Long-term outcome of undisplaced fatigue fractures of the femoral neck in young male adults

H. K. Pihlajamäki,
J.-P. Ruohola,
M. Weckström,
M. J. Kiuru,
T. I. Visuri

From Central Military Hospital, Helsinki, Finland

The incidence and long-term outcome of undisplaced fatigue fractures of the femoral neck treated conservatively were examined in Finnish military conscripts between 1970 and 1990.

From 106 cases identified, 66 patients with 70 fractures were followed for a mean of 18.3 years (11 to 32). The original medical records and radiographs were studied and physical and radiological follow-up data analysed for evidence of risk factors for this injury. The development of avascular necrosis and osteoarthritis was determined from the follow-up radiographs and MR scans.

The impact of new military instructions on the management of hip-related pain was assessed following their introduction in 1986. The preventive regimen (1986) improved awareness and increased the detected incidence from 13.2 per 100 000 service-years (1970 to 1986) to 53.2 per 100 000 (1987 to 1990). No patient developed displacement of the fracture or avascular necrosis of the femoral head, or suffered from adverse complications. No differences were found in MRI-measured hip joint spaces at final follow-up. The mean Harris Hip Score was 97 (70 to 100) and the Visual Analogue Scale 5.85 mm (0 to 44).

Non-operative treatment, including avoidance of or reduced weight-bearing, gave favourable short- and long-term outcomes. Undisplaced fatigue fractures of the femoral neck neither predispose to avascular necrosis nor the subsequent development of osteoarthritis of the hip.

H. K. Pihlajamäki, MD, PhD, Orthopaedic Surgeon, Adjunct Professor
M. Weckström, MD, Research Fellow
T. I. Visuri, MD, PhD, Orthopaedic Surgeon, Adjunct Professor
Department of Orthopaedic Surgery
J.-P. Ruohola, MD, Research Fellow
Research Institute of Military Medicine
Central Military Hospital, P. O. Box 50, FIN-00301 Helsinki, Finland.

M. J. Kiuru, MD, PhD, MSc, Radiologist, Adjunct Professor
Department of Radiology
Helsinki University Central Hospital, P. O. Box 266, FIN-00029 HUS, Helsinki, Finland.

Correspondence should be sent to Dr H. K. Pihlajamäki; e-mail: harri.pihlajamaki@helsinki.fi

doi:10.1302/0301-620X.88B12.17996 $2.00

J Bone Joint Surg [Br] 2006;88-B:1574-9.
Received 6 April 2006; Accepted after revision 8 August 2006

The mechanism of the gradual onset of a stress fracture of the femoral neck in young healthy adults differs from that of traumatic high-energy fractures. Stress fractures can be subdivided into fatigue fractures, caused when normal bone is exposed to repeated abnormal stress, and insufficiency fractures, where normal stress is applied to abnormal bone.[1-3] Under a constant load, osteoclast resorption and osteoblastic reconstruction of bone are in equilibrium, resulting in normal remodelling. If loading increases, additional bone resorption occurs.[4,5] Increased osteoclastic activity at sites of stress may cause local weakening and predispose to microdamage.[6] If allowed to progress, such microfractures may progress to complete fractures.[7]

All bony structures surrounding the hip joint, including the acetabulum,[8] the femoral head[9,10] and the neck,[11-13] are vulnerable to fatigue fractures. Fatigue fractures of the femoral neck are relatively uncommon during military service, the incidence ranging from 3.3% to 8%.[14-17] Stress fractures of the femoral neck localised to the superior surface are termed tension fractures, and those localised to the inferior surface, compression fractures.[16,18] The tension fractures are potentially unstable and liable to displace without surgical fixation. Compression fractures, being mechanically stable, are usually treated non-operatively with six or eight weeks of partial or non-weight-bearing. Displaced fractures carry a high risk of the development of avascular necrosis of the femoral head, and osteoarthritis.[11,12]

Injuries to the knee or hip joint in general have been associated with a higher incidence of osteoarthritis of the hip.[19] A high level of physical activity in men under 50 years, even after controlling for body mass index, smoking and use of alcohol or caffeine has been found to be associated with osteoarthritis of the hip and knee.[20] Running and other forms of sports have also been shown to increase the risk of osteoarthritis of the hip.[21-24] In light of these observations, the possibility that a bony injury associated with undisplaced fatigue fractures of the femoral neck might contribute to the development of subsequent osteoarthritis at the hip needs to be considered.

The long-term outcome of undisplaced fatigue fractures of the femoral neck has not been described. The aims of this study were to evaluate the incidence, symptoms, morphological characteristics, clinical course, risk factors and long-term outcomes of such fractures, with an emphasis on the development of osteoarthritis of the hip.

Patients and Methods

Between 1 January 1970 and 31 December 1990, a total of 106 Finnish military conscripts were treated for 110 undisplaced fatigue fractures of the femoral neck. The patients were identified through a computer search of the Finnish National Hospital Discharge Register, established in 1967, using the appropriate diagnostic codes of the Eighth (1969 to 1986) and the Ninth (1987 to 1995) editions of the *International Classification of Diagnosis* (ICD) and linking them with the codes of the military hospitals. During the same period, a total of 17 displaced fatigue fractures of the femoral neck were detected and excluded from the study. All the fractures which were undisplaced at the time they were detected were included in the study. The medical records and radiographs from the period of military service were available for evaluation for all 106 patients, and long-term follow-up data were collected by inviting all these patients to a follow-up examination. Approval for the study was obtained from the local Medical Ethics Committee.

In Finland, at the age of 18 years, all men become liable for compulsory military service of between 8 and 11 months. During the study period, an average of 36 606 men started their military service annually. At the beginning of the initial three months basic training the majority of conscripts were between 19 and 20 years old. Regular army personnel were excluded from the study.

All conscripts performing their military service between 1970 and 1990 constituted the population at risk.

In 1986, new instructions designed to increase awareness of fatigue fracture were issued by the army. Conscripts complaining of pains in the hip, the proximal part of the femur or the groin associated with or following physical activity were to be promptly referred for bone or MR scans at the main military hospital. The influence of the new protocol was assessed in the present study by examining the change in incidence of undisplaced fatigue fractures of the femoral neck after 1986.

From the original medical records, data on the patients' health and medication, possible prior injuries and surgical operations were recorded. Data were gathered on symptoms experienced in the lower limbs after entering military service, and during activity preceding radiological identification of the fracture. In addition, we studied the management and clinical course of each fracture.

The body mass index (BMI)[25] in kg/m^2 at the time of detection of the fatigue fracture was noted and classified according to Llewellyn-Jones and Abraham.[26] This describes a BMI of 19 kg/m^2 to 24.9 kg/m^2 as normal for an adult male younger than 30 years. The BMIs were compared with published results of 223 conscripts born in 1958 and serving their compulsory military service in 1978.[27]

Fig. 1

Radiograph of the right hip of a conscript, aged 20 years, who had experienced hip pain for several weeks during marching and running. A fracture, originally tension-type, extending through the femoral neck can be seen (arrows).

For the present study, the existence and morphological features of the fractures were confirmed from the original, conventional anteroposterior (AP) and frog-leg lateral radiographs. Fatigue fractures were classified as compression or tension types on the basis of their localisation.[16,18,28]

Over the 21 years of the study, treatment trends underwent changes, mainly concerning weight-bearing and physical limitations. None of the undisplaced fractures were treated surgically. During the earlier years of the study, treatment included a period of non-weight-bearing and even bed rest. Gradually the regime became more liberal, and towards the later years some patients were allowed to walk without crutches. In general, all strenuous physical activity was suspended for a mean of 12.6 weeks (2 to 28). However, those with a fracture extending through the neck of the femur were instructed to remain on bed rest for one to three weeks and prescribed non-weight-bearing for four to eight weeks (Fig. 1).

All the patients concerned were asked to participate in a follow-up, including physical and radiological examin-

ations, between 2002 and 2005 with a maximum of three written invitations to attend. Of the 106 patients invited, 66 participated in the follow-up. For the long-term outcome analysis, data collected from patients participating in the final follow-up examination were used.

Details of the original treatment were confirmed and information on the subsequent management of the affected hip after military service were established. Where required, the medical records and radiographs for subsequent treatment were requested from the hospitals concerned and reviewed. Physical examination included determination of the dominant lower limb. At the final assessment, AP radiographs were taken and an MR scan of the pelvis was obtained to detect osteonecrosis of the femoral head and osteoarthritic changes to the hip joint. The joint space was measured from the digital MRI data at the long-term follow-up visit and compared with the contralateral hip. All radiological results were interpreted by a musculoskeletal radiologist. The MR scans were performed on a 1.0 T scanner (Sigma Horizon, GE Medical Systems, Milwaukee, Wisconsin) using routine coronal T_1-, T_2- and axial T_2-weighted sequences. The diagnosis of an undisplaced stress fracture, originally based on accepted radiological, bone scan or MRI criteria, was verified at follow-up examination by evaluating the whole series of radiological images of each patient.

At the final review the patients were asked to complete a ten-point (0 mm to 100 mm) visual analogue scale (VAS) assessment for pain experienced in the week preceding the examination, with 0 mm denoting none, 10 mm to 30 mm slight, 40 mm to 60 mm moderate, 60 mm to 90 mm severe, and 100 mm denoting the worst imaginable pain. Functional status was estimated using the Harris Hip Score (HHS).[29]

Possible predisposing or risk factors were considered, including the BMI, the measured neck-shaft angle of the femur, the dominant lower limb, and the limb most often affected by fatigue fracture.

The chi-squared test was used to determine the significance of differences between two independent groups at $p < 0.05$, and Student's *t*-test was used to compare independent unskewed means. Incidence rate ratios with 95% confidence intervals (CI) were calculated for the fractures between 1970 and 1986 and between 1987 and 1990. Statistical analysis was performed using SPSS for Windows (version 12.0.1; SPSS Inc., Chicago, Illinois).

Results

None of the 110 undisplaced fractures suffered displacement during the period of conscription. Following light duties during recovery from the symptoms, all conscripts but one returned to normal duty and completed their military service. One conscript had to interrupt his military service as the symptoms interfered with his ability to march and participate in physical training.

The 21-year study period produced a total of 546 317 service-years, based on the total number of conscripts over the study period multiplied by the average duration of their military service, with an overall incidence of undisplaced femoral neck fatigue fracture of 20.1 per 100 000 service-years. Following implementation of the new regulations in 1986, there was a fourfold (95% CI 2.7 to 5.9) detected fracture increase, from 13.2 per 100 000 service-years between 1970 and 1986 to 53.2 per 100 000 between 1987 and 1990.

The mean follow-up of the 66 (62.3%) patients who participated in the review was 18.3 years (11 to 32). At the time of conscription their mean age was 20.1 years (19 to 26), mean height was 176.6 cm (164 to 195), mean weight was 69.6 kg (51 to 113) and BMI was 22.3 kg/m^2 (18.07 to 35.27). According to the classification of Llewellyn-Jones and Abraham,[26] six patients were underweight (BMI 15 kg/m^2 to 18.9 kg/m^2) and eight were overweight (BMI 25 kg/m^2 to 29 kg/m^2). The mean BMI of 223 contemporaneous control conscripts was 22.47 kg/m^2 (16.19 to 34.33) and for the 106 patients in the whole study cohort, 21.17 kg/m^2 (18.07 to 35.27).

Among the 66 patients available for long-term review, pain at the hip was experienced in 36 (55%) at the time of fracture detection, in the groin in 16 (24%), and in the femur in 14 (21%), but none described pain in the knee. Two patients (3%) also had pain in the posterior aspect of the hip joint. The mean time to detection of the fractures was 13.9 weeks (3 to 34) after entering military service. In 38 patients (58%) the fractures occurred within the first three months, during the period of basic training, but only six (9%) occurred during the last three months of service. The remaining 22 patients (33%) sustained their fractures after the first three months, and before the last three months of service, with no specific trend.

Fractures presented on the right side in 36 (55%), on the left side in 26 (39%), and bilaterally in four (6%) patients. The right leg was the dominant lower limb in 38 (58%) patients and the left leg in 28 (42%). In all patients, the neck-shaft angle on radiographs was between 125° and 135°. There were 67 compression-type fractures and three tension-type. At the final follow-up, the mean joint space of the injured and uninjured hips were 2.05 mm (0.66 to 3.3) and 1.97 mm (0.66 to 3.86), respectively. The difference was not statistically significant ($p = 0.297$). None of the patients developed avascular necrosis of the femoral head (Fig. 2).

At the final follow-up, the intensity of pain was expressed by 62 patients using the VAS. The mean score of pain intensity was 5.85 mm (0 to 44) on a scale of 100 mm. No pain was felt in 43 patients, and two reported pain levels between 40 mm and 44 mm. The mean HHS was 97 (70 to 100). A total of 36 (58%) patients showed no physical disability according to the HHS (HHS 100). Seven (11%) patients had HHS of 70 to 90, and 19 (31%) had HHS of 91 to 99, reflecting only mild disability.

Fig. 2a

Fig. 2b

Fig. 2c

a) Radiograph of the right hip of a conscript, aged 19, with exercise-induced hip pain of two-months' duration before detection of a compression-type fatigue fracture. The anteroposterior radiograph reveals sclerosis and a subtle fracture line (arrow), b) four and a half months later, the fracture is still visible. c) At review 17 years after the first radiograph the patient is symptomless, but sclerosis in the femoral neck still remains at the site of the former fatigue fracture. Comparison with the uninjured side shows no evidence of osteoarthritis.

The risk factor analysis did not reveal any predisposing or risk factors. The BMIs of the contemporaneous control conscripts and of those with undisplaced fatigue fractures of the femoral neck did not indicate a significant difference ($p = 0.817$). The neck-shaft angles were all within normal limits. No correlation was found between the dominant leg and the fracture site ($p = 0.339$).

Discussion

The increased incidence of undisplaced fatigue fractures of the femoral neck seen in the present study after the introduction of the new care instructions in 1986 demonstrated the important impact of the awareness programme. In another study commencing in 1997 with a follow-up of 5.8 years, 185 fatigue fractures of the femur were diagnosed with MRI.[13] Of these, 93 (50%) occurred in the neck of femur, giving an incidence of 100 cases per 100 000 service-years, a twofold increase compared with 1986 to 1990. This suggests a significant underdiagnosis of this fracture during the period of the current study. In another previous study, elite-unit conscripts had repeated MRI examinations during their period of service, regardless of symptoms.[30] In that study, there was one symptomatic undisplaced fatigue fracture of the femoral neck among 21 conscripts, with a

total of 75 bone stress injuries of the lower extremities of which 45 remained asymptomatic. Nielens et al[31] have reported a runner who had multiple asymptomatic bone stress reactions and a painful fatigue fracture of the femoral neck. Our method of selection only identified symptomatic patients with radiologically-confirmed fatigue fractures, leaving subclinical asymptomatic fatigue fractures undetected.

The underlying pathomechanism of a fatigue fracture of the femoral neck is currently unclear. Risk factors mentioned in previous studies include abnormal hip morphology,[32,33] high body weight and small body size,[33,34] but there is contradictory evidence regarding body size and composition.[35,36] In athletes, neither increased nor decreased BMI has been reported to be a risk factor for stress fractures.[37] However, all somatotypes were represented in our study, and all conscripts were required to participate in the same training programmes. A narrow tibial bone width has also been proposed as a risk factor related to stress fracture in general.[38,39] A correlation between a low femoral bone density and stress fractures in military recruits has been found.[40,41] Tibial bone widths or femoral bone densities were not available in our study. However, none of the analysed factors, including neck-shaft angle, BMI, and leg dominance compared with the fatigue fracture side, were found to be a risk factor for femoral neck fatigue fractures.

The mean follow-up of 18.3 years (11 to 32) of our study should be sufficient to reliably detect the development of avascular necrosis of the femoral head. In one report of 71 patients under the age of 65 years with traumatic fractures of the femoral neck, the development of osteonecrosis was very gradual from over five years to as long as ten years in one-third of the cases.[42] Routine radiography may reveal avascular changes at six months after fracture, but usually not until between one and two years after injury.[43]

Avascular necrosis is found in a high proportion of displaced fractures of the femoral neck.[44] The tamponade effect of the haemarthrosis that occurs in displaced fractures, as well as vascular damage, has been implicated as a predisposing factor to avascular necrosis.[44-47] The gradual development of undisplaced fatigue fractures does not cause a haemarthrosis and may account for none of the conscripts in our series developing avascular necrosis or secondary osteoarthritis of the hip joint. A known aetiological factor for the development of fatigue fractures is a repetitive cycling load, seen in most athletic activities as a repetitive impact on the hip joint. Previously, Lievense et al[48,49] found a moderate association between osteoarthritis of the hip and both physical workload and sporting activity.

The nature and clinical course in undisplaced and displaced fatigue fractures of the femoral neck are entirely different, with the latter associated with adverse sequelae such as post-operative infection, nonunion, avascular necrosis of the femoral head, secondary osteoarthritis and hip replacement.[11,12,16,17,50-57]

Our findings indicate that both the short- and long-term prognoses of undisplaced fatigue fractures of the femoral neck can generally be regarded as good. Weisstroffer et al[58] reported the outcome of such fractures, ten of which were displaced, six tension-type and nine compression-type undisplaced, in 25 patients after a five- to seven-year follow-up. Of these, two of the seven non-operatively treated compression-type fracture patients reported physical disability according to the Musculoskeletal Function Assessment,[58] compared with seven (41%) in the operatively-treated group.

Overall, our findings indicate that undisplaced fatigue fractures of the femoral neck do not predispose to avascular necrosis or subsequent osteoarthritis. The benign nature of these fractures was also shown in the fact that the outcome was not dependent on the choice or type of conservative management. It seems evident that when these fractures are detected without displacement and subjected to immediate non-surgical treatment, including no or reduced weight-bearing, favourable short- and long-term outcomes can be expected. This study demonstrated the important impact of an awareness programme for early identification and diagnosis which potentially prevents progression to a displaced fracture.

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.

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