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Original Article

Bone Mineral Density, Hip Axis Length and Risk of Hip Fracture in Men: Results from the Cornwall Hip Fracture Study

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Abstract. Bone mineral density (BMD) and hip axis length (HAL) are important determinants of fracture risk in women. There are, however, few data concerning their predictive risk in men. The aim of this study was to determine the relationship between BMD, HAL and the risk of hip fracture in men. A case–control design was used. Cases were men aged 50 years and over with a minimal-trauma hip fracture admitted to the Royal Cornwall Hospital, Truro, during 1995–1997. Controls were recruited from a large general practice within the catchment area of the hospital. Subjects were invited for assessment of BMD at the lumbar spine and proximal femur, using dual-energy X-ray absorptiometry. HAL was assessed using machine software. Data concerning BMD were available in 62 fracture cases and 100 controls. After adjusting for age, height and weight, a reduction in BMD was associated with a significant increase in the risk of hip fracture [odds ratio (OR) 1.8–4.0 per standard deviation (SD) reduction, depending on site]. HAL was similar in both fracture and control groups (12.0 cm vs 12.0 cm). After adjusting for height, there was no association between HAL and the risk of hip fracture (OR per 1 SD increase in HAL = 0.9; 95% confidence interval 0.6, 1.3). Compared with those with a cervical fracture (n = 31), those with an intertrochanteric fracture (n = 31) had lower BMD at all skeletal sites, though this was significant for the trochanteric site only. It is concluded that BMD though not hip axis length is a risk factor for low-trauma hip fracture in Caucasian men.

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Introduction

Hip fractures are an important health burden [1]. The majority of fractures occur in women, though at least one-third occur in men [2]. A knowledge of the risk factors for hip fracture may help target preventive therapy, with the aim of reducing the attendant morbidity and mortality.

Bone mineral density (BMD) is one of the most important determinants of skeletal strength. Studies in women indicate that for each standard deviation (SD) reduction in bone mass the risk of hip fracture increases by a factor of 1.5–3 [3]. Less is known, however, about the influence of BMD in determining fracture risk in men. Several observational studies suggest that BMD is lower among men who have sustained a hip fracture than those without, though in most of these the number of individuals studied has been relatively small [4–11].

Recent studies have suggested that geometric parameters of the proximal femur may be additional determinants of fracture risk [12–16]. In women, a 1 SD increase in hip axis length (HAL) – the distance from the base of the greater trochanter to the inner pelvic rim along the femoral axis – is associated with a 1.8-fold increase in hip fracture risk [12], the effect being independent of bone mass. There are, however, no data concerning the influence of HAL on risk of hip fracture in men.

The aim of this study was to determine the relationship between BMD, HAL and the risk of hip fracture in men.

Materials and Methods

A case–control design was used. The study was undertaken at the Royal Cornwall Hospital in Truro; this is the only referral center for acute orthopedic care to a geographically defined population of 384 000 which includes 65 858 men aged over 50 years. One hundred consecutive male admissions with a 'low-trauma' hip fracture aged 50 years and over were recruited during a 14 month period between 1995 and 1997. 'Low trauma' was defined as a fall from standing height or less. The fracture cases were identified by daily review of the admissions unit and the orthopedic wards. Fractures were classified as 'cervical' or 'intertrochanteric' according to their radiographic appearance. One hundred controls were recruited from a large general practice within the catchment area of the hospital. Control subjects were recruited concurrently with the cases, and were selected to broadly match their age distribution. Subjects who agreed to take part completed an interviewer-administered questionnaire, which in the fracture cases was within 48 h of admission. The questionnaire included questions concerning lifestyle, comorbid factors and aspects of health. Height (cm) was recorded in 74 of the fracture cases, and weight (kg) in 85 cases at the time of admission (or within the subsequent 3 months). Both height and weight were recorded in 97 of the controls. The study was approved by the local ethics committee of the hospital.

Bone Mass Assessment

BMD measurements were performed at the lumbar spine and the proximal femur on all subjects capable of lying still in a specified position on the scanner for at least 10 minute BMD was measured by dual-energy X-ray absorptiometry (DXA) using a Hologic QDR 1000 (Hologic, Waltham, MA). In the fracture cases, measurements were performed within 7 days of admission. The controls had proximal femur measurements made at the right hip, while in the fracture cases the non-fractured side was assessed. HAL was recorded using automated software provided with the scanner. The coefficient of variation in assessment of HAL and BMD at the lumbar spine and femur in our unit is 0.4%. BMD was measured in all the controls and 62 cases. The reasons for non-scanning among the cases include early death, extreme frailty and concurrent comorbid conditions (36) and refusal (2). In a further 4 cases measurements were not made at the proximal femur because of prosthesis (2), frailty (1) or extreme obesity (1).

Statistical Analysis

Descriptive statistics were used to characterize the distribution of age, height, weight, body mass index, HAL and BMD in the cases and controls. Logistic regression was used to determine the association between both BMD, HAL and the risk of hip fracture. Adjustments were made for age, and subsequently height and weight. The results were expressed as the odds ratio (OR) and 95% confidence interval (CI). Logistic regression was used also to assess, among individuals with fracture, the influence of BMD and HAL in predicting fracture type (intertrochanteric vs cervical).

Results

Subject Characteristics

The descriptive characteristics of the 62 cases and 100 controls with data concerning BMD and HAL are presented in Table 1. Compared with the controls, men with hip fractures had significantly lower body mass index (BMI) and weight ($p<0.01$); they were slightly older but not significantly. Among the fracture cases, those not scanned ($n = 38$), compared with those scanned ($n = 62$), were slightly older (mean age 82.6 years vs 78.0 years; $p<0.01$) and a greater proportion had concurrent comorbid diseases (79% vs 64%; $p = 0.02$), though there was no significant difference in height, weight or BMI (data not shown).

Bone Mineral Density

BMD at all sites was strongly correlated, Spearman's correlation (r_S) ranging between 0.50 and 0.83. Using the World Health Organization (WHO) definition of osteoporosis (T-score $\leqslant -2.5$ SD), and using the manufacturer's normal values, 83% of fracture cases were osteoporotic at the femoral neck, and 36% at the lumbar spine (the corresponding figures for the controls were 39% and 5% respectively). BMD was significantly lower in those with a hip fracture at the proximal femur (all four sites) and at the lumbar spine compared with the controls (Table 2). After adjusting for age, height and weight, the risk of hip fracture increased for each 1 SD

Table 1. Characteristics of hip fracture cases and controls

Variable	Fracture cases ($n = 62$)	Controls ($n = 100$)	Significance level
	Mean (SD)	Mean (SD)	
Age (years)	78.4 (10.1)	75.1 (9.6)	NS
Height (cm)	171.2 (8.7)	170.6 (7.7)	NS[a]
Weight (kg)	67.6 (10.7)	77.7 (16.3)	<0.01[a]
Body mass index (kg/m^2)	23.4 (3.3)	26.7 (5.5)	<0.01[a]

[a] After adjusting for age.

Table 2. BMD and hip axis length in hip fracture cases and controls

Variable	Fracture cases (n = 62)	Controls (n = 100)	Sigificance level	Odds ratio per 1 SD change[a]	
	Mean (SD)	Mean (SD)		OR[b] (95% CI)	OR[c] (95%CI)
Lumbar spine BMD (g/cm^2)	0.92 (0.2)	1.08 (0.2)	<0.01	2.4 (1.6, 3.5)	1.8 (1.2, 2.9)
Femoral neck BMD (g/cm^2)	0.61 (0.1)	0.76 (0.1)	<0.01	4.2 (2.5, 7.1)	3.1 (1.8, 5.3)
Trochanteric BMD (g/cm^2)	0.58 (0.13)	0.75 (0.13)	<0.01	4.1 (2.5, 6.6)	3.9 (2.2, 6.9)
Intertrochanteric BMD (g/cm^2)	0.82 (0.14)	1.06 (0.16)	<0.01	4.9 (2.9, 8.3)	4.0 (2.3, 7.1)
Ward's triangle BMD (g/cm^2)	0.38 (0.11)	0.52 (0.14)	<0.01	4.5 (2.6, 8.0)	3.7 (2.0, 6.8)
Hip axis length (cm)	12.0 (0.8)	12.0 (0.8)	NS	0.9 (0.7, 1.3)	0.9 (0.6, 1.3)[d]

[a] For BMD, per 1 SD *decrease* in measurement; for HAL, per 1 SD *increase* in measurement.
[b] Adjusting for age.
[c] Adjusting for age, height, weight.
[d] Adjusting for age and height.

reduction in bone mass at all sites measured: lumbar spine (OR = 1.8), femoral neck (OR = 3.1), trochanter (OR = 3.9), intertrochanteric area (OR = 4.0) and Ward's triangle (OR = 3.7) (Table 2).

Hip Axis Length

Data concerning HAL were available in 58 cases and all the controls. Among the control group, HAL correlated with height (r_S = 0.55; p<0.01) though not age or BMI. Mean HAL was similar between cases and controls (12 cm vs 12 cm) (Table 2). After adjusting for age and height there was no association between HAL and risk of hip fracture (OR per 1 SD increase in HAL = 0.9; 95% CI 0.6, 1.3).

Type of Hip Fracture

Among the 62 hip fracture cases with BMD measurements, there were 31 men with a cervical fracture and 31 with an intertrochanteric fracture. Compared with those with an intertrochanteric fracture, those with a cervical fracture were slightly older (79.0 years vs 77.0 years), taller (172 cm vs 170.4 cm) and lighter (67.5 kg vs 67.8 kg); however, none of these differences was statistically significant. Those with an intertrochanteric fracture had lower BMD at all sites, though this was significant for the trochanteric region only (Table 3). After adjustment for age, height and weight, the risk of intertrochanteric (compared with cervical) fracture increased per standard deviation reduction in bone mass at the trochanteric region (OR = 2.5; 95% CI 1.2, 5.4) (Table 3). HAL was slightly greater among those with a cervical fracture (12.1 vs 11.8 cm; p = NS). After adjustment for age and height, the risk of an intertrochanteric fracture with each standard deviation increase in hip axis length was comparable to that of a cervical fracture (OR = 0.6, 95% CI 0.3, 1.4).

Discussion

In a case–control study we have shown that a reduction in BMD was associated with an increased risk of hip fracture in men. The association was stronger for measurements at the proximal femur than the lumbar spine. In contrast to previous published findings in

Table 3. BMD and hip axis length in individuals with cervical and intertrochanteric fractures

Variable	Cervical (n = 31)	Intertrochanteric (n = 31)	Odds ratio per 1 SD change[a]	
	Mean (SD)	Mean (SD)	OR[b] (95%CI)	OR[c] (95%CI)
Lumbar spine BMD (g/cm^2)	0.96 (0.20)	0.88 (0.19)	1.7 (1.0, 2.9)	1.5 (0.8, 3.1)
Femoral neck BMD (g/cm^2)	0.63 (0.11)	0.60 (0.11)	1.6 (0.8, 3.3)	1.7 (0.8, 3.7)
Trochanteric BMD (g/cm^2)	0.63 (0.14)	0.53 (0.10)[d]	2.9 (1.4, 5.9)	2.5 (1.2, 5.4)
Intertrochanteric BMD (g/cm^2)	0.85 (0.14)	0.79 (0.14)	1.8 (0.9, 3.5)	1.6 (0.8, 3.2)
Ward's triangle BMD (g/cm^2)	0.38 (0.10)	0.37 (0.11)	1.1 (0.6, 2.3)	1.4 (0.7, 3.2)
Hip axis length (cm)	12.1 (0.64)	11.8 (0.84)	0.6 (0.3, 1.2)	0.6 (0.3, 1.4)[e]

[a] Intertrochanteric versus cervical fracture. For BMD, per 1 SD *decrease* in measurement; for HAL, per 1 SD *increase* in measurement.
[b] Adjusting for age.
[c] Adjusting for age, height and weight.
[d] Significant, p<0.01.
[e] Adjusting for age and height.

women, we found no association between HAL and hip fracture risk in men. Bone mass, at all sites, was lower in those with an intertrochanteric fracture compared with those with a cervical fracture, though the difference was significant for the trochanteric measurement site only.

There are certain limitations which need to be considered in interpreting these findings. Fracture cases were recruited consecutively, and none of those invited to participate declined. Controls were recruited from a local general practice, and a proportion of those invited (46%) declined to participate. If this was because they were less healthy and therefore likely to have lower bone mass than those who took part, the observed differences in BMD between fracture cases and controls may have been overestimated. An alternative strategy would have been to select the controls from a hospital population; however, such a group, because of concurrent illness, may not be representative and it may be difficult to extrapolate the findings to the general population. Moritz et al. [17], in considering this issue, suggested community controls comprise the more appropriate control group in case–control studies of hip fracture in the elderly.

The frailty and poor mobility of cases immediately after the hip fracture caused difficulties in obtaining data concerning bone mass in a significant proportion (38%). Individuals in whom BMD was not assessed were older and a greater proportion had comorbidities than those who were assessed – factors again likely to be linked with lower BMD. The effect of such selection bias, if present, would be to underestimate the strength of the relationship between hip fracture and BMD.

Our study was cross-sectional, one of the major limitations with such a design being that it is not possible to determine the temporal nature of the observed associations. Prospective studies are required to determine the predictive risk of both HAL and BMD in determining future fracture risk. In addition in this study we looked at a group of UK Caucasians, so our findings may not necessarily be applicable to other racial/ethnic groups and/or in different study settings.

Cross-sectional and prospective studies in women have shown strong associations between bone mass assessed at various skeletal sites and the risk of hip fracture [3]. There are, however, few data in men. Data from several observational studies suggest that men with hip fracture have lower bone mass than same-sex controls; however, the numbers of fracture cases included in these studies are relatively small (<40) [4,6,8,9,11,18].

The magnitude of the risk of hip fracture associated with femoral neck BMD has been reported in several studies. Nguyen et al. [7] reported a 66% reduction in the risk of hip fracture ($n = 31$) per 1 SD *increase* in BMD at the femoral neck, while De Laet et al. [11], reported a 3-fold increase in risk of fracture ($n = 23$) per 1 SD *decrease* in BMD. These data are similar to our own finding of a 3.1-fold increase in risk per 1 SD *decrease* in femoral neck BMD.

In our study the strength of association between bone mass and fracture risk was greater for measurements at the hip than those at the spine. This may be due in part to the presence of concurrent degenerative disease which leads to an artifactual increase in spinal bone density [19,20].

Men with trochanteric fractures had a lower bone mass at all skeletal sites than those who had sustained cervical fractures. The difference, however, was significant only for trochanteric BMD. Similar findings have been reported using the Singh Index in men [21] and DXA in women [4,5]. In contrast, however, to previous reports in women we could not confirm a protective effect of femoral neck BMD [5].

Unlike previous published findings in women, we found no association between HAL and hip fracture risk in men. In women an increase in HAL has been linked with hip fracture risk in several studies [12,22]. To our knowledge there are no previous reports concerning the influence of HAL on fracture risk in men. Two previous studies suggested no difference in femoral neck axis length (FNAL; one of the component parameters of HAL) between fracture cases and controls [15]; however, the link between FNAL and hip fracture risk is less clear [13,23]. The mechanism by which an increase in HAL confers an increase in susceptibility to fracture in women is unknown. Studies suggest that the risk persists after adjustment for body height and weight, indicating it is not a surrogate for body size (itself linked with an increased risk of hip fracture) [12]. It has been suggested that HAL is a marker for the ability of the femur or pelvis to absorb or avoid the impact of a fall [24]. There are important gender differences in both the shape of the proximal femur and pelvis including the pelvic brim [25,26] which may influence bone strength or resistance to fracture. It is possible that one or more of these shape parameters interacts with HAL, and explains the discrepant findings in relation to fracture risk in men and women.

In summary, our study findings suggest that bone mass is an important determinant of fracture risk in men. In contrast HAL does not appear to be associated with the risk of hip fracture and should not therefore be included in risk evaluation. Our study also highlights the need for caution in extrapolating the predictive risk of HAL observed in female Caucasians to other population groups.

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