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Original Article

Calcaneal stress fractures in civilian patients: an epidemiological study

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Abstract

Objective: To conduct a retrospective magnetic resonance imaging (MRI) analysis of calcaneal stress fractures and construct an epidemiological profile of these injuries.

Methods: Of 258 MRIs analyzed, nine were consistent with calcaneal stress fractures. These were evaluated by two investigators to confirm the diagnosis. The calcaneus was divided into three anatomical regions: anterior calcaneus (delimited by the angle of Gissane), mid-calcaneus (delimited by the angle of Gissane and tuberosity of the posterior facet), and posterior calcaneus (delimited by the tuberosity of the posterior facet). Fractures were classified as low-grade (grade I, when associated with periosteal edema; II, endosteal; III, muscular) or high-grade (grade IV, when there was a visible fracture line on MRI).

Results: The average patient with a calcaneal stress fracture was an overweight (66.7%) female (66.7%) amateur athlete (66.7%), with a left-sided (55.6%) grade IV fracture (77.8%) of the posterior portion of the calcaneus (66.7%), sustained while running (77.8%), and took 1 to 2 years to be diagnosed (66.7%).

Conclusion: Calcaneal stress fractures are more frequent in women, amateur athletes, middle age, and in those with overweight. Younger patients usually present with grade I, II, or III fractures, while middle-aged patients present most often with grade IV fractures; lesions tend to be more common in the anterior region than in the mid- or posterior calcaneus.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Fractures, stress/epidemiology; Calcaneus/injuries; Magnetic resonance imaging.

Introduction

Calcaneal stress injuries were first reported in the German literature in 1937[1,2]. Stress fractures are the result of repetitive microtrauma to normal bone, and have an incidence of 1% to 7% among all sports activities. They are considered the second most common foot injury, accounting for 20% of all fatigue-induced fractures[3-5]. These injuries occur primarily in military recruits, long-distance runners, and the obese. Women have a particularly high prevalence, with reports that these lesions may account for up to 39% of all fractures in females[3,4,6-11].

Heel pain is a common complaint in adults, and can cause discomfort and disability. However, due to the low incidence of this type of fracture and low level of suspicion, it is diagnosed rarely as compared to other conditions, such as hindfoot tendinopathy, plantar fasciitis, neuropathies, retrocalcaneal bursitis, and calcaneal (Achilles) tendinopathy[4].

Several risk factors have been associated with development of calcaneal stress fracture, including insufficient physical activity and inadequate footwear[12,13]. Conventional radiography, especially in the early stages of these lesions, cannot establish a definitive diagnosis. Instead, bone scintigraphy and magnetic resonance imaging (MRI) are considered the most reliable imaging methods for the diagnosis of stress fracture. Both modalities have excellent sensitivity, but MRI also offers high specificity and is considered the optimal imaging method for diagnosis of stress fractures[11].

Study performed at the Hospital Santa Teresa, Petrópolis, RJ, Brazil.
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The objective of this study was to conduct a retrospective MRI analysis of stress fractures and outline the epidemiological profile of this injury.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 82503418.6.0000.5245. An informed consent form was signed by the patients involved.

From January 2015 to December 2017, all MRI scans of patients presenting to the study hospital with hindfoot pain were retrospectively evaluated.

The exclusion criteria were patients who presented with acute calcaneal fracture or with any infection involving the ankle and/or foot. Patient charts were analyzed to collect data on demographic parameters and clinical history, including time from symptom onset until definitive diagnosis and type of activity that triggered heel pain. Of 258 MRIs analyzed, 11 were consistent with stress fracture, but two were excluded because the patients presented with acute trauma. Therefore, the sample consisted of nine patients (Table 1).

Magnetic resonance imaging of the ankle was obtained in at least two different planes. Of these, the sagittal and axial planes, in T1-weighed spin-echo and fast-spin T2-weighed sequences with fat suppression, were the most common. Additional sequences were also requested, such as STIR (short-tau-inversion-recovery). All MRIs were evaluated by two investigators to certify that they represented stress fractures. To determine the location of the lesion, as proposed by Sormaalaet al.[14], the calcaneus was divided into three anatomical regions: The anterior calcaneus (delimited by the angle of Gissane), mid-calcaneus (delimited by the angle of Gissane and tuberosity of the posterior facet), and posterior calcaneus (delimited by the tuberosity of the posterior facet) (Figure 1).

Calcaneal stress fractures were classified as low-grade (grade I, when associated with periosteal edema; grade II, endosteal edema; grade III, muscle edema) or high-grade (grade IV) when there was a visible fracture line on MRI[15-17] (Figures 2A, 2B). Because the calcaneus is an essentially trabecular bone, the low-grade fractures were pooled for analysis by the two investigators, as these lesions are difficult to assess.

Statistical analysis

Due to the small sample size, no inferential analysis of significance could be performed; the statistical analysis was descriptive, based on graphs, frequency distributions, and calculation of (mean, median, standard deviation, coefficient of variation – *CV* – for the age variable). The variability of age distribution was considered low if , moderate if , and high if.

Graphs were plotted in Microsoft Excel 2007. All other analyses were carried out in SPSS Statistics for Windows, Version 22.0.

Results

The baseline sample of this study is composed of nine patients with calcaneal stress fractures, six women (67.7%) and three men (33.3%), as shown in figure 3.

The age distribution of the patients, overall and by gender, is described in table 2. Patient age ranged from 36 to 74 years (mean, 50.8 years; median, 48.0 years; standard deviation, 11.8 years), and variability was moderate (CV=0.23). The variability of age distributions in the female and male subgroups was also moderate. Women with calcaneal stress fractures were generally older than men (4.2 years on average). A comparison of mean and median age in the male and female subgroups is shown in figure 4.

The frequency distribution of variables that characterize patients and their fractures, overall and stratified by gender, is shown in table 3. The frequency distribution of age shows that the most typical age groups for calcaneal stress fractures are between 36 and 56 years (66.6%). The typical patient with a calcaneal stress fracture was an overweight (66.7%) female (66.7%) amateur athlete (66.7%), with a left-sided (55.6%) grade IV fracture (77.8%) of the posterior portion of

Table 1. Demographic data and clinical history of the included patients

Code	Age (years)	Gender	Site of fracture	Side	Meters	Weight	Bmi	Time elapsed from symptoms to diagnosis	Athlete	Cause	Level
1	43	Female	Posterior portion	Right	1,68	62	22,0	About 1 year	Amateur	Running	I, II, III
2	41	Female	Posterior portion	Left	1,72	75	25,4	About 1,5 year	Amateur	Running	IV
3	46	Male	Posterior portion	Right	1,78	86	27,1	About 2 years	Amateur	Running	IV
4	62	Male	Media portion	Right	1,7	84	29,1	About 1 year	No	Walking	IV
5	36	Male	Posterior portion	Left	1,76	68	22,0	One week	Amateur	Running	IV
6	50	Female	Posterior portion	Left	1,67	70	25,1	About 10 months	No	Running	IV
7	57	Female	Posterior portion	Right	1,72	73	24,7	1 Year	Amateur	Running	IV
8	48	Female	Media portion	Left	1,74	69	22,8	About 6 months	Amateur	Running	IV
9	74	Female	Anterior portion	Left	1,69	74	25,9	About 1 year	No	Walking	I, II, III

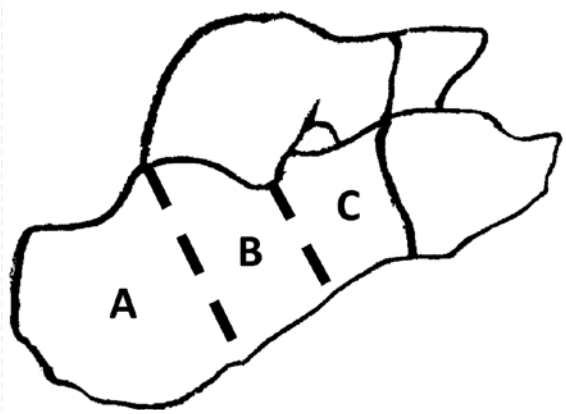

Figure 1. Calcaneus divided into three anatomical regions: A – posterior; B – medial; C – anterior.

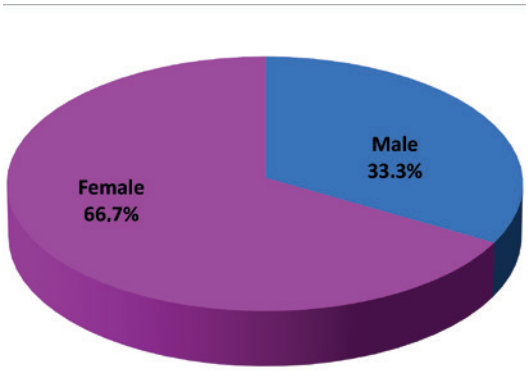

Figure 3. Gender distribution of the sample.

Figure 2. A and B – Plain radiographs and MRI of a grade IV calcaneal stress fracture.

Table 2. Key statistics for the patient age variable, overall and stratified by gender

Statistic	Overall	Female	Male
Minimum	36	41	36.0
Maximum	74	74	62.0
Mean	50.8	52.2	48.0
Standard deviation	11.8	12.1	13.1
CV	0.23	0.23	0.27
Median	48.0	49.0	46.0

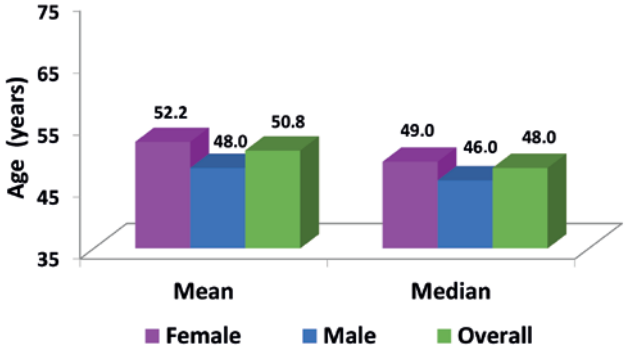

Figure 4. Mean and median patient age, overall and stratified by gender.

the calcaneus (66.7%), sustained while running (77.8%), which took 1 to 2 years to be diagnosed (66.7%).

Table 4 shows the main statistics related patient age, stratified into subgroups determined by the variables. These findings suggest that, among patients with calcaneal stress fractures, amateur athletes are older than non-athletes; those who are overweight are older than patients with normal

Table 3. Characteristics of patients and their injuries

Variable	Overall n=9		Female n=6		Male n=3	
	F	%	F	%	F	%
Age (years)						
36 |— 46	3	33,30%	2	33,30%	1	33,30%
46 |— 56	3	33,30%	2	33,30%	1	33,30%
56 |— 66	2	22,20%	1	16,70%	1	33,30%
66 |— 76	1	11,10%	1	16,70%	0	0,00%
Athlete						
No	3	33,30%	2	33,30%	1	33,30%
Amateur	6	66,70%	4	66,70%	2	66,60%
Classification of BMI						
Normal	3	33,30%	2	33,30%	1	33,30%
Overweigth	6	66,70%	4	66,70%	2	66,60%
Fracture's cause						
Walking	2	22,20%	1	16,70%	1	33,30%
Running	7	77,80%	5	83,30%	2	66,60%
Level of fracture						
I, II e III	2	22,20%	2	33,30%	0	0,00%
IV	7	77,80%	4	66,70%	3	100,00%
Side of fracture						
Right	4	44,40%	2	33,30%	2	66,70%
Left	5	55,60%	4	66,70%	1	33,30%
Site of fracture						
Anterior portion	1	11,10%	1	16,70%	0	0,00%
Media portion	2	22,20%	1	16,70%	1	33,30%
Posterior portion	6	66,70%	4	66,70%	2	66,70%
Time elapsed from symptoms to diagnosis						
Less than 1 year	3	33,30%	2	33,30%	1	33,30%
1 to 2 years	6	66,70%	4	66,70%	2	66,60%

Table 4. Key statistics for the patient age variable, stratified by subgroup

Subgroup	Mean	Median	Standard deviation	Minimum	Maximum	CV
Athlete						
No	45.2	44.5	7.1	36	57	0.16
Amateur	62.0	62.0	12	50	74	0.19
BMI classification						
Normal	42.3	43	6	36	48	0.14
Overweight	55.0	53.5	12	41	74	0.22
Cause of fracture						
Walking	68.0	68	8.5	62	74	0.12
Running	45.9	46	6.8	36	57	0.15
Fracture grade						
I, II, III	58.5	58.5	21.9	43	74	0.37
IV	48.6	48	8.9	36	62	0.18
Affected side						
Right	44.7	48	7.6	36	50	0.17
Left	53.8	51.5	12.9	41	74	0.24
Fracture site						
Anterior calcaneus	74.0	74	-	74	74	-
Mid calcaneus	55.0	55	9.9	48	62	0.18
Posterior calcaneus	45.5	44.5	7.3	36	57	0.16
Time elapsed from symptom onset to diagnosis						
Less than 1 year	52.0	51.5	9	43	62	0.17
1 to 2 years	49.8	48	14.6	36	74	0.29

weight; those who walk are older than those who run; those with grade I, II, and III fractures are older than those with grade IV lesions; those who presented with lesions on the left side were older than those who had lesions on the right side; the oldest patient of the sample had an injury of the anterior calcaneus, while those who presented with mid-calcaneus injuries were older than those who presented with lesions in the posterior portion. There was no substantial age difference between patients with a symptom-to-diagnosis interval of less than 1 year versus 1 to 2 years.

Figure 5 shows the frequency and mean age of patients in subgroups stratified by gender and BMI classification. The highest frequency of calcaneal stress fractures (44.4%) was found in overweight women with a mean age of 55.5 years, while the lowest frequency (11.1%) was in men with normal weight and a mean age of 36 years. Therefore, based on this sample, we estimate that an overweight woman is four times more likely to experience a calcaneal fracture than a man of normal weight.

Discussion

Although calcaneal stress fractures are considered unusual injuries, MRI should be considered for early diagnosis in patients with heel pain, especially in overweight, physically active women.

The diagnosis of calcaneal stress fractures can be a challenge for the orthopedic surgeon. Localization of pain and tenderness in the plantar and/or posterior region will often induce diagnostic suspicion of plantar fasciitis or other soft-tissue conditions. Due to its relatively uncommon incidence when compared to other stress fractures and other causes of heel pain, calcaneal stress fractures are often misdiagnosed or neglected[18,19]. Although the literature shows that, on physical examination, pain is usually located in the plantar or posterior

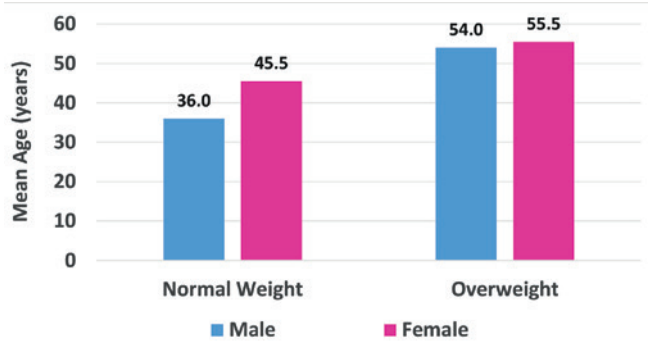

Figure 5. Frequency and mean age in patient subgroups stratified by gender and BMI classification.

region of the calcaneus[3], most of our patients reported pain in the lateral aspect of the heel. This may be due to the course of the branches of the posterior tibial nerve (lateral plantar nerve and calcaneal branch).

According to the literature, several different imaging modalities, such as plain-film radiography, computed tomography, bone scintigraphy, and MRI, are frequently used for the diagnosis of stress fractures[20,21]. Conventional ankle radiographs show a dense line of sclerosis; however, this sign only becomes visible several weeks after the onset of injury[20]. Conversely, MRI and bone scintigraphy allow more accurate documentation and characterization of stress fractures[11]. Fredericson et al.[22] compared MRI to technetium scans in 14 runners with symptoms of leg pain, and found that MRI was more accurate than bone scintigraphy. These findings were confirmed by Miller et al.[23]. Bone scintigraphy has demonstrated high sensitivity but low specificity for the diagnosis of stress fractures[24]. Therefore, MRI has proved ideal test for the diagnosis of stress fractures, since it combines high sensitivity and specificity for the assessment of medullary edema, periosteal inflammatory reaction, and fracture lines[25,26]. In addition, it is worth noting that, according to Kanstrup[27], the radiation dose effect of bone scintigraphy lasts up to 2 years, which makes MRI an even more attractive modality.

This study analyzed MRI scans of 258 patients with heel pain, nine of whom were diagnosed with a stress fracture. Regarding the time elapsed between first complaint and imaging, 33.3% of the patients were diagnosed in the first year since symptom onset and 66.7% between the first and second year of symptoms. Thus, although MRI was the most appropriate modality to establish the diagnosis, there was still a delay in requesting imaging, which consequently delayed the diagnosis.

According to the literature, calcaneal stress injuries are usually located in the posterior region[7,9]. Sormaala et al.[14] observed that 56% of injuries were located in the posterior region, 26% in the anterior region, and 18% in the mid-calcaneus. Other studies have observed that 95 to 100% of these lesions were located in the posterior region[7,9]. However, these studies were restricted to conventional radiography. The disparity in results was attributed to the high sensitivity of MRI in locating fractures in different portions of the calcaneus. Our study confirmed the findings of Sormaala et al.[14], with a predominance of lesions in the posterior tuberosity (66.7%). Despite the small number of patients in our study, we observed that lesions of the anterior calcaneus (11.1%) occurred mainly in elderly patients (median age 74 years), followed by mid-calcaneal injuries (22.2%) at a median age of 55 years and posterior injuries (66.7%) at a median of 44 years.

Sormaala et al.[14] analyzed MRIs and classified 41% of lesions as low-grade, while only 15% of calcaneus fractures were detected on plain radiographs. Therefore, they concluded that, in order to ensure early diagnosis, MRI should be requested in patients who present with a complaint of heel pain, especially in military recruits, athletes, and the obese, even when radiographs are normal. In this study, probably due to the delay in obtaining MRI and consequent late diagnosis, seven of the nine analyzed patients (77.8%) had grade IV lesions. Perhaps earlier diagnosis might have led us to observe a greater number of grade I, I, and III stress lesions.

According to the literature, stress injuries of the calcaneus are more common in female and obese patients (BMI≥30). Our study showed a higher prevalence in female and overweight, though not obese, patients (44.4%), as determined by BMI. However, due to the small sample size, we cannot rule obesity out as a risk factor.

This study has some limitations. We did not analyze some variables that could interfere with the development of stress fractures of the calcaneus, such as flat feet and limb discrepancies, and did not obtain data on bone mineral density or history of menopause for female patients. In addition, the small sample size is an issue, as mentioned above.

Conclusion

In civilians, calcaneal stress fractures are more frequent in women, amateur athletes, middle-aged non-athletes, and those with overweight. Younger patients usually present with grade I, II, or III fractures, while middle-aged patients present most often with grade IV fractures. Lesions tend to be more common in the anterior region than in the mid- or posterior calcaneus.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PJL *(https://orcid.org/0000-0003-4967-7576) conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, data collection, bibliographic review, survey of the medical records, formatting of the article, approved the final version; RESP *(https://orcid.org/0000-0002-3572-5576) conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, approved the final version; LECA *(https://orcid.org/0000-0002-8488-184X) interpreted the results of the study, participated in the review process, bibliographic review, formatting of the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

References

1. Asal. Über Entstehung und Verhütung der Spontanfrakturen an den unteren Extremitäten. Veröffentl. Gebiete. Herressaanitätsw. 1937;104:32.
2. Scheller F. Überlastungsschäden am Knochengerüst junger Männer. Med Welt. 1939;13:1333.
3. Boden BP, Osbahr DC. High-risk stress fractures: evaluation and treatment. J Am Acad Orthop Surg. 2000;8(6):344-53.
4. Gehrmann RM, Renard RL. Current concepts review: Stress fractures of the foot. Foot Ankle Int. 2006;27(9):750-7.
5. Aldridge T. Diagnosing heel pain in adults. Am Fam Physician. 2004 15;70(2):332-8.
6. Darby RE. Stress fractures of the os calcis. JAMA. 1967;200(13):1183-4.
7. Hopson CN, Perry DR. Stress fractures of the calcaneus in women marine recruits. Clin Orthop Relat Res. 1977;(128):159-62.
8. Greaney RB, Gerber FH, Laughlin RL, Kmet JP, Metz CD, Kilcheski TS, Rao BR, Silverman ED. Distribution and natural history of stress fractures in U.S. Marine recruits. Radiology. 1983;146(2):339-46.
9. Weber JM, Vidt LG, Gehl RS, Montgomery T. Calcaneal stress fractures. Clin Podiatr Med Surg. 2005;22(1):45-54.
10. Yale J. A statistical analysis of 3,657 consecutive fatigue fractures of the distal lower extremities. J Am Podiatry Assoc. 1976;66(10): 739-48.
11. Spitz DJ, Newberg AH. Imaging of stress fractures in the athlete. Radiol Clin North Am. 2002;40(2):313-31.
12. Shaffer RA, Brodine SK, Almeida SA, Williams KM, Ronaghy S. Use of simple measures of physical activity to predict stress fractures in young men undergoing a rigorous physical training program. Am J Epidemiol. 1999;149(3):236-42.
13. Rome K, Handoll HH, Ashford R. Interventions for preventing and treating stress fractures and stress reactions of bone of the lower limbs in young adults. Cochrane Database Syst Rev. 2005;2005(2):CD000450.
14. Sormaala MJ, Niva MH, Kiuru MJ, Mattila VM, Pihlajamäki HK. Stress injuries of the calcaneus detected with magnetic resonance imaging in military recruits. J Bone Joint Surg Am. 2006; 88(10):2237-42.
15. Kiuru MJ, Niva M, Reponen A, Pihlajamäki HK. Bone stress injuries in asymptomatic elite recruits: a clinical and magnetic resonance imaging study. Am J Sports Med. 2005;33(2):272-6.
16. Kiuru MJ, Pihlajamäki HK, Perkiö JP, Ahovuo JA. Dynamic contrast-enhanced MR imaging in symptomatic bone stress of the pelvis and the lower extremity. Acta Radiol. 2001;42(3):277-85.
17. Fredericson M, Bergman AG, Hoffman KL, Dillingham MS. Tibial stress reaction in runners. Correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. Am J Sports Med. 1995;23(4):472-81.
18. Resnick D, Niwayama G. Diagnosis of bone and joint disorders. Philadelphia, Pa: W. B. Saunders; 1981.
19. Sutton MG St J, Oldershaw PJ, Ketler MN, editors. Textbook foot and ankle. Cambridge (MA): Blackwell Science; 1996.
20. Fishco WD, Stiles RG. Atypical heel pain. Hyperparathyroidism-induced stress fracture of the calcaneus. J Am Podiatr Med Assoc. 1999;89(8):413-8.
21. Miltner O. [Stress reactions in bones of the foot in sport: diagnosis, assessment and therapy]. Unfallchirurg. 2013;116(6):512-6.
22. Liong SY, Whitehouse RW. Lower extremity and pelvic stress fractures in athletes. Br J Radiol. 2012;85(1016):1148-56.
23. Fredericson M, Bergman AG, Hoffman KL, Dillingham MS. Tibial stress reaction in runners. Correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. Am J Sports Med. 1995;23(4):472-81.
24. Miller TL, Harris JD, Kaeding CC. Stress fractures of the ribs and upper extremities: causation, evaluation, and management. Sports Med. 2013;43(8):665-74.
25. Burke R, Chiang AL, Lomasney LM, Demos TC, Wu K. Multiple anterior tibial stress fractures complicated by acute complete fracture of the distal tibia. Orthopedics. 2014;37(4):217, 274-8.
26. Bergman AG, Fredericson M, Ho C, Matheson GO. Asymptomatic tibial stress reactions: MRI detection and clinical follow-up in distance runners. AJR Am J Roentgenol. 2004;183(3):635-8.
27. Arendt EA. Stress fractures and the female athlete. Clin Orthop Relat Res. 2000;(372):131-8.
28. Kanstrup IL. Bone scintigraphy in sports medicine: a review. Scand J Med Sci Sports. 1997;7(6):322-30.