Fatigue injuries of the femur

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The purpose of this study was to describe the anatomical distribution and incidence of fatigue injuries of the femur in physically-active young adults, based upon MRI studies. During a period of 70 months, 1857 patients with exercise-induced pain in the femur underwent MRI of the pelvis, hips, femora, and/or knees.

Of these, 170 patients had a total of 185 fatigue injuries, giving an incidence of 199 per 100 000 person-years. Bilateral injuries occurred in 9% of patients. The three most common sites affected were the femoral neck (50%), the condylar area (24%) and the proximal shaft (18%). A fatigue reaction was seen in 57%, and a fracture line in 22%. There was a statistical correlation between the severity of the fatigue injury and the duration of pain (p = 0.001).

The location of the pain was normally at the site of the fatigue injury. Fatigue injuries of the femur appear to be relatively common in physically-active patients.

Fatigue injuries may occur at various sites in the femur, including the head, neck, shaft, supracondylar, and condylar regions. Their frequency and anatomical distribution vary between military recruits and athletes. Earlier studies, based upon plain radiographs and bone scans, reported that between 15% and 25% of all bone fatigue injuries in military recruits, and between 6% and 7% of all such injuries in athletes, occurred in the femur. Others have reported that fewer than 10% of all fatigue injuries of bone involve the femoral neck.

Displaced fractures of the femoral neck and shaft usually require surgical treatment, their post-operative clinical course being potentially complicated by osteonecrosis of the femoral head, delayed union, malunion, and osteoarthritis. MRI is a valuable tool for evaluating an early fatigue injury, and for grading its recovery, with findings that can range from marrow oedema to a fracture line itself. The purpose of this study, therefore, was to assess the distribution and incidence of femoral fatigue injuries in physically-active young adults, based upon MRI studies.

Patients and Methods

This study took place at the Central Military Hospital in Helsinki. A computer search identified 1857 consecutive patients who had been referred with exercise-induced pain in the femur (hip, groin, thigh or knee region) during military service. All the patients presented over a 70-month period, commencing in March 1997, and all had an MRI examination of the affected area.

Inclusion criteria for this study comprised: 1) a negative finding on plain radiography obtained at the primary military health care unit; 2) a physical examination by an orthopaedic surgeon (HKP) and 3) a femoral fatigue injury found by MRI on the same side as the pain. The exclusion criteria were recent trauma or infection involving the pelvis, femora, or knees. The study was approved by the Medical Ethics Committee of our institution.
All Finnish men become liable for six, nine, or 12 months of military service at the age of 18 years; this is voluntary for women. Each year, approximately 26,500 men and 500 women undergo this training with the same military equipment being used for both sexes. Within the catchment area of the Central Military Hospital the total exposure time for the population at risk during the study period was 85,318 person-years. This was calculated by registering the dates of entry, transfer, or discharge of every conscript within this area.

Physical examination had involved taking a careful history, palpation, estimation of the range of movement of the hip and knee joints and a record of any skin changes. The patient’s ability to walk and to jump on one foot (a hop test) was also recorded in addition to any other observations which were felt to be relevant.

All patients had an MRI scan of the pelvic and femoral areas using a 1.0T scanner (Sigma Horizon, GE Medical Systems, Milwaukee). Routine, coronal T1-weighted spin-echo sequences were obtained, followed by coronal and axial T2-weighted fast spin-echo sequences with fat suppression as well as a coronal short tau inversion recovery (STIR) sequence. The field of view was 32 to 48 cm x 24 to 48 cm, and the slice thickness was 4.0 to 5.0 mm, with a 0.5 to 1.0 mm intersection gap. A knee coil with a field of view of 10 to 16 cm was used with a slice thickness of 3 to 4 mm, and a 0.5 or 1.0 mm intersection gap. Sagittal, proton density spin-echo sequence images with fat suppression or sagittal T1-weighted spin-echo sequence images were also obtained. T2-weighted fast spin-echo axial and coronal sequences with fat suppression were also undertaken.

**Fig. 1**
MRI of a 20-year-old man with a 16-day history of right hip and groin pain. The coronal STIR image demonstrates a low-signal-intensity fracture line (arrow) in the femoral neck with associated high-signal-intensity endosteal and periosteal oedema.

**Fig. 2a**
MRI scans of a 19-year-old man with a 30-day history of right knee pain. Figure 2a – A coronal, proton-density, fat-saturated image demonstrates a low-signal fracture line (arrow) just above the epiphyseal line with surrounding high-signal-intensity marrow oedema in the medial femoral condyle. Figure 2b – A sagittal T1-weighted image to show the fracture line (arrow) with surrounding marrow oedema.
Fatigue Injuries of the Femur

Two musculoskeletal radiologists re-evaluated the MR images retrospectively and independently once the site and type of fatigue injury had been identified. In cases of disagreement, a third musculoskeletal radiologist interpreted the MRI. Fatigue injuries throughout the femur were recorded. The femoral shaft was divided into proximal, middle, and distal thirds. In those patients with a fatigue injury of the femoral neck, the neck-shaft angle was also measured. Fatigue injuries were graded as: grade I (endosteal marrow oedema); grade II (periosteal and endosteal marrow oedema); grade III (muscle, periosteal and endosteal marrow oedema); grade IV (fracture line); grade V (callus in cortical bone).

The Kruskal-Wallis test was used to test differences in the continuous skewed data between the groups while differences in the crosstabulars were tested using the Pearson chi-squared test. Correlation between continuous skewed data and ordinal data was tested using Spearman’s correlation coefficient (Rs). Significance was as \( p \leq 0.05 \). Data analysis was performed using SPSS for Windows version 12.0 (SPSS Inc, Chicago, Illinois).

Results

Of the 1857 patients who underwent MRI studies, 170 met the inclusion criteria. There were 23 women and 147 men with a mean age of 20.4 years (18 to 29). The incidence of femoral fatigue injury in these patients was 199/100,000 person-years. For our institution, this implies a mean of 29 patients per year. Based upon MRI, a total of 185 femoral fatigue injuries was detected, including 15 (9%) patients with bilateral injuries.

Of the 185 femoral injuries, 93 (50%) occurred in the neck (Fig. 1), 44 (24%) in the condylar area (Fig. 2), 34 (18%) in the proximal shaft (Fig. 3), six (3%) in the supracondylar area, four (2%) in the middle third of the shaft, two (1%) in the proximal, middle and distal shaft area, one (0.5%) in the distal shaft (Fig. 4), and one (0.5%) in the head (Table I). There were no trochanteric or subtrochanteric injuries. Injuries of the femoral neck were more common in women (14 of 23, 60.9%) than men (74 of 147, 50.3%) (\( p = 0.347 \)). In all patients with an injury to the femoral neck the neck-shaft angle was normal (125˚ to 135˚).

Of the 185 femoral injuries, there was marrow oedema in 57%. A low-signal fracture line (grade IV) occurred in 22% of these, the neck and the proximal shaft being the
most commonly involved. Of the 93 femoral neck injuries, both marrow oedema (grade I) and a fracture line (grade IV) occurred equally (39%). Of the latter (n = 36), 21 (58%) were a tiny fracture or cortical crack perpendicular to the inferior cortex of the neck, six (17%) were a fracture line covering half to two-thirds of the thickness of the neck, and in one (3%) the line was subcapital. There were no fatigue injuries on the tension side of the femoral neck.

The median time from the onset of pain to the diagnosis of a fatigue injury on MRI was 30 days (3 to 270). For most patients, hip and groin pain related to injuries of the femoral neck and proximal shaft, and knee pain to condylar and supracondylar lesions (Table II). The median time from the onset of pain to the confirmation of a fatigue injury by MRI was less severe at the beginning of exercise, and increased with continuing stress and, when advanced, became constant. There were no specific findings on physical examination, such as skin changes, tenderness to palpation, restriction of hip and/or knee movements, or in the tests of walking ability or hopping.

### Discussion

Based upon MRI findings, the risk of Finnish military conscripts sustaining a femoral fatigue injury was 199/100 000 person-years. The conscripts included in our study are representative of those undertaking their military service. In earlier studies, the frequency of all bony fatigue injuries in the lower limb has been between 2% and 31% of all military trainees in those studies depending on the military branch and/or the military or athletic training programme. When MRI is widely used to investigate exercise-induced musculoskeletal pain, as in our institution, the early stages of bone fatigue injuries are revealed; this may explain the differences between our results and those of others. Moreover, marrow oedema, seen as an increased intramedullary signal on STIR and fat-suppressed, T2-weighted fast spin-echo sequences, has been reported in subjects undergoing intensive physical training, in asymptomatic patients, and in individuals with altered biomechanics. This is thought to represent accelerated bone remodelling in response to repetitive stress. If the stress is prolonged or recurrent, the rate of osteoclastic resorption surpasses that of osteoblastic new bone formation and can lead to bone fatigue injury, including fatigue fractures.

Bilateral injuries occurred in approximately 10% of patients. In earlier studies of athletes, 17% of all lower-limb fatigue fractures and 26% of femoral lesions have been bilateral. Despite such findings, and other research, the exact aetiology of these injuries is unknown. In our study, the femoral neck was the most common site of injury, accounting for half of all cases. In previous studies of military recruits, this prevalence has been < 10%, and 31% of all military trainees in those studies depending on the military branch and/or the military or athletic training programme. When MRI is widely used to investigate exercise-induced musculoskeletal pain, as in our institution, the early stages of bone fatigue injuries are revealed; this may explain the differences between our results and those of others. Moreover, marrow oedema, seen as an increased intramedullary signal on STIR and fat-suppressed, T2-weighted fast spin-echo sequences, has been reported in subjects undergoing intensive physical training, in asymptomatic patients, and in individuals with altered biomechanics.

### Table II. Distribution and grades of MRI findings for the femoral fatigue injuries

<table>
<thead>
<tr>
<th>Site of injury</th>
<th>Grades</th>
<th>Number of injuries (%)</th>
<th>Number of bilateral injuries</th>
<th>Gender Female:Male</th>
<th>Median duration of pain before MRI (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>I</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Neck</td>
<td>II</td>
<td>36</td>
<td>16</td>
<td>5</td>
<td>36.0</td>
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<tr>
<td>Trochanteric area</td>
<td>III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Subtrochanteric area</td>
<td>IV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proximal shaft</td>
<td>IV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Middle shaft</td>
<td>I</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Distal shaft</td>
<td>II</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Entire shaft area</td>
<td>III</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Supracondylar area</td>
<td>IV</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Condylar area</td>
<td>IV</td>
<td>41</td>
<td>1</td>
<td>2</td>
<td>44 (24)</td>
</tr>
<tr>
<td>Total (%)</td>
<td></td>
<td>106</td>
<td>27</td>
<td>15</td>
<td>50</td>
</tr>
</tbody>
</table>

* includes proximal, middle and distal shaft

### Table II. Site of pain in relation to the site of the injury

<table>
<thead>
<tr>
<th>Site of pain</th>
<th>Hip</th>
<th>Groin</th>
<th>Thigh</th>
<th>Knee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neck</td>
<td>83</td>
<td>8</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Trochanteric area</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Subtrochanteric area</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proximal shaft</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Middle shaft</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distal shaft</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Entire shaft area</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Supracondylar area</td>
<td>-</td>
<td>-</td>
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<td>1</td>
</tr>
<tr>
<td>Condylar area</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
<td>10</td>
<td>10</td>
<td>52</td>
</tr>
</tbody>
</table>

* includes proximal, middle and distal shaft
neck and lead to fatigue injury. In our study, however, the neck-shaft angle was normal in all patients with a fatigue injury of the femoral neck.

A greater proportion of women than men sustained a fatigue injury to the femoral neck. The increased risk to women has been explained by anatomical, biomechanical (wide pelvis, coxa vara, genu valgum) and intrinsic (hormonal, nutritional) factors by other authors. The female athletic triad of disordered eating, amenorrhea, and altered bone mineral density also contributed to this increased risk. However, earlier studies of exercise-induced femoral fatigue injuries in athletes suggest an even distribution between men and women.

One-fifth of all our fatigue injuries appeared in the femoral shaft with a distribution similar to that previously reported in athletes; the proximal third was the most common site. In contrast, earlier military studies have suggested that the middle and distal shafts are the most usually affected. In our study, however, injury at these sites was uncommon. This testifies both to their rarity and to the high sensitivity of MRI in identifying fatigue-induced bone marrow oedema.

Boden and Speer suggested that fatigue injuries of the femoral shaft are related to training errors. At the junction of the proximal and middle thirds of the femoral shaft lies the insertion of the adductor muscles, which may sometimes cause fatigue injuries at this site, particularly if subject to repetitive stresses. A thin rim of high signal on the MRI scan along the medial periostium, involving the proximal to mid-femoral shaft alone, or with an increased medullary or cortical signal, has been interpreted differently. Some consider it to be an adductor avulsion syndrome (thigh splints) corresponding to tibial shin splints, while others feel it represents the early stage of a fatigue fracture.

The time between the onset of symptoms and a positive finding on MRI was approximately four weeks. In earlier studies, this period has varied from a few days to several months. The time to diagnosis was less for those patients with a fatigue injury of the femoral neck and the proximal shaft than for those with condylar lesions. While physicians who treat physically-active patients are aware of fatigue injuries of the femoral neck and proximal shaft as a cause of hip or groin pain, condylar fatigue injuries are less well known.

A displaced femoral fatigue fracture is a significant cause of morbidity. According to Devas, fatigue fractures of the femoral neck which appear on the inferior aspect (compression fractures) are thought to be mechanically stable and at a low risk of displacement. Fractures which appear on the superior aspect of the femoral neck (tension fractures) are at an increased risk of displacement. Fatigue fractures of the femoral shaft are regarded as low risk as most can be treated conservatively. Some studies, however, have shown that displaced femoral shaft fractures can lead to adverse consequences and prolonged morbidity.

In our study, the findings on physical examination were non-specific, which is in agreement with earlier reports. The femur, which is the longest and heaviest tubular bone in the body, being surrounded by strong muscles, is difficult to palpate. Only the femoral condyles are easily palpable. Restriction of hip and knee movements can be identified clinically. However, the patients in our study exhibited neither pain on palpation nor a clear restriction of hip and/or knee movement.

The most usual site for a femoral fatigue injury is the femoral neck followed by the condylar area and proximal shaft. Such injuries appear to be relatively common in physically-active patients. The site of pain is usually situated at the site of the injury while patients with injuries in the upper femur have a shorter history of pain than those in the condylar area.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


