress fractures have been reported in world-class male and female athletes, as well as in soldiers involved in rigorous basic training.[1,4,5,20,24] Stress fractures can occur with compression or tension forces. The femoral neck illustrates this nicely. Tension or distraction forces produce stress fractures on the superior aspect along cement lines. Compression forces produce fractures on the inferior aspect of the neck, which result in diffuse shear microfractures.

The diagnosis of stress fractures requires a high index of suspicion because overuse injuries of surrounding soft tissue can mimic and mask the underlying bony lesion. Plain radiographs, techetium-99m bone scan, CT, and MRI can all help with the diagnosis, but short of a bone biopsy to verify callus formation, the diagnosis of a fatigue-type stress fracture depends on history, physical examination, and the compilation of findings from the various radiologic tests. Plain film radiographs can be diagnostic for stress fractures, but symptoms typically precede radiographic changes by a period of weeks to months. When radiographic findings are present, they can include periosteal, endosteal, or medullary new bone formation and fracture lines.[5] Factors further complicating accurate radiologic readings in the sacral area include overlying bowel gas shadows and the fact that there must be a 30% to 50% change in trabecular bone density before changes are evident on radiographs.[12,13] In the present series of eight athletes, radiographs were helpful in two cases (cases 3 and 6) because of the presence of bony sclerosis.

In general, technetium-99m bone scans are very sensitive for stress fractures but nonspecific.[2,5,21,22] A normal scan virtually excludes the diagnosis.[5] In the sacral region, specificity is even more difficult. Images are small and overlaps of anatomic structures make exact localization of tracer uptake more difficult. In this series, all eight athletes showed increased uptake in the sacral region with a round or teardrop configuration to the tracer. Radiologists unaccustomed to considering the diagnosis of sacral stress fracture in young healthy adults typically worded their reports as follows: moderate-to-intense uptake in and about the sacroiliac joint; consider inflammatory joint disease, joint infection, trauma, and, less likely, tumor. In case 7, the nuclear medicine imaging SPECT system added a whole new dimension in defining more precisely the location of injury. Coronal and transverse images proved to be the most helpful.

Computed tomography scans are quite sensitive and specific for most stress fractures.[5] Depending on the fracture location, findings can include cortical disruption and periosteal, endosteal, or medullary new bone formation. Fracture lines may not be seen well unless they lie in the axial plain of the machine. In only three of six cases did the primary CT reading by the radiologist successfully identify the site of the lesion within the sacrum. Secondary reading in conjunction with the bone scan and MRI films did identify the site of injury in one additional case. Patchy sclerosis with discrete sclerotic lines was seen in case 3, bony sclerosis in case 4, and attenuated coursing lines in case 2 that were interpreted as impacted trabeculae typical of microtrabecular fractures.

Magnetic resonance imaging is sensitive for stress fractures but nonspecific. Abnormal edema of the bone marrow is present with most fractures, and linear areas of abnormal signal can sometimes be seen involving the cortex and medullary cavity.[5] Research MRI scans were obtained in seven of the eight cases. The primary reading by the radiologist identified the site of injury in all cases. Bone marrow edema was present within the sacral ala in all cases, and sclerotic fracture lines were evident in five of the seven cases (cases 1, 2, 3, 4, and 7).

The diagnosis of a fatigue-type stress fracture of the sacrum in the present series of cases was based on the patients' running history, young age, and the spectrum of findings from the various noninvasive radiologic tests. Bone scans were very sensitive in identifying the general location of the problem to the sacroiliac joint area, but CT and MRI were necessary to localize the lesion to within the sacral ala. Case 5 was the only case where bone marrow edema was seen on both sides of the sacroiliac joint in the sacrum and adjacent ilium. The CT and MRI findings further suggest that sacral stress fractures are diffuse shear microfractures of the trabecular bone typical of repetitive compression forces.

The most recent case added to the series was evaluated only with plain radiographs and bone scan imaging (case 8). Her running history, physical findings, and positive bone scan were typical of the other seven cases. She was similarly treated and improved as expected. Computed tomography and MRI tests were important in the earlier cases to define the injury, but may not be necessary if the patient improves as anticipated.

Isolated cases of fatigue-type stress fractures of the sacrum have been reported in the medical literature.[1,4,5,20,24] They include a 20-year-old female gymnast, a 28-year-old female world-class runner, three young male army recruits, a 40-year-old male runner (80 km per week), a 32-year-old male 10-km racer, and a 31-year-old male Olympic athlete. All eight of these cases were initially evaluated with radiographs and subsequent technetium polyphosphate scintigrams. Two had subsequent CT scans that showed sclerosis and callus formation.[20,24] Two others had MRI studies[1]; one was negative and the other showed decreased marrow signal consistent with bone marrow edema. Interestingly, two soldiers had follow-up bone scans at 2 and 3 months when they became asymptomatic.[24] Both scans showed resolution of the sacroiliac foci.

This fairly rapid return to normal is uncharacteristic of stress fractures in other locations. In the current series of female athletes, the patient in case 1 had a normal repeat bone scan 1 year after the original sacral stress fracture diagnosis. Similarly, the patient in case 3 had a repeat CT 4 months after the first CT and 8 months after the onset of her sacral pain. The sclerotic patches and lines previously seen were no longer present. These findings suggest a more rapid and complete healing of the microfractures in the more vascular trabecular bone of the sacrum than in long bone stress fractures that involve the less vascular cancellous bone.

One soldier and a male competitive runner and former Olympic medal winner had concomitant stress fractures, respectively, of the tibia and pubic bone.[1,24] The patient in case 3 in our series also had a second stress fracture of the inferior pubic ramus along with the sacral fracture. These cases are important to illustrate that sufficient mechanical forces were present to cause stress fractures in well-recognized sites at the same time as the sacral injuries. This adds credence to the fact that what is seen in the sacrum truly represents a stress fracture injury.

One may argue that case 3 represents an insufficiency-type stress fracture because of the low bone density found on the initial quantitative CT study. As noted previously, this athlete also had a simultaneous stress fracture of the pubic ramus. Other authors have reported a 50% prevalence of pubic ramus fractures in patients with insufficiency-type sacral stress fractures.[17] In case 3, because of the patient's relatively young age, normal menses, activity level, and the equivocal bone density studies (quantitative CT scan was below the fracture threshold while the dual-energy x-ray absorptiometry scan was in the low normal range), her fractures were thought to be fatigue stress fractures occurring in osteopenic bone. In this case, the osteopenic bone was thought to be secondary to years of a nutritionally deficient vegetarian diet.

An internationally competitive female runner with a sacral stress fracture had prolonged amenorrhea and a quantitative CT bone density slightly below the fracture threshold of 110 mg/cm^2.[4] Four of the eight patients in the present series also had menstrual irregularities. The patients in cases 7 and 8 had prior amenorrhea/oligomenorrhea, and the patients in cases 1 and 4 had amenorrhea at the time of diagnosis. Three of these four athletes had bone density determinations. In contrast to the case described in the literature, all three athletes had normal bone mineral content. Interestingly, all four athletes with histories of menstrual disorders in our series had prior stress fractures. Only one other athlete, in case 3, had a prior stress fracture but normal menses. These cases highlight the importance of asking female athletes about their menstrual cycles and correcting estrogen deficiency states if they exist.

In the literature review of fatigue-type sacral stress fractures, only in the six male cases was information provided concerning time required from injury to full activity (average, 1.7 months; range, 0.75 to 3).[1,20,24] Two female athletes (cases 4 and 5) in our series were unable to return to full activity for reasons unrelated to their sacral stress fracture. In the other six cases, the average time to being pain-free was 6.6 months (range, 0.75 to 9), and the average time to full activity was 8 months (range, 2.5 to 14). Those women with the best diets, regular menses, and few prior problems with stress fractures or menstrual irregularities healed the fastest. Although the healing rates for these premenopausal athletes was considerably longer than for their male counterparts, the rates were still less than the average 11 months (range, 4 to 24) required for complete resolution of symptoms in osteoporotic women with insufficiency-type sacral stress fractures.[17]

Overall, the sacrum appears to be a relatively rare area for a fatigue-type stress fracture, but the reported incidence may be greater if a high index of suspicion leads to the systematic ordering of radionuclide bone scans in athletes with chronic sacroiliac pain in an activity-related setting. Those athletes with a history of an eating disorder, oligomenorrhea, or amenorrhea should receive a bone density evaluation, appropriate blood and hormonal studies, and replacement hormonal therapy when indicated. Nutritional deficiencies and psychological concerns also need to be addressed.

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