ORIGINAL ARTICLE

# $^{99m}$Tc-MDP bone SPECT in evaluation of the knee in asymptomatic soccer players

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**Objective:** To evaluate stress fractures in leg (particularly around the knee, tibia, and femur) and knee pathology in active asymptomatic (no symptoms in the preceding month) soccer players.
**Method:** The study included 42 asymptomatic soccer players (21 women, 21 men; age range 19–31 years). Players from seven teams in the major female professional and amateur male soccer leagues were examined by technetium-99m-methylene diphosphonate ($^{99m}$Tc-MDP) bone scintigraphy during the soccer season. Four hours after intravenous injection of 20 mCi $^{99m}$Tc-MDP, standard imaging included anterior planar spot images of the legs, lateral images of the knee, and single photon emission computed tomography (SPECT).
**Results:** Although the players were asymptomatic, increased tracer uptake, indicating stress fracture, was found in 28 (66%). Most of the stress fractures were in the tibia (62%) and femur (5%). In the 42 subjects (84 legs), 35 sites (42%) showed rupture of the posterior horn of the lateral meniscus and bone bruising of the tibial plateau, 16 sites (19%) showed rupture of the anterior horn of the medial meniscus, 11 sites (13%) showed bone bruising of the lateral femoral condyle, eight sites (10%) showed bone bruising of the medial femoral condyle, and there was avulsion injury to the infrapatellar tendon insertion in the anterior tibia in 34 sites (40%). There were 11 anterior cruciate ligament injuries.
**Conclusion:** Bone SPECT is very accurate, easy to perform, cost effective, may give valuable information before magnetic resonance imaging studies in the detection of meniscal tears, and may be used successfully when magnetic resonance imaging is unavailable.

The popularity of soccer has increased in recent years and, according to Federation Internationale De Football Associations (FIFA), it is now played by at least 40 million people.[1] Currently, FIFA, the world governing body of football, unifies 203 national associations and represents about 200 million active players, of which about 40 million are women.[2]

Football injuries predominantly occur in the ankle and knee joints as well as the muscles of the leg.[2 3] Stress fractures, also known as march fractures, commonly involve the bones of the lower extremities and are a well recognised cause of skeletal pain in athletes and other young people.[4] There have been previous reports of stress fractures of the tibia in footballers.[5 6]

Skeletal scintigraphy is generally recognised as the best method of evaluating suspected stress injuries because of its high sensitivity and ability to show abnormalities in bone metabolism well before they are manifested radiographically.[7] It is particularly suited to the examination of complex bony structures, such as the knee, where the ability to separate activity from overlying or underlying bone and view uptake in all three orthogonal planes is valuable.[7]

Bone single photon emission computed tomography (SPECT) has some advantages over other imaging techniques such as computed tomography and magnetic resonance imaging (MRI) in that it readily allows evaluation of both knees simultaneously and other joints or parts of the skeleton suspected of being sites of pathology can also be examined during the same study.[8] Bone SPECT imaging is useful in the evaluation of acutely and chronically painful knees, particularly for diagnosis of meniscal tears and anterior cruciate ligament (ACL) injury.[9–11] In some patients with ACL injuries, there may be tracer uptake in the lateral femoral condyle or posterolateral tibia plateau resulting from injury to these sites as part of the trauma process. In posterior cruciate ligament injuries, uptake may also be seen in the anterolateral tibial plateau.[8]

Our aim in this study was to evaluate stress fractures in leg (particularly around the knee, tibia, and femur) and knee pathology in active soccer players with no symptoms in the preceding month (defined as asymptomatic).

## MATERIALS AND METHODS

### Study population

The study population consisted of 42 subjects (21 women, 21 men; age range 19–31; mean age 22.3 years), with no signs and symptoms of active knee pathology or recent trauma history. These symptomatic soccer players from seven teams (42 players) in major female professional and amateur soccer leagues were evaluated with bone SPECT during the playing season.

### Bone scintigraphy and bone SPECT

Bone scintigraphy was performed three or four hours after the intravenous administration of 740 MBq (20 mCi) technetium-99m-methylene diphosphonate ($^{99m}$Tc-MDP) using a large field of view gamma camera equipped with a high resolution collimator. Standard images including anterior planar spot images of the lower extremities, lateral images of the knee, and SPECT were obtained. A rotating gamma camera (GE Starcam 4000 CX/T) was used for image acquisition. Sixty four projections of 30 seconds each, with 64×64 matrix, in 360° circular rotation were acquired. All

**Abbreviations:** ACL, anterior cruciate ligament; MDP, methylene diphosphonate; MRI, magnetic resonance imaging; SPECT, single photon emission computed tomography

images were interpreted visually by two experienced nuclear medicine physicians.

### Classifications of bone scan findings

Stress fracture lesions detected by bone scintigraphy were classified quantitatively into three groups according to the number of lesions and scintigraphic visualisation. Scintigraphic patterns of the stress fractures were classified into three grades of bone response according to dimension, bone extension, and tracer concentration in the lesions (fig 1).

### Knee SPECT

Bone SPECT images were interpreted according to the following criteria: crescent shape of increased activity in the medial or lateral tibial plateau, posterior focal medial or lateral femoral condylar activity, and increased activity in the infrapatellar tendon insertion. Increased tracer accumulation in the lateral femoral condyle or posterolateral tibial plateau was considered an important bone SPECT finding related to ACL injury.[8 11]

Figure 2 gives line drawings of the cross sectional anatomy showing the relevant sites of increased radionuclide uptake.

## RESULTS

Table 1 summarises the localisation and grade of focal tracer uptake diagnosed as stress fracture. Increased tracer uptake was identified in the femur and tibia of 54 sites (62%). Most of the stress fractures were located in tibiae (62%). The diffuse tibial uptake was graded as A in 14 subjects, B in four subjects, and C in 10. Different grades of lesions were often found in the same subject.

Table 2 shows the results of bone SPECT of the asymptomatic soccer players. In the 42 subjects (84 legs), 35 sites (42%) showed abnormal uptake (fig 3), indicating rupture of the posterior horn of the lateral meniscus and bone bruising of the tibial plateau, 16 sites (19%) showed rupture of the anterior horn of the medial meniscus, eight sites (10%) showed bone bruising of the medial femoral condyle, 11 sites (13%) showed bone bruising of the lateral femoral condyle, and avulsion injury of the infrapatellar tendon insertion into the anterior tibia was detected in 34 sites (40%). Different localisations of the knee lesions were often found in the same patient. There were 11 ACL injuries.

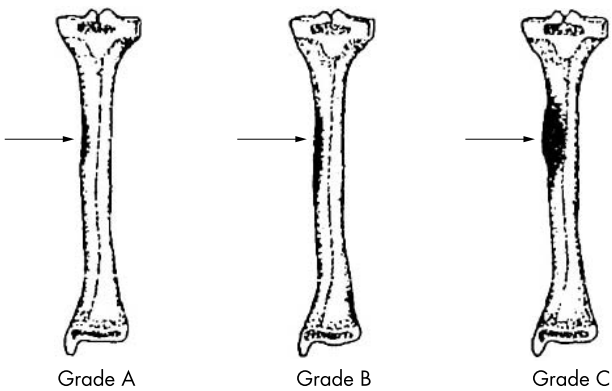


**Figure 1** Stress fracture scintigraphic patterns were classified into three grades of bone response according to dimension, bone extension, and tracer concentration in the lesions: grade A, small, ill defined lesion with slightly increased activity in the cortical region; grade B, larger than grade A, well defined, elongated lesion with moderately increased activity in the cortical region; grade C, wide fusiform lesions with greatly increased activity in the corticomedullary region.

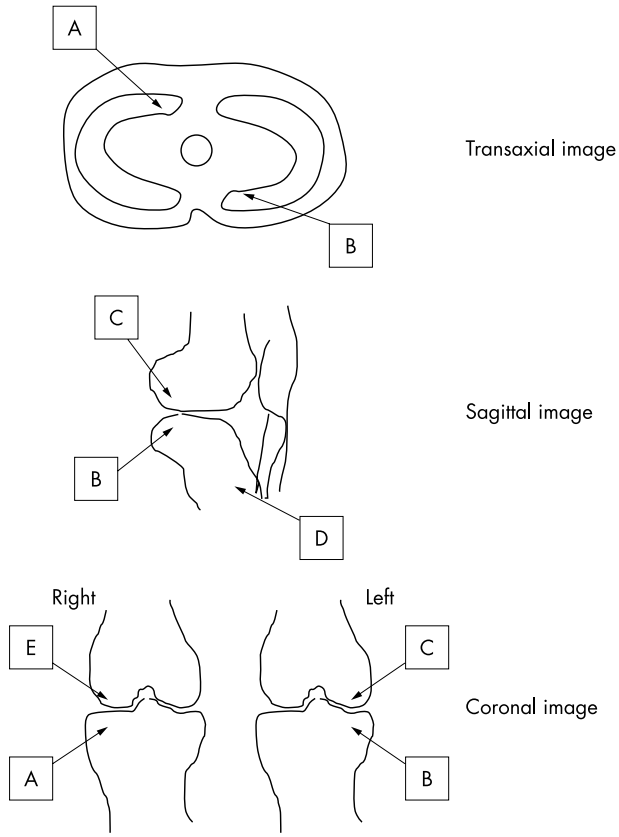


**Figure 2** Cross sectional anatomy showing the relevant sites of increased radionuclide uptake. (A) Rupture of the anterior horn of the medial meniscus; (B) rupture of the posterior horn of the lateral meniscus and bone bruising of the tibial plateau; (C) bone bruising of the lateral femoral condyle; (D) avulsion injury to the infrapatellar tendon insertion into the anterior tibia; (E) bone bruising of the medial femoral condyle.

**Table 1** Localisation and grade of focal tracer uptake in the leg

| | Grade A | | Grade B | | Grade C | | |
|---|---|---|---|---|---|---|---|
| **Localisation** | **F** | **M** | **F** | **M** | **M** | **F** | **Total** |
| Right femur | 2 | – | – | – | – | – | 2 |
| Left femur | 2 | – | – | – | – | – | 2 |
| Right tibia | 8 | 4 | 4 | – | 10 | 2 | 28 |
| Left tibia | 8 | 4 | 4 | – | 6 | 2 | 24 |
| Total | 20 | 8 | 8 | – | 16 | 4 | |

F, Female; M, male.

**Table 2** Results of SPECT bone scans of the knee in asymptomatic soccer players

| | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **M** |
| Right knee | 4 | 5 | 12 | 9 | 2 | 1 | 6 | 11 | 4 | 1 |
| Left knee | 2 | 5 | 7 | 7 | 2 | 6 | 7 | 10 | 1 | 2 |
| Total | 6 | 10 | 19 | 16 | 4 | 7 | 13 | 21 | 5 | 3 |

Lesions: A, rupture of the anterior horn of the medial meniscus; B, rupture of the posterior horn of the lateral meniscus and bone bruising of the tibial plateau; C, bone bruising of the lateral femoral condyle; D, avulsion injury at the infrapatellar tendon insertion into the anterior tibia; E, bone bruising of the medial femoral condyle.
F, Female; M, male.

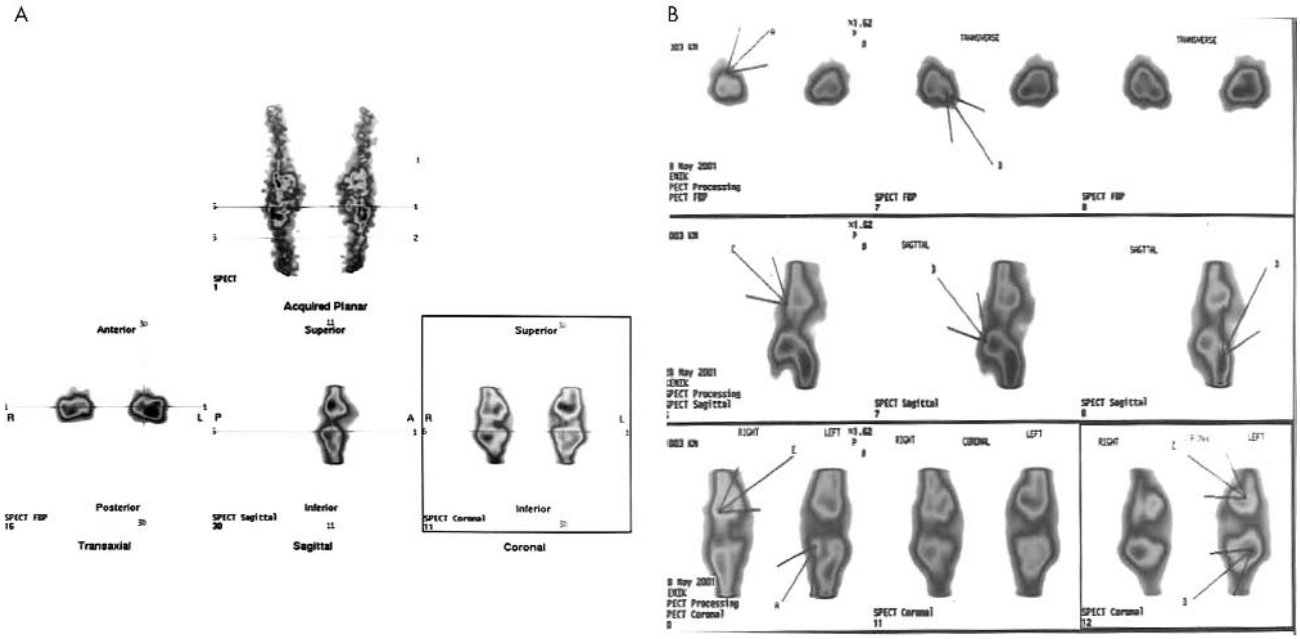


**Figure 3** Transverse, sagittal, and coronal slices of single photon emission computed tomography (SPECT) images showing increased tracer uptake in the knee of a 22 year old woman.

## DISCUSSION

Soccer injuries occur as a result of several factors: player factors (joint instability, muscle tightness, conditioning, and rehabilitation); equipment (type of shoe and shin guards); playing surface (grass versus artificial turf); rules (sportsmanship and adherence to rules); other miscellaneous factors.

In a group of older players (25–41 years old), the most severe types of knee injuries (ligament ruptures and meniscal tears) and muscle strains were recorded with approximately equal frequency (25%, 25%, and 26%).[12] We found approximately 30% of meniscal tears and 13% ACL injuries in our cohort. Previous studies on ACL injuries have shown that men have a higher incidence of ACL tears than women in a variety of sports. The results of our study are very similar (table 2). Intrinsic and extrinsic factors suggested for this discrepancy include hormonal effects, ligament size, body weight, experience, technique, and unequal access to adequate training facilities.[13] A further factor may be that men play more aggressively than women. Also it may be related to the fact that, in some studies, injury incidence is defined as the number of injuries occurring during a study period. In adult male players, the incidence is 12–35 injuries per 1000 hours of outdoor games and 1.5–7.6 injuries per 1000 hours of practice, whereas in female players, the incidence seems to be lower.[2] In our study population, men had a higher incidence of ACL tears than women, which may be explained by this finding. Bjordal *et al*[1] suggested that it is difficult to perform a prospective study of the relatively rare ACL injury in soccer. Many ACL injuries are misdiagnosed at the first clinical examination. Lack of skilled medical examiners and the high cost of diagnostic tools such as MRI used in the initial evaluation may increase the cost of diagnosis. Therefore the ability of bone SPECT to detect meniscal tears early may have economic significance.

Scintigraphy detects stress fractures from the early pathological metabolic bone response that occurs in the periosteal-cortical region. Radiography detects stress fractures late in the bone reaction process (2–12 week after positive scintigraphy), is insensitive for diagnosing mild stress fractures, and remains negative during their resolution.[4]

Stress fractures result from excessive, repetitive loads on the bone which cause an imbalance between bone resorption and formation. The origins of stress fractures are probably site specific and depend on bone density and geometry, the direction of the load, the vascular supply to the bone, the surrounding muscular attachments, skeletal alignment, and the type of athletic activity. A high incidence of stress fractures has been reported in women runners.[14] Our study shows a higher incidence of stress fractures of the tibia in female footballers than in male footballers (73% *v* 55%). We also found that most stress fractures were in the tibia (64%) and femur (5%), usually in the bone shaft.

A number of risk factors have been suggested for stress fractures in female athletes. Bone mass accretion is compromised in late maturing girls,[15 16] and low bone mineral density has been consistently reported in athletes with hypo-oestrogenic amenorrhoea.[17] These athletes generally do not attain peak bone mass and may enter menopause with significantly lower bone density than normal women.[18] Injuries commonly result from overuse of bone weakened by osteopenia.[19] Numerous studies have shown a correlation between menstrual irregularities and incidence of stress fractures among athletes.[17]

Initial theories to explain the well documented association between hypo-oestrogenic amenorrhoea and bone loss focused on the role of oestrogen as a mediator of bone resorption.[17] However, accumulating evidence suggests that metabolic factors associated with nutritional deprivation may be more important in regulating bone activity. Studies of bone turnover in amenorrhoeic distance runners have shown a pattern of bone remodelling characterised by reduced bone turnover and reduced bone formation rather than the increased bone turnover and increased bone resorption typical of hypo-oestrogenism.[20]

In conclusion, the lower cost of bone SPECT compared with MRI suggests that it should be the preferred mode of investigation in some clinical situations. However, bone SPECT does not provide the anatomical detail that can be

obtained with MRI. Our results suggest that bone SPECT may be valuable for detecting meniscal tears of the knee, especially when MRI is unavailable.


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### The land of the free

- Recent news from the US may take some folks by surprise. The Arkansas House of Representatives recently passed a bill that makes the selling of ''clean'' urine for cheating drug tests an offence punishable by three months in jail and a US$500 fine. Texas, Nebraska, South Carolina, and Pennsylvania have also banned the sale of urine, with south Carolina leading the pack, where the penalty is three years in jail if convicted. For the interested, there is a burgeoning internet market in urine, with test kits for warming urine and chemicals to mask drug metabolites readily available.