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BRIEF ARTICLE

Analysis of stress fractures in athletes based on our clinical experience

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Abstract

AIM: To analyze stress fractures in athletes based on experience from our sports medicine clinic.

METHODS: We investigated the association between stress fractures and age, sex, sports level, sports activity, and skeletal site in athletes seen at our sports medicine clinic between September 1991 and April 2009. Stress fractures of the pars interarticularis were excluded from this analysis.

RESULTS: During this period (18 years and 8 mo), 14276 patients (9215 males and 5061 females) consulted our clinic because of sports-related injuries, and 263 patients (1.8%) [171 males (1.9%) and 92 females (1.8%)] sustained stress fractures. The average age of the patients with stress fractures was 20.2 years (range 10-46 years); 112 patients (42.6%) were 15-19 years of age and 90 (34.2%) were 20-24 years of age. Altogether, 90 patients (34.2%) were active at a high recreational level and 173 (65.8%) at a competitive level. The highest proportion of stress fractures was seen in basketball athletes (21.3%), followed by baseball (13.7%), track and field (11.4%), rowing (9.5%), soccer (8.4%), aerobics (5.3%), and classical ballet (4.9%). The most common sites of stress fractures in these patients were the tibia (44.1%), followed by the rib (14.1%), metatarsal bone (12.9%), ulnar olecranon (8.7%) and pelvis (8.4%). The sites of the stress fractures varied from sport to sport. The ulnar olecranon was the most common stress fracture site in baseball players, and the rib was the most common in rowers. Basketball and classical ballet athletes predominantly sustained stress fractures of the tibia and metatarsal bone. Track and field and soccer athletes predominantly sustained stress fractures of the tibia and pubic bone. Aerobics athletes predominantly sustained stress fractures of the tibia. Middle and long distance female runners who sustained multiple stress fractures had the female athlete triad.

CONCLUSION: The results of this analysis showed that stress fractures were seen in high-level young athletes, with similar proportions for males and females, and that particular sports were associated with specific sites for stress fractures. Middle and long distance female runners who suffered from multiple stress fractures had the female athlete triad.

Key words: Athletes; Bone mineral density; Female athlete triad; Stress fracture; Vitamin D insufficiency

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INTRODUCTION

Stress fractures are common injuries in athletes and military recruits. A stress fracture can be defined as a partial or complete fracture of bone that results from repeated application of stress lower than that required to fracture the bone in a single loading situation[1]. It is generally accepted that the tibia is the most common site of stress fractures, followed by the metatarsal and tarsal bones[2,3]. Running activities are the most common sports activities that result in stress fractures[2,3].

Epidemiological studies have identified the clinical risk factors of stress fractures in athletes and military recruits. The etiology of stress fractures is multifactorial and many clinical risk factors have been identified; polymorphism of vitamin D receptor (FokI and BsmI)[4], low serum levels of 25(OH)D[5], high serum parathyroid hormone level[6], low stiffness index (heel quantitative ultrasound parameter)[4,7], low bone mineral content and density (BMC and BMD, respectively) of the hip[6], tall stature[6,8], leanness[8], poor physical fitness/condition[6,9,10], sense of burnout[8], iron deficiency[8], higher age[9], gender (female)[9,11], low bone turnover[7], smoking[10], and amenorrhea[10]. However, no consensus has been reached. It is important for physicians to understand the features and etiology of stress fractures for the prevention and treatment of this crucial sports injury. The aim of this study was to analyze stress fractures in athletes based on experience from our sports medicine clinic. We investigated the association between stress fractures and age, sex, sports level, sports activity, and skeletal site in athletes seen at our sports medicine clinic. Cases with the female athlete triad (eating disorder, amenorrhea, and low BMD)[12] or vitamin D insufficiency were also included.

MATERIALS AND METHODS

During the 18 years and 8 mo period between September 1991 and April 2009, a total of 14276 patients consulted our sports medicine clinic because of sports-related injuries. Of these patients, the study subjects selected were athletes who sustained stress fractures.

A stress fracture was determined clinically as an area of marked focal, bony tenderness in association with evidence of a fracture on plain radiographs or magnetic resonance (MR) images, or a focal area of markedly increased uptake on the delayed phase of a technetium 99m-labeled bone scan. In particular, the bone scan was used to detect stress fractures of the rib in rowers, and MR images provided a rapid, anatomically precise diagnosis of stress fractures of the ulnar olecranon in baseball pitchers without additional radiation exposure. The uptake of technetium 99m, particularly in the tibial diaphysis, has had various interpretations; localized focal uptake of technetium 99m suggests a stress fracture (Figure 1), whereas its linear uptake along the periosteum suggests periostitis or stress syndrome (shin splints)[13-15]. Therefore, the tibiae showing localized focal uptake but not linear uptake of technetium 99m were diagnosed as having a stress fracture. Patients with

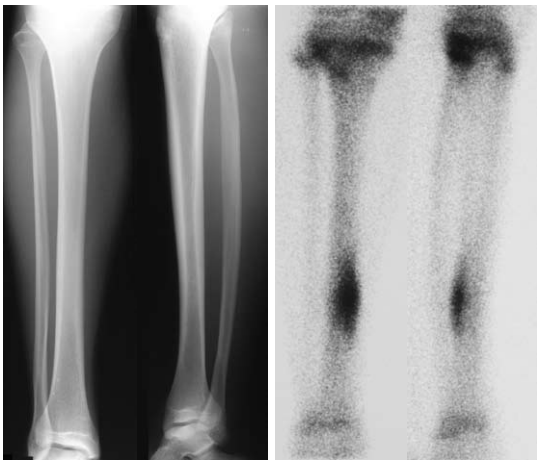

Figure 1 A case of stress fracture of the tibia diagnosed by technetium 99m-labeled bone scan. Although there were no abnormal findings on the plain radiographs of the tibia, the bone scan showed the uptake of technetium 99m in the tibial diaphysis. The localized focal uptake of technetium 99m suggests a stress fracture.

acute shin splints have a spectrum of MR findings (normal appearance, periosteal fluid only, abnormal marrow signal intensity, and stress fracture), which suggests this clinical entity is part of a continuum of stress response in bone[16]. However, the strong association between chronic symptoms and a normal-appearing MR image implies that this modality has less utility in these patients[16]. Thus, MR images were not useful for distinguishing shin splints and stress fractures in athletes.

Athletes were defined as young and middle-aged persons who engaged in low-recreational, high-recreational, and competitive sports activities according to the following categories; non-athlete (sports activity a few times a month), low-recreational (sports activity once or twice a week), high-recreational (sports activity three or more times a week, belonging to a high school sports team or a sports society), and competitive (competitive sports activity, belonging to a professional, industrial, or college sports team).

We analyzed the cases of stress fractures in athletes seen at our clinic and compared our results with those of previously published studies. In particular, the following features of each stress fracture patient were noted: age, sex, sports level, sports activity, and fracture site. Cases with the female athlete triad or vitamin D insufficiency were also included. Stress fractures of the pars interarticularis were excluded from the study.

RESULTS

Of the 14276 patients, 9215 were male and 5061 were female. Stress fractures were seen in 263 patients (171 males, 92 females). The proportion of stress fractures was 1.8% in all patients (1.9% in males, 1.8% in females). The age distribution is shown in Table 1. The average age of the patients with stress fractures was 20.2 years (range 10-46 years); 112 patients (42.6%) were 15-19 years of age and 90 (34.2%) were 20-24 years of age. Altogether,

Table 1 Age and sex of athletes with stress fractures

Age (yr)	*n* (%)	Male/Female
10-14	24 (9.1)	17/7
15-19	112 (42.6)	76/36
20-24	90 (34.2)	57/33
25-29	21 (8.0)	9/12
⩾ 30	16 (6.1)	12/4
Total	263 (100)	171/92

Table 2 Sports represented in stress fracture series

Sport	*n* (%)	Male/Female
Basketball	56 (21.3)	32/24
Baseball	36 (13.7)	35/1
Track and field	30 (11.4)	9/21
Rowing	25 (9.5)	23/2
Soccer	22 (8.4)	20/2
Aerobics	14 (5.3)	2/12
Classical ballet	13 (4.9)	0/13
Rugby	8 (3.0)	6/2
Tennis	7 (2.7)	7/0
Volleyball	6 (2.3)	1/5
Others	46 (17.5)	36/10
Total	263 (100)	171/92

90 patients (34.2%) were active at a high recreational level and 173 (65.8%) at a competitive level.

The distribution of sports activities associated with stress fractures is shown in Table 2. The highest proportion of stress fractures was seen in basketball athletes (21.3%), followed by baseball (13.7%), track and field (11.4%), rowing (9.5%), soccer (8.4%), aerobics (5.3%), and classical ballet (4.9%). The distribution of stress fracture sites is shown in Table 3, and includes reports by other investigators[2]. The most common sites of stress fractures in these patients were the tibia (44.1%), followed by the rib (14.1%), metatarsal bone (12.9%), ulnar olecranon (8.7%) and pelvis (8.4%). The proportions of olecranon and rib stress fractures were higher in our clinic than in other facilities (Table 3).

The sites of the stress fractures varied from sport to sport. The ulnar olecranon was the most common stress fracture site in baseball players, and the rib was the most common in rowers. Basketball and classical ballet athletes predominantly sustained stress fractures of the tibia and metatarsal bone. Track and field and soccer athletes predominantly sustained stress fractures of the tibia and pubic bone. Aerobics athletes predominantly sustained stress fractures of the tibia.

Four young elite middle and long distance female runners sustained multiple stress fractures as well as low body mass index and the female athlete triad (eating disorder, amenorrhea, and low lumbar spine BMD) (Table 4).

One athlete who sustained a stress fracture had vitamin D insufficiency; a young Kendo female athlete (19 years of age) was diagnosed as having a stress fracture in the medial malleolus of the tibia by a technetium 99m-labeled bone scan (Figure 2) and vitamin D insufficiency as determined by serum 25(OH)D concentration (< 30 ng/mL). Following conservative treatment with the active form of vitamin D_3 (alfacalcidol), this patient returned to play in 6 mo.

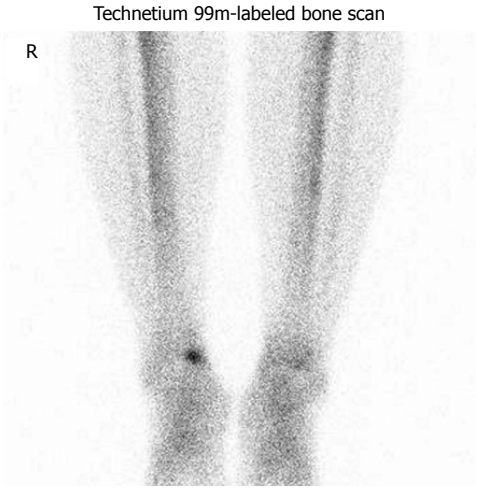

Figure 2 A case of stress fracture of the medial malleolus of the tibia. Although there were no abnormal findings on the plain radiographs of the ankle, the bone scan showed the uptake of technetium 99m in the medial malleolus of the tibia. The localized focal uptake of technetium 99m suggests a stress fracture.

DISCUSSION

An analysis of stress fractures treated in our sports medicine clinic showed that running and jumping activities were the most common sports activities that resulted in stress fractures in the lower limbs, and that stress fractures were commonly seen in the tibia (Table 3). Particular sports were associated with specific stress fracture sites. Furthermore, in our experience, multiple stress fractures can be associated with the female athlete triad. One athlete who sustained a stress fracture had vitamin D insufficiency.

The ulnar olecranon was the most common stress fracture site in baseball players. Because the athletes in two professional baseball teams were obliged to consult us, the proportion of olecranon stress fractures might have been higher in our clinic than in other facilities (Table 3). Stress fractures of the olecranon may be caused by repeated extensor tug on the olecranon by the triceps muscle[17], or impaction force on the olecranon due to impingement between the olecranon and the olecranon fossa with valgus stress[18].

The rib was the most common stress fracture site among rowers. Because rowers in the high school and university related to our university hospital were obliged to consult us, the proportion of rib stress fractures might have been higher in our clinic than in other facilities (Table 3). The most frequently reported cause of rib stress fractures is direct pull on muscles, (i.e. serratus anterior and rectus abdominis muscles)[19]. Recently, however, rib loading (which mostly occurs during the drive phase of the rowing stroke) has been hypothesized to contribute to the occurrence of these fractures[19].

The female athlete triad including eating disorders, functional hypothalamic amenorrhea, and low BMD is a

Table 3 Proportion of stress fractures in athlete[2]

Investigator (yr)	Ovara (1978)	Sugiura (1983)	Matheson (1987)	Tajima (1997)	Muto (1998)	Sakai (1999)	Iwamoto (2009)
No. of case	142	162	330	111	251	183	263
Upper limb							
Metacarpal bone	1.4				0.3		
Humerus	0.7				1.2		
Ulna	0.7	1.2			5.2	1.6	8.7
Trunk							
Rib	8.6		3.6	1.8	4.0	2.7	14.1
Spine	0.7	2.4	0.6		11.9	4.9	0.8
Pelvis	1.4		1.6		2.4	4.9	8.4
Lower limb							
Femur	6.3	3.7	7.2	0.9	3.2	3.3	1.5
Patella		1.2		1.8	0.3		0.4
Lower leg	67.6	67.3	55.7	68.5	37.8	51.9	48.3
Tibia		54.3			32.3	42.6	44.1
Fibula		13.0			5.6	9.3	4.2
Tarsal bone	0.7		25.3	2.7	3.6	5.4	1.1
Metatarsal bone	18.3	15.4	8.8	20.7	28.7	25.1	12.9
Sesamoid	1.4		0.9		0.5		2.7
Toe phalanx	0.7						0.8

Table 4 Stress fractures in middle and long distance female runners

	Case 1	Case 2	Case 3	Case 4
Age (yr)	19	22	22	20
Body mass index (kg/m^2)	18.2	17.5	17.7	17.7
Menstruation status	Amenorrhea	Amenorrhea	Amenorrhea	Amenorrhea
Estradiol[1] (pg/mL)	32	36	< 20	21
Bone mineral density (Z score, %)				
Lumbar spine	72	81	91	81
Femoral neck			102	92
Stress fracture				
Number of fracture	4	2	3	2
Fracture site	R. Metatarsus R. Metatarsus Bil. Femur	Bil. Tibia	L. Metatarsus L. Calcaneus 8th thoracic spine	R. Calcaneus L. Pubic bone

[1]< 35 pg/mL in postmenopausal women. R: Right; L: Left; Bil: Bilateral.

serious problem in athletes[12]. Middle and long distance female runners who suffered from multiple stress fractures had the female athlete triad, suggesting that the risk of stress fractures was increased in cases with the female athlete triad. There is a potential link between body mass index, energy deficit, and hypothalamic dysfunction, and the pathophysiology underlying low BMD in hypothalamic amenorrhea is directly related to nutritional issues[20-22]. There may be both a nutritional component affecting formation and an estrogen-related component affecting resorption (uncoupling of bone formation and resorption). The first aim is to increase energy availability by increasing energy intake and/or reducing exercise energy expenditure; weight gain and an increase in energy availability (> 30 kcal/kg of fat-free mass per day) in those young women are clinical priorities to facilitate resumption of their menses[20-22]. Adequate amounts of bone-building nutrients such as calcium (1000-1300 mg/d), vitamin D (400-800 IU/d), and vitamin K (60-90 μg/d) are also needed to maintain bone health[20-22]. Leptin administration for relative leptin deficiency in women with hypothalamic amenorrhea was reported to improve reproductive, thyroid, and growth hormone axes and markers of bone formation, suggesting that leptin, a peripheral signal reflecting the adequacy of energy stores, is required for normal reproductive and neuroendocrine function[23].

Many clinical risk factors of stress fractures have been identified. In particular, polymorphism of vitamin D receptor (FokI and BsmI), vitamin D insufficiency, low bone mass, low body mass index, poor physical fitness/condition, gender (female), low bone turnover, and amenorrhea were suggested to be clinical risk factors of stress fractures[4-11].

One athlete in our study who sustained a stress fracture had vitamin D insufficiency. Hypovitaminosis D may result from reduced sun exposure and the widespread use of sun blockers, resulting in less efficient formation of vitamin D in the skin, as well as from dietary deficiency. Hypovitaminosis D is classified into two categories: vitamin D deficiency as a severe form, and vitamin D insufficiency as a mild form[24,25]. According to current recommendations, serum 25(OH)D concentrations < 30 ng/mL are considered to indicate insufficiency[25], while values < 10 ng/mL

are classified as deficiency[26]. Vitamin D deficiency causes rickets in children and osteomalacia in adults. Vitamin D insufficiency can lead to secondary hyperparathyroidism, bone loss, osteoporosis, and increased risk of fractures[27]. Vitamin D insufficiency is frequently encountered in the general population and even in elite athletes[28-30].

A lower level of serum 25(OH)D concentration was found to be a general predisposing factor for stress fractures in military recruits[5], indicating a relationship between vitamin D insufficiency and the occurrence of stress fractures. Thus, the need for additional vitamin D in the prevention of stress fractures was suggested and calcium and vitamin D supplementation was shown to decrease the incidence of stress fractures in female recruits[31]. Thus, it is important to evaluate vitamin D status in athletes and military recruits for the prevention of stress fractures. Generally, athletes do not meet the US dietary reference intake for vitamin D, and inadequate endogenous synthesis is the most probable reason for insufficient/deficient status[32]. It is imperative that sports dietitians and physicians routinely assess vitamin D status and make recommendations to help athletes achieve a serum 25(OH)D concentration of $\geqslant$ 32 ng/mL and preferably $\geqslant$ 40 ng/mL[32].

Vitamin D is now recognized as important for cardiovascular health and its deficiency as a potential risk factor for several cardiovascular disease processes[33]. A report on calcium and vitamin D supplementation and coronary artery calcification in the Women's Health Initiative suggested that treatment with moderate doses of calcium plus vitamin D_3 did not seem to alter coronary artery calcified plaque burden among postmenopausal women[34]. A systematic review suggests that vitamin D supplements at moderate to high doses may reduce cardiovascular disease risk, whereas calcium supplements seem to have minimal cardiovascular effects[35]. Thus, we have recognized that calcium and vitamin D supplementation may not be harmful in athletes with calcium and vitamin D insufficiency/deficiency.

In conclusion, an analysis of stress fractures, based on experience from our sports medicine clinic, showed that particular sports were associated with specific stress fracture sites. In addition, some female athletes who sustained multiple stress fractures also had the female athlete triad. One athlete who sustained a stress fracture had vitamin D insufficiency.

COMMENTS

Background

Stress fractures are common injuries in athletes and military recruits. Epidemiological studies have identified the clinical risk factors of stress fractures in athletes and military recruits. Although the etiology of stress fractures is multifactorial and many clinical risk factors have been identified, no consensus has been reached.

Research frontiers

It is important for physicians to understand the features and etiology of stress fractures for the prevention and treatment of this crucial sports injury. In this study, we analyzed stress fractures in 263 athletes based on experience from our sports medicine clinic. The association between stress fractures and age, sex, sports level, sports activity, and skeletal site in athletes seen at our sports medicine clinic was investigated and cases with the female athlete triad [eating disorder, amenorrhea, and low bone mineral density (BMD)] or vitamin D insufficiency were also included.

Innovations and breakthroughs

Running and jumping activities were the most common sports activities that resulted in stress fractures in the lower limbs, and stress fractures were commonly seen in the tibia. Particular sports were associated with specific stress fracture sites. The ulnar olecranon was the most common stress fracture site in baseball players, and the rib was the most common in rowers. Basketball and classical ballet athletes predominantly sustained stress fractures of the tibia and metatarsal bone. Track and field and soccer athletes predominantly sustained stress fractures of the tibia and pubic bone. Aerobics athletes predominantly sustained stress fractures of the tibia. Middle and long distance female runners who sustained multiple stress fractures had the female athlete triad. One athlete who sustained a stress fracture had vitamin D insufficiency.

Applications

Physicians may be able to establish the strategy for prevention and treatment of stress fractures by understanding the features and etiology of this crucial sports injury.

Terminology

A stress fracture can be defined as a partial or complete fracture of bone that results from repeated application of stress lower than that required to fracture the bone in a single loading situation. The female athlete triad includes eating disorders, functional hypothalamic amenorrhea, and low BMD. Hypovitaminosis D is classified into two categories: vitamin D deficiency as a severe form, and vitamin D insufficiency as a mild form. According to current recommendations, serum 25(OH)D concentrations < 30 ng/mL are considered to indicate insufficiency, while values < 10 ng/mL are classified as deficiency.

Peer review

The authors show the case history of stress fractures in their sport medicine center; moreover they review the literature about stress fracture causes, risk factors and nutritional therapy. The study of bone features in young healthy people presenting bone weakness represents a topical issue.

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