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Research Article

Femoral Neck Shaft Angle in Men with Fragility Fractures

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Introduction. Femoral neck shaft angle (NSA) has been reported to be an independent predictor of hip fracture risk in men. We aimed to assess the role of NSA in UK men. *Methods*. The NSA was measured manually from the DXA scan printout in men with hip (62, 31 femoral neck and 31 trochanteric), symptomatic vertebral (91), and distal forearm (67) fractures and 389 age-matched control subjects. Age, height, weight, and BMD (g/cm^2: lumbar spine, femoral neck, and total femur) measurements were performed. *Results*. There was no significant difference in mean NSA between men with femoral neck and trochanteric hip fractures, so all further analyses of hip fractures utilised the combined data. There was no difference in NSA between those with hip fractures and those without (either using the combined data or analysing trochanteric and femoral neck shaft fractures separately), nor between fracture subjects as a whole and controls. Mean NSA was smaller in those with vertebral fractures (129.2° versus 131°: $P = 0.001$), but larger in those with distal forearm fractures (129.8° versus 128.5°: $P = 0.01$). *Conclusions*. The conflicting results suggest that femoral NSA is not an important determinant of hip fracture risk in UK men.

1. Introduction

Osteoporosis is generally considered to be a condition affecting women, but up to 30% of fragility fractures occur in men [1–3]. The lifetime risk of fracture at the age of 50 years has been estimated to be 20% for men [1, 4]. Bone mineral density (BMD) has long been recognised as an important skeleton determinant of fracture risk, but it is becoming apparent that skeletal geometry also influences the risk. This has been most extensively studied in women at the hip, in terms of hip axis length (HAL), femoral neck axis length (FNAL), neck shaft angle (NSA), and femoral neck width (FNW). The role of all of these factors as independent predictors of hip fracture risk is controversial in both sexes, with studies giving conflicting results [5, 6]. This uncertainty may have arisen partly because of differences in study design, numbers of patients studied, and also because of wide variations in geometric parameters in different countries and races [7, 8]. Given this variation, it may be necessary to generate data specific to the population under consideration. It may also be necessary to generate gender-specific data, as suggested by our previous paper [9], which showed that men had a mean femoral NSA of 130° (SD 3.3, range 121–138°), whilst women had a significantly ($P < 0.0001$) smaller mean femoral NSA of 128° (SD 1.7, range 119–137°). Only one study has examined hip geometry solely in men in England and this failed to show any relationship between HAL and hip fracture [10]. However, it did not measure NSA or femoral neck width, so there is a need for further study of the role of femoral geometry in men.

Men with forearm fractures and vertebral fractures are at increased risk of developing hip fractures [10, 11], which may be due in part to altered skeletal geometry. We have therefore examined femoral neck NSA measurements in

three UK case-control studies of low trauma hip, vertebral, and distal forearm fractures in men [12–14]. These studies have previously demonstrated significantly lower BMD in men sustaining these fractures compared with controls, and between 42% and 83% were osteoporotic on the basis of a T-score ≤ -2.5 using male-specific reference data [12–14]. It is also important to note that there can be differences in geometry between femoral neck and trochanteric hip fractures and for this reason, these fractures types need to be considered separately. The Cornwall Hip Fracture recruited men with hip fractures of the femoral neck and trochanteric regions and so provides an opportunity to study the role of NSA in both fracture types.

2. Methods

2.1. Subjects. The full details of each of the three studies have already been published, but they will be described briefly [12–14]. In all three, low trauma fractures were defined as those occurring spontaneously without trauma or following a fall from standing height or less. Local research ethics committee approval was obtained. All subjects gave their written informed consent.

2.1.1. Case-Control Study of Hip Fractures. Data were collected from the Cornwall Hip Fracture Study of men with low trauma femoral neck hip fractures [12]. One hundred consecutive admissions of men over 50 years with low trauma hip fractures to the Royal Cornwall Hospital in Truro between 1995 and 1997 were recruited. One hundred age-matched controls were recruited concurrently from a large general practice within the catchment area of the hospital. Fracture subjects were recruited during their admission, so it was only possible to perform DXA scans on 62 men with hip fracture (31 with femoral neck, 31 with trochanteric fractures) and 100 control subjects. Of the men with trochanteric fractures, only 16 could have their NSA measured because the rest had bilateral hip fractures, so no hip DXA could be performed.

2.1.2. Case-Control Study of Vertebral Fractures. Men referred to the Bone Clinic in Newcastle upon Tyne with symptomatic low trauma vertebral fractures aged 80 years or less were invited to take part in the study [13]. The spine radiographs were reviewed to confirm the presence of at least a 20% reduction in anterior and/or posterior vertebral height. Control subjects were recruited from the age-sex registers of General Practitioners to match the age of the index case within two years. Those with a previous diagnosis of osteoporosis were excluded. Of the control subjects who agreed to take part (43% of those approached), one was selected at random to serve as the control and underwent the same clinical assessment and investigations as the patients with vertebral deformation. Spinal radiographs were not taken in the control subjects however, because of the relatively high-radiation exposure involved. In total, 91 case-control pairs were recruited.

2.1.3. Case-Control Study of Distal Forearm Fractures. A retrospective case-control study design was chosen and all men aged 40–80 years who had suffered a distal forearm fracture between 1996 and 1998 were identified from the Accident and Emergency Department records of attendance at Derbyshire Royal Infirmary [14]. The case notes and X-ray reports were then examined to confirm the fracture and eligibility. In this way, 147 men were identified of whom 103 responded to questionnaires and 67 agreed to dual energy X-ray absorptiometry (DXA) scanning. A total of 198 age-matched control subjects were selected from a preexisting local database of 692 healthy men without distal forearm fractures, so that two control subjects were matched with each man with fracture taking part in the study.

2.2. Bone Area, Bone Mineral Content, and Bone Mineral Density. In all studies, anthropometric measurements were performed, including height and weight. DXA was used to determine scan area (cm^2), BMC (g), and areal BMD (g/cm^2). The lumbar spine (L1 to L4) and hip (total hip, femoral neck) were measured. Hip measurements were always taken from the left side, unless there was a fracture or joint replacement. DXA scanning was performed using either Hologic QDR 1000 or QDR 2000 equipment (Hologic Instruments, Waltham, Mass, USA) [12–14], but there was no consistent difference in measurements obtained with the two machines [13]. Daily calibration checks were performed using the Hologic spine phantom and had a coefficient of variation of 0.5% throughout the studies. *In vivo* precision for measurement with these systems is 1.0% at the lumbar spine (L1–L4) and 1.5% for the femoral neck.

2.3. Femoral Neck Shaft Angle Measurements. Although the Hologic 1000 machine was a pencil-beam machine demonstrating virtually no magnification error, the Hologic 2000 DXA scanner included a fan beam capability and so created the potential for magnification errors. This precluded the measurement of HAL or FNW. However, we have previously found the effect of possible magnification on NSA to be minimal using a fan beam scanner [9]. Subjects were all positioned on the DXA using the standardised international recommendations as described recently [15]. For completeness, the following is extracted from the article: "The patient is positioned straight on the table (spine is straight on the image), not rotated (spinous processes are centred) and centred in the field (roughly equal soft tissues fields on either side of the spine). The patient has the femur positioned straight on the table (shaft parallel to the edge of the picture), with 15–25° of internal rotation where possible, achieved by the use of a single positioning device, thereby presenting the long axis of the femoral neck perpendicular to the X-ray beam, providing the greatest area and the lowest BMC (and the lowest BMD). This is confirmed on the scan by seeing little or none of the lesser trochanter." Such standardisation of subject position should reduce error in measuring the NSA, although extreme angles of anteversion at the hip were not specifically excluded. The NSA was measured from a Hologic standard DXA scan printout using a method

Table 1: Summary of anthropometric and BMD data from the three case-control studies.

Study	Group	Age (Years)	Height (m)	Weight (kg)	Spine BMD (g/cm^2)	Femoral neck BMD (g/cm^2)	Total hip (g/cm^2)	Percentage with osteoporosis
Forearm	Fracture $n = 67$	60.97	1.727	81.71	0.985	0.748	0.951	42
	Control $n = 198$	60.60	1.731	79.7	1.065***	0.848***	1.026***	10***
Vertebral	Fracture $n = 91$	64	1.691	70.36	0.812	0.709	0.787	56
	Control $n = 91$	64	1.732***	78.12***	1.060***	0.845***	1.009***	3***
Hip	Fracture $n = 62$	78.4	1.712	67.6	0.92	0.61	0.716	83
	Control $n = 100$	75.1	1.706	77.7**	1.08**	0.76**	0.921***	39***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

adapted from that of Faulkner et al. and Quereshi et al., 2001 [15, 16] and previously published by the authors [9]. All measurements were made by a single observer (the corresponding author). The femoral neck axis was identified on the printout by the DXA analysis software. A line was then drawn manually from the junction between the greater trochanter and the femoral neck down to a point in the middle of the shaft at the bottom of the scan (Figure 1). The junction of these two lines gives the femoral NSA, which was measured with a long-armed protractor with 0.5° intervals (a BIOMET Inc. goniometer). The method described gave an intraobserver error of 0.79%, interobserver error of 1.2%, and precision of ±1.2%. The details of how these errors and precision were derived have been given in our previously published paper [9] and are similar to those given in other papers in this field [5, 6, 8, 16–18].

2.4. Statistical Methods. Statistical analysis was performed using standard statistical software packages (Graphpad Prism) and SPSS for Windows (SPSS Inc. Chicago, Ill). Descriptive statistics were obtained and data were tested for normality using Kolmogorov-Smirnov test for Gaussian distribution. All data were normally distributed. Each of the three case-control studies available had their NSAs measured in men with fractures and control subjects. These were then examined separately to look for any correlations with age, height, weight, and BMD using Pearson correlation coefficients. The groups were then compared via Student's t-tests (unpaired) to see if there was any significant difference in NSA between fracture and control subjects (Figure 2). Chi-squared tests were performed to compare proportions. As there were significant differences in height and weight, ANCOVA tests were performed in order to adjust the NSA results for these covariables.

3. Results

Table 1 summarises the anthropometric and BMD data for the three individual studies, all of which have been previously published [12–14]. Only the vertebral fracture study demonstrated any significant height differences between fracture and control subjects, presumably because of height loss associated with vertebral fractures. Weight was significantly lower in the men with hip and vertebral fractures compared with their respective control subjects, but not in the forearm study.

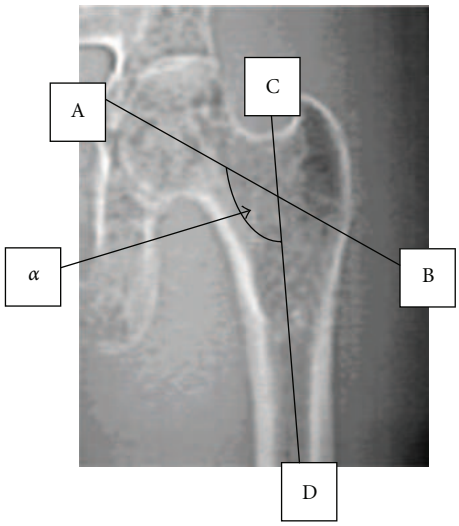

Figure 1: Measurement of the femoral NSA from the DXA scan printouts. The line AB is the hip axis marked on by the scanner's software. A line is then drawn from C to D, in which C is the point at which the greater trochanter joins the femoral neck and D is the midpoint of the shaft at the bottom of the picture. The angle α is the femoral neck shaft angle.

Table 2 shows the correlations found between NSA and age, height, weight, and BMD at the lumbar spine, femoral neck, and total femur for each of the study groups. The only significant correlations identified were inverse relationships with height and lumbar spine BMD amongst control subjects

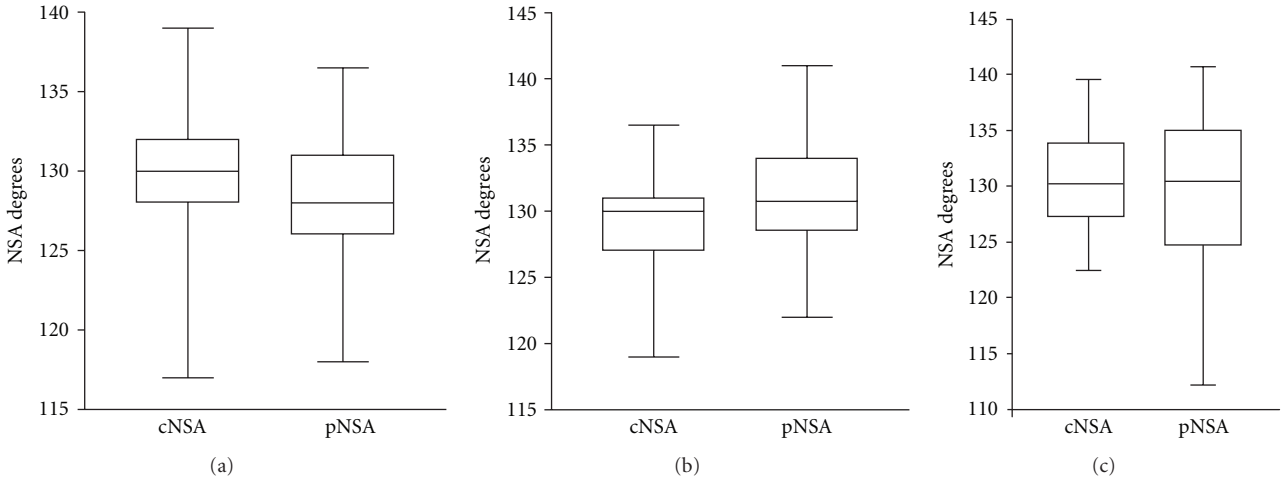

Figure 2: (a) Box and whisker plot of femoral NSA in male patients with distal forearm fractures (pNSA) compared with control subjects (cNSA). (b) Box and whisker plot of femoral NSA in male patients with symptomatic vertebral fractures (pNSA) and control subjects (cNSA). (c) Box and whisker plot of femoral NSA in male patients with hip fractures (pNSA) compared with control subjects (cNSA).

Table 2: Correlations (r) between neck shaft angles and anthropometric and BMD data.

Study	Group	Age	Height	Weight	Spine BMD	Femoral neck BMD	Total hip BMD
Forearm	Fracture $N = 67$	0.04	−0.07	−0.07	0.167	0.097	0.058
	Control $N = 198$	0.03	−0.27***	−0.09	−0.19*	−0.06	−0.09
Vertebral	Fracture $N = 91$	0.06	−0.01	0.19	0.1	0.03	0.02
	Control $N = 91$	0.11	−0.22*	0.006	−0.15	−0.1	−0.09
Hip	Fracture $N = 62$	0.08	−0.17	−0.19	0.09	−0.1	0.06
	Control $N = 100$	0.09	−0.004	−0.03	0.02	0.001	−0.009

* $P < 0.05$, *** $P < 0.001$.

Table 3: Results of the means and ranges of NSAs in each study.

Study group	Control group Mean (SD) and range	Fracture group Mean (SD) and range	Difference of the means 95% CI	P value (unpaired t-test)
Forearm study (67 fracture and 198 control subjects)	129.8 (3.495) 117 to 139	128.5 (3.519) 118 to 136.5	−1.265 (−0.29 to −2.24)	0.01
Vertebral study (91 case-control pairs)	129.2 (3.573) 119 to 136.5	131 (3.536) 122 to 141	1.752 (0.72 to 2.78)	0.001
Hip study (62 fracture and 100 control subjects)	130.7 (3.506) 122.5 to 139	130.1 (5.496) 111 to 143.5	−0.58 (−0.82 to 1.97)	0.42

in the forearm fracture study and with height alone in the control subjects in the vertebral fracture study

The means, ranges, and standard deviations in each control group are all very similar (Table 3). The mean NSA for men with forearm fractures was significantly smaller than that of control subjects, whereas it was significantly larger in the men with vertebral fractures. However, the differences were small in each case and were in opposite directions. The NSA data for hip fracture subjects was first of all analysed by each fracture type to establish whether or not there was any difference between them. The femoral neck fractures had a mean of 129.8°, SD of 6.155, and range of 111° to 143.5° compared with mean 130.6°, SD 5.228, and range 121.5° to 139° for the trochanteric fracture group, with no significant difference between them ($P = 0.67$). Neither was there any significant difference in NSA between the femoral neck fracture group and control subjects ($P = 0.31$), nor the trochanteric and control group ($P = 0.90$). Therefore, all further analyses used the data from both hip fracture groups combined. There was no significant difference seen between the men with hip fractures (combined data) compared with control subjects. Combining all data showed no significant differences in NSA between fracture subjects (mean 130° and SEM ± 0.29) and control subjects (mean 129.9° and SEM ± 0.18): $P = 0.88$. ANCOVA tests were performed to adjust NSA for height and weight as covariables. The results are shown in Tables 4, 5, and 6 and show that doing so results in no significant difference in NSA between fracture groups

Table 4: ANCOVA test results for differences in NSA in the forearm-fracture study after adjusting for weight and height as covariables.

Source	Adjusted means		SS	df	MS	F	P
	Fracture group	Control group					
Height	128.4	125.2	526.86	1	526.86	1.18	0.27
Adjusted error			116516.07	262	444.72		
Adjusted total			117042.94	263			
Weight	128.7	125.1	658.74	1	658.74	1.49	0.22
Adjusted error			116022.87	262	442.84		
Adjusted total			116681.61	263			

Table 5: ANCOVA test results for differences in NSA in the vertebral fracture study after adjusting for weight and height as covariables.

Source	Adjusted means		SS	df	MS	F	P
	Fracture group	Control group					
Height	129.6	127.7	159.98	1	159.98	0.8	0.37
Adjusted error			35706.05	179	199.48		
Adjusted total			35866.03	180			
Weight	128.9	128.4	6.97	1	6.97	0.04	0.84
Adjusted error			34844.67	179	194.66		
Adjusted total			34851.64	180			

Table 6: ANCOVA test results for differences in NSA in the hip fracture study after adjusting for weight and height as covariables.

Source	Adjusted means		SS	df	MS	F	P
	Fracture group	Control group					
Height	124.0	130.7	1695.96	1	1695.96	5.28	0.02
Adjusted error			51422.31	160	321.39		
Adjusted total			53118.28	161			
Weight	127.1	128.7	76.51	1	76.51	0.25	0.617762
Adjusted error			48959.79	160	306		
Adjusted total			49036.3	161			

and control subjects, except when NSA is adjusted for height in the hip fracture group when the difference just makes significance at $P = 0.02$.

4. Discussion

In all three case-control studies, BMD has been found to be significantly lower in the fracture groups than control subjects, with significantly higher proportions osteoporotic. The measurement of NSAs from DXA scan printouts has produced very consistent means, ranges, and standard deviations across the studies. They are also similar to those described in our previous work in men from the Newcastle Thousand Families Study, which gave a femoral NSA of 130° and SD of 3.3 and range of 121–138° [9]. Furthermore, the mean values and ranges are similar to those reported in other studies [5, 6, 8, 16–18]. There were few correlations between NSA and height and BMD; those that were observed could well have been the result of multiple testing. The lack of change with age would suggest that the NSA is fixed over time. A study in Finland also found no relationship between age and NSA, but did confirm that men had larger NSAs than women [19].

No significant difference in NSA could be found between those with hip fractures and control subjects and between the fracture groups and control groups as a whole. Furthermore, the NSA results for the distal forearm fracture and vertebral fracture studies were conflicting, being in opposite directions. When all data were combined, there was no significant difference in NSA between those with and those without fractures. Furthermore, ANCOVA, to adjust for height and weight, resulted in the previous differences between vertebral and forearm fracture subjects and controls disappearing. The only significant difference occurred between hip fracture and control subjects after adjusting for height ($P = 0.02$), but there was no difference after adjusting for weight. This suggests that there is no role for NSA in predisposing to hip fractures in men from the United Kingdom. These results are at variance with other studies. Karlsson et al. (1996) showed that men with hip fractures have a wider pelvis, shorter HAL, wider femoral necks, and larger NSAs than male control subjects [5]. A larger study by Gómez Alonso et al. (2000)

found that one standard deviation increase in NSA or FNW approximately doubled the risk of hip fracture in men, but there was no association with HAL [6]. These contradictions could be due to the wide geographic differences in hip geometry that have been reported [7, 8], and data may need to be specific for race and gender. However, a recent large Chinese study published by Zhang et al., including 4067 men (38 with hip fractures) across an age range from 15 to over 85 years, confirmed our findings [20]. The NSA did not change with age and there was no significant difference in NSA between hip fracture subjects and controls. They did find significantly lower BMD and reduced cross-sectional area [20].

The study has a number of limitations. It is relatively small and it is possible that larger studies could reveal important, but smaller effects of NSA. It was also unable to assess other aspects of structure and geometry, such as FNW which may be important in determining hip fracture risk in addition to low BMD. Such factors may also contribute to the known increased risk of hip fracture following vertebral or forearm fractures. The vertebral fracture study included neither vertebral morphometry nor spinal radiographs of the control subjects and so could not exclude the possibility of asymptomatic fracture and, indeed, was never designed to do so. Approximately, 20–25% of vertebral fractures are clinically diagnosed [21] and therefore the control group may not have been a true control population, which may have altered the results obtained. However, there was a significant difference in height between the vertebral fracture group and control subjects. One particular strength of the hip fracture study is that all the hip fracture subjects had femoral neck fractures. There have been differences in geometry reported between trochanteric and femoral neck hip fractures [18, 19], and so it is important to investigate the possible geometric contributions to these fractures separately.

It is worth noting that the men in the hip fracture study had a larger standard deviation than in the other groups. These men had their DXA scans performed whilst they were in hospital, and it is possible that the recent fracture made it more difficult for them to lie in the ideal scanning position. This could reduce the ability of the study to detect a true difference.

5. Conclusions

A manual method of measuring femoral NSAs from DXA scan printouts has been described. The method has proven to be both reliable and precise. It has given consistent results in terms of means, ranges, and standard deviations in all the studies in which it was used. In our previous work, men were shown to have larger femoral NSAs than women, despite their lower fracture risk [9]. Furthermore, the results of NSA measurements in the forearm, vertebral fracture, and hip fracture studies could find very little evidence to support a role for NSAs even after ANCOVA testing to adjust for height and weight as covariables. This suggests that NSA is not an important determinant of hip fracture risk in English men. Other aspects of geometry and structure may be more important risk factors and need evaluation.

Conflict of Interests

The authors declare no conflict of interests.

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