Imaging-detected Bone Stress Injuries at the Tokyo 2020 Summer Olympics: Epidemiology, Injury Onset, and Competition Withdrawal Rate

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Abstract

Background

Prevention and early detection of injuries are essential in optimising sport participation and performance. The aim of this study is to investigate the epidemiology, history, and competition withdrawal rate of imaging-detected bone stress injuries during the Tokyo 2020 Olympic Games.

Methods

We collected and analysed imaging and patient information data in athletes with bone stress injuries diagnosed in the Olympic Village polyclinic during the Games. Two physicians independently and retrospectively reviewed all imaging examinations.

Results

A total of 10,305 individual athletes from 206 National Olympic Committees competed at the Games, during which 567 MRIs and 352 X-rays were performed at the Olympic Village polyclinic. Radiology examinations revealed four stress fractures and 31 stress reactions in 29 athletes (median age 24 years, range 18–35 years). Of these, 72% of patients (n = 21) had symptoms before entering the Olympic Village. Bone stress injuries were more common in women (55%), the lower extremities (66%), and track and field athletes (45%). Six patients (21%) did not start or did not finish their competitions.

Conclusions

This study revealed 35 imaging-detected bone stress injuries in the polyclinic of the Tokyo 2020 Olympic Village. The high proportion of patients with symptoms before entering the village and the high proportion of competition withdrawals suggests the usefulness of an early MRI examination.

Background

Bone stress injuries are some of the most common injuries in athletes of all ages and skill levels. Prevention and early detection are essential in optimising sport participation and performance. Under some circumstances, stress fractures may even require a more extended treatment than typical traumatic fractures [1]. It has also been reported that a higher magnetic resonance imaging (MRI) grade of the stress fracture can delay return to competition [2, 3].

Previous studies of bone stress injury at the Olympic Games were conducted at Rio de Janeiro (2016) and London (2012) [4–10], where they accounted for approximately 3% of all injuries [11]. In both of these summer Olympics, bone stress injuries were found to be more common in female athletes and most common in track and field competitors [11, 12].

However, previous reports detailing bone stress injuries in the Olympic Games have not correlated imaging findings with medical history because of the lack of connectivity between Picture Archiving and Communication System (PACS) and Electronic Medical Records (EMR). Such connectivity was established for Tokyo 2020, allowing this correlation and aiding in understanding the clinical impact of these injuries. Therefore, the present study aims to investigate the epidemiology, athlete history, and clinical impact, including competition withdrawal rate, of imaging-detected bone stress injuries during the Tokyo 2020 Olympic Games.

Methods

This retrospective study was approved by the ethics committee of Tokyo Medical and Dental University and the International Olympic Committee (IOC). Our study and intent to publish the data were approved by the IOC.

This study used imaging and clinical data from the PACS and EMR collected at the Tokyo 2020 Summer Olympic Games. Medical and imaging services were open for 30 days, from the opening of the Olympic Village on 13 July 2021 until its closing on 11 August 2021. We used athlete accreditation numbers to assure athlete identity and acquire information in PACS and EMR. We treated all information with strict confidence and de-identified our medical database after the Games. Informed consent was waived because all data in our epidemiological study were anonymised and unidentifiable. We obtained approval from the IOC to use anonymised imaging and demographic data for publication. Data were collected, stored, and analysed with strict attention to data protection and athletes' confidentiality.

Imaging data acquisition

Diagnostic imaging was performed using the Discovery XR656HD digital X-ray system (GE Healthcare, Brazil) and two MRIs: the 1.5T Signa Explorer and the 1.5T Signa Voyager (GE Healthcare, Brazil) installed at the Olympic Village polyclinic. MRI images were obtained using short tau inversion recovery (STIR) or fluid-sensitive fast spin-echo sequences such as T2-weighted and proton density-weighted with fat suppression in at least two planes and T1-weighted in one or two planes, as appropriate for each anatomical location. No intravenous gadolinium was used.

We reviewed all X-rays, MRIs, and EMR databases to identify imaging-detected bone stress injuries. We excluded non-athlete patients such as team staff, and cases of direct trauma as determined by clinical history in the EMR.

Imaging interpretation

A board-certified musculoskeletal radiologist (TA, with seven years of experience in musculoskeletal imaging) and a board-certified orthopaedic surgeon (JA, with nine years of experience in musculoskeletal imaging) independently reviewed all MRI and radiographic images of patients with bone stress injuries. The two readers were blinded to clinical history other than that a stress injury was suspected. Stress fracture was diagnosed by the presence of sclerosis, periosteal reaction, cortical thickening, and/or a fracture line at the site of pain on X-ray or MRI. Bone stress reaction was defined as an ill-defined hyperintensity area on a fluid-sensitive sequence of MRI at the symptomatic site in a patient without apparent fracture. Two physicians recorded the location of the lesion and its Fredericson classification [13] in all cases (grade 0 = normal; grade 1 = periosteal oedema; grade 2 = marrow oedema visible on T2-weighted images only; grade 3 = marrow oedema visible on both T1-weighted and T2-weighted images; grade 4a = intracortical signal changes in multiple focal areas; grade 4b = linear region of intracortical signal changes). To evaluate the distribution of MRI grading, grade 1 and grade 2 were defined as low-grade injuries, and grade 3 and grade 4 were determined as high-grade injuries. If there was disagreement between the two physicians' readings, the consensus final result was described.

Data collection of clinical information and competition results

We recorded the following information by EMR: sex/gender, age, nationality, sport, date of injury onset, and past medical history. We obtained the competition results by EMR and from the official Olympic website. We correlated these clinical data and competition results with the imaging findings.

Results

Epidemiology

There were 10,305 individual athletes representing 206 nations, territories, and principalities in competition at the Tokyo 2020 Olympic Games, during which the Olympic Village polyclinic performed 567 MRI scans and 352 X-ray scans between 13 July and 11 August 2021. The total number of bone stress injuries was 35 lesions (four stress fractures and 31 stress reactions), seen in 29 patients (16 female and 13 male athletes) (Figs. 1 and 2). Table 1 shows the locations of bone stress injuries. Because some patients had bone stress injuries at multiple sites, we counted the injury locations on a lesion-by-lesion basis. Table 2 reveals the sports of athletes with bone stress injuries. We defined marathon and race walking as road events in track and field, and the remainder of track and field events as either track or field as appropriate.

Table 1
Location of imaging-detected bone stress injuries in the Tokyo 2020 Olympic Games

Location (lesion based)	Stress fracture	Stress reaction	Total
Lower extremity total	3	20	23
Tibial diaphysis	1	4	5
Medial malleolus	0	1	1
Medial tibial plateau	0	1	1
Femoral head	0	1	1
Femoral neck	0	1	1
Intertrochanter of the femur	0	1	1
Medial femoral condyle	0	1	1
Metatarsal bone	1	4	5
Tarsal Bone	0	6	6
Proximal phalanx	1	0	1
Spine			
Lumbar spine	1	3	4
Upper extremity			
Phalanx	0	2	2
Metacarpal bone	0	1	1
Pelvis			
Acetabulum	0	1	1
Pubis	0	2	2
Sacrum	0	1	1
other			
Clavicle	0	1	1
Total	4	31	35

Table 2
Sports for imaging-detected bone stress injuries in athletes at the Tokyo 2020 Olympic Games

	Stress fracture					**Stress reaction**				
	lower extremities	Upper extremities	Spine	Pelvis	Total	lower extremities	Upper extremities	Spine	Pelvis	Total
Athletics	2			1	3	8	0	1	1	10
Track	1				1	4		1		5
Road					0	2			1	3
Field	1		1		2	2				2
Artistic gymnastics						1				1
Handball								1	1	2
Judo						1				1
Modern pentathlon						1				1
Rhythmic gymnastics						2				2
Triathlon						2				2
Volleyball						1				1
Water polo									1*	1*
Weightlifting							1			1
Wrestling							1(Clavicle)			1
Football								1		1
Boxing	1				1		1			1

*This patient also had a stress reaction in the lower extremity.

The median age of injured patients was 24 years (range, 22–26) for stress fracture and 24 years (range, 18–35) for stress reaction. The continents to which the patients' nations belong were as follows: Africa (one stress fracture and 12 stress reactions), Europe (two stress fractures and six stress reactions), North America (one stress fracture and two stress reactions), South America (two stress reactions), Oceania (two stress reactions), and one other (one stress reaction from the Refugee Olympic Team). There were no bone stress injuries in Asian athletes, as was also the case in London 2012 and Rio de Janeiro 2016 [11].

Medial tibial stress syndrome was present in five patients, two of whom had bilateral lesions (Fig. 3). In the Fredericson classification, three patients were classified as grade 3, one as grade 4a, and one as grade 4b. MRI-based grading of all patients with bone stress injury showed 16 with high-grade injuries and 13 with low-grade injuries.

Medical history

Data collection from EMR revealed the chronology of bone stress injuries. Twenty-one patients (72%) had symptoms before entering the Olympic Village. One patient with a femoral neck stress reaction had a history of a prior sacral stress fracture.

Table 3 lists athletes with imaging-detected bone stress injuries who did not start (DNS) or did not finish (DNF) the competitions. One athlete with stress fracture did not finish the competition, and five athletes with stress reactions resulted in four DNF and one DNS.

Table 3
Detail of patients who did not start or finish the competitions

Location	Continent	Sport	Sex	Onset	Result
Stress fracture					
1st proximal phalanx of the foot	Europe	Track and Field (Field)	F	During the preliminary round	DNF
Stress reaction					
Talus	Africa	Triathlon	M	Four weeks before MRI	DNF
Tibia	Africa	Track and Field (Track)	M	Ten days before MRI	DNS
Calcaneus	Africa	Track and Field (Track)	F	Two months before MRI	DNF
Sacrum	Africa	Track and Field (Road)	F	Four days before MRI	DNF
Femoral neck	Europe	Track and Field (Road)	F	One month before MRI	DNF
Abbreviations: DNF, did not finish; DNS, did not start					

Discussion

Clinical implications

During the Tokyo 2020 Olympic Games, 29 patients (0.3% of all athletes) out of 567 MRI scans at the polyclinic were diagnosed with bone stress injuries. Bone stress injuries were more common in women (55%), in the lower extremities (66%), and among track and field athletes (45%). These results were very similar to those from Rio de Janeiro 2016, in which there were a total of 25 athletes (0.2% of all athletes) with stress injury (9 stress fractures, 16 stress reactions), 72% of which were in women, 84% of which were in the lower extremities, and 44% of which were in track and field athletes [11]. The current study provided additional details within the category of track and field, separately providing data on road events (marathon and race walking). Although we did not calculate the total number of athletes in each category, about half of the athletics patients (n = 6, 46%) competed in track events.

High-intensity training is unavoidable for Olympic athletes, meaning that delayed diagnosis can result in progression of the MRI grade of bone stress injury. Hoenig et al., in their systematic review and meta-analysis [3], reported that higher MRI-based grading of bone stress injury was associated with an increased time to return to competition. The result that more than half of the cohort in this study had high-grade injuries also emphasizes the importance of prevention and early diagnosis in Olympic athletes.

We also described the details of injury onset and DNS/DNF athletes with imaging-detected bone stress injuries. Most patients (72%) with bone stress injuries had symptoms before their arrival at the Olympic Village. Furthermore, six of 29 patients (21%) did not start or did not finish their competitions, and four of the six patients who withdrew had symptoms before entering the Olympic Village. In Olympic athletes, early MRI examination of symptomatic patients, even before their arrival at the Games, may reduce the risk of default and stress injury progression. This emphasis on early diagnosis clearly extends to athletes of all levels.

Limitations

Our study had several limitations. First, many of the patients in this study did not undergo radiography, therefore we could not assess the utility of MRI compared with that of radiographs. Second, we could not evaluate the prevalence of known risk factors that could lead to low energy availability, described as the Relative Energy Deficiency in Sport (RED-S) [14–17]. Because of the polyclinic's limited hours, it was difficult to obtain information on risk factors such as eating disorders and menstrual function. Another limitation is that only patients who visited the polyclinic and underwent radiology examinations were included in this study; potential patients with bone stress injuries who did not undergo radiology examinations or did not visit the polyclinic were not evaluated. Finally, we relied on prior imaging reports to identify patients with bone stress injuries; it is possible that some patients with more subtle symptoms could have been missed.

Conclusions

The epidemiological characteristics of bone stress injuries in the Tokyo 2020 Olympics showed a trend similar to that reported for the Rio de Janeiro 2016 Olympics.

Three-quarters of the patients with bone stress injuries had symptoms before entering the village, and over 20% of patients did not start or finish their competitions. Early MRI examination of symptomatic patients, even before their arrival at the Games, may reduce the risk of stress injury progression for Olympic athletes.

List Of Abbreviations

DNF, did not finish

DNS, did not start

EMR, Electronic Medical Records

IOC, International Olympic Committee

MRI, Magnetic Resonance Imaging

PACS, Picture Archiving and Communication System

STIR, short tau inversion recovery

Declarations

Ethics approval and consent to participate

The research was approved by the IOC and by the ethics committee of Tokyo Medical and Dental University (#M2021-053). All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was waived with the approval of the ethics committee of Tokyo Medical and Dental University, as all data in our epidemiological study were anonymised and unidentifiable.

Availability of data and materials

Unpublished data are not available for sharing. Inquiries about data availability are made by contacting the corresponding author.

Competing interests

The authors have no conflicts of interest to disclose.

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Author's contributions

TA, HK, LE, and BF conceived and designed the study. TA, JA, HK conducted the data collection and analysis with input from BF, LE, UT, YS. TA drafted the manuscript with input from UT, YS, LE, HK, JA, HK, KY, KO, and BF. All authors have read and approved the final manuscript.

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Figures

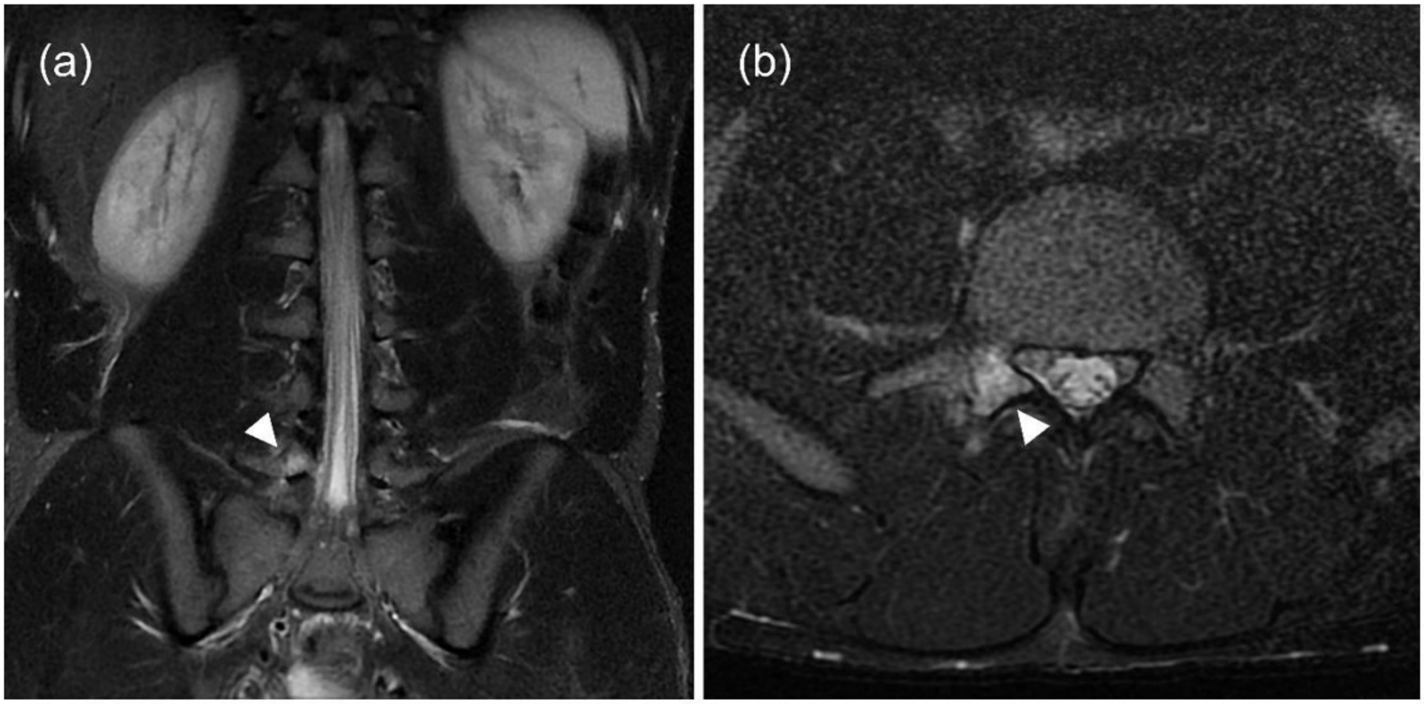

Figure 1

A football player diagnosed with a stress reaction of the right L5 pars interarticularis

The increased T2 signal intensity was detected on (a) coronal and (b) axial STIR images of MRI (arrows).

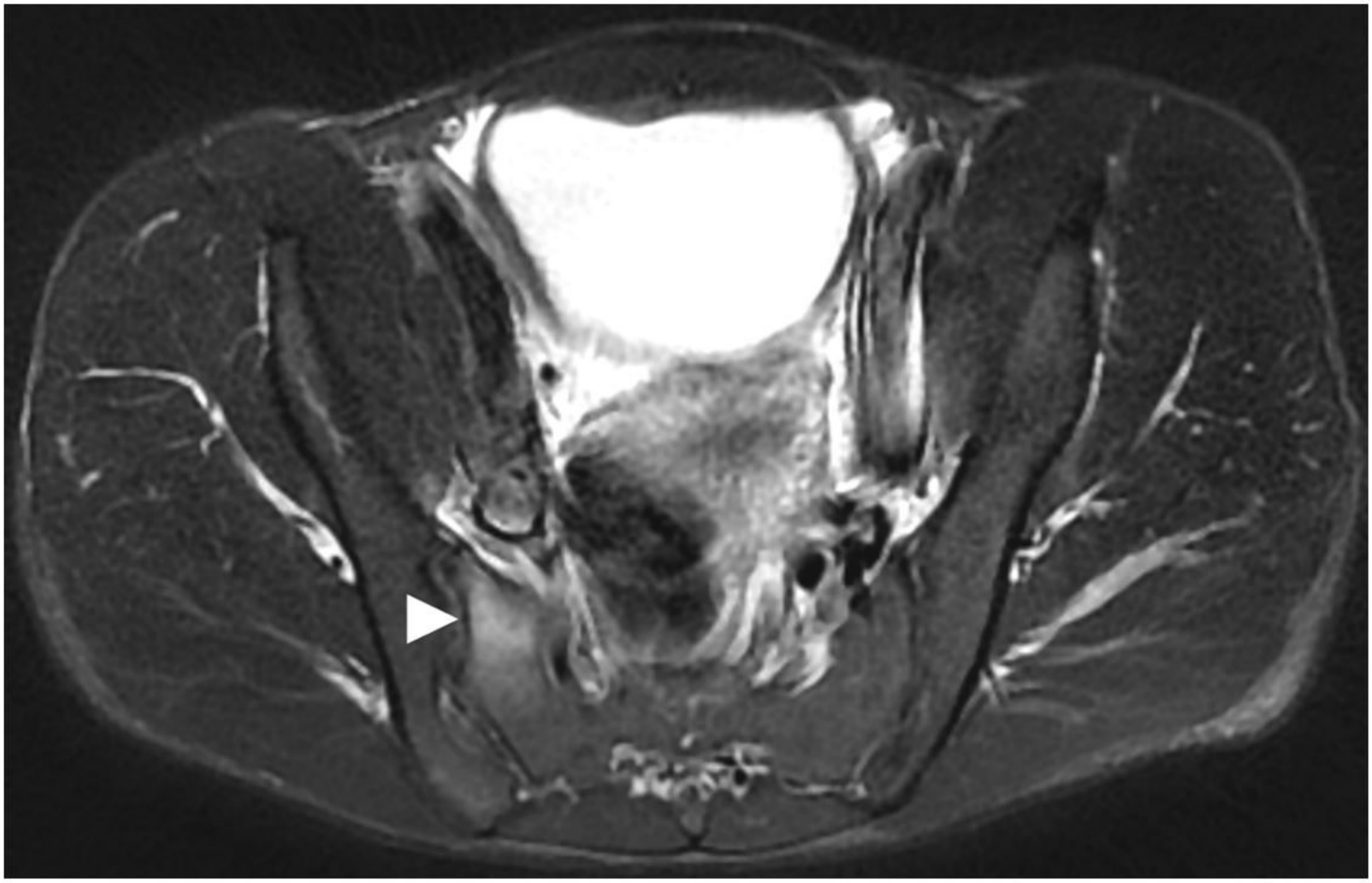

Figure 2

A track and field athlete with a sacral stress reaction

The increased intensity was detected at the right lateral mass of the sacrum on the axial STIR image (arrow).

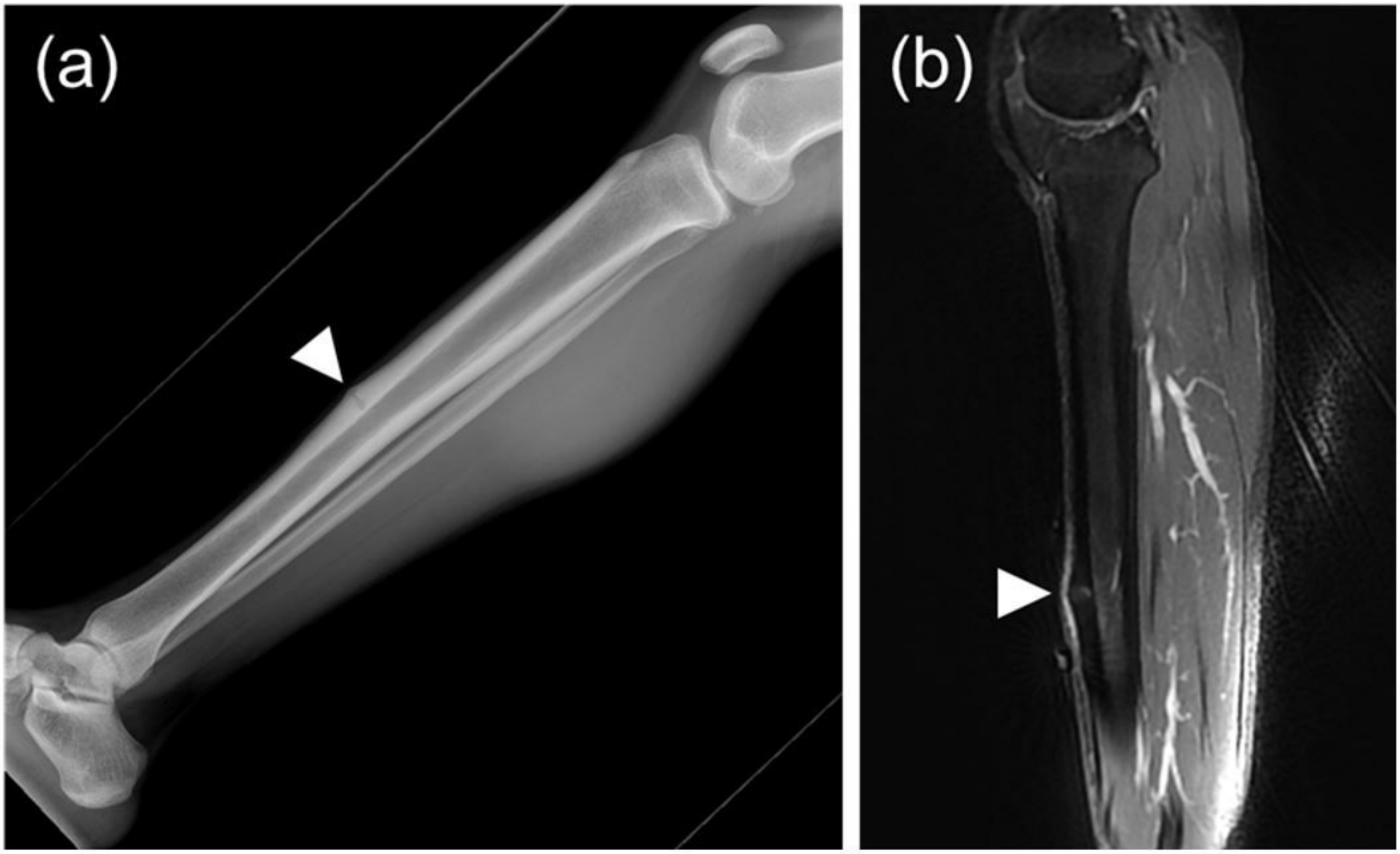

Figure 3

Medial tibial stress syndrome evaluated as Grade 4b in the Fredericson classification

(a) The lateral view of the lower leg X-ray demonstrated cortical thickening and fracture line of the tibial diaphysis (arrow). (b) MRI showed abnormal signal intensity in the tibial cortex, and bone marrow oedema on STIR (arrow).