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The proximal femoral morphometry of Turkish women on radiographs

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SUMMARY

In this study, proximal femoral morphometry was measured on radiographs of Turkish women. Hip fractures have high morbidity and mortality rates for people and is generally seen in elderly. It is known that the body mass index (BMI) and proximal femoral morphometry are important determinants of fracture risk. Our aim is to perform the measurements of proximal femoral morphometry and body mass index. A total of 190 Turkish women were included in the study. The anthropometric and BMI measurements were recorded and the morphometric measurements (HAL, FAL, FW, HW, TW and Q angle) were made on the radiographs. For statistical analysis, the Pearson linear correlation was performed using the SPSS 10.0 software. The averages of the femoral morphometric measurements and BMI were found to be: 10.80 cm, 10.14 cm, 5.21 cm, 3.54 cm, 8.42 cm, 131.52 degree, and 28.02 kg/m^2 (HAL, FAL, HW, FW, TW, Q angle and BMI), respectively. Strong positive correlations were found between BMI and TW (r= 0.230; p= 0.002), BMI and FW (r= 0.169; p= 0.023), BMI and HW (r= 0.175; p= 0.018). These results suggest that there is a relationship between the values of the proximal femoral morphometry and BMI.

Key words: Body mass index – Osteoporosis – Proximal femoral morphometry – Turkish women

INTRODUCTION

There are metric differences in skeletal components among populations and these variations are related to genetic and environmental factors (geography, diet, life style…). Variations in human skeletal measurements also determine the racial characteristics of the populations. Anthropometric skeletal measurements are used to show up regional diversity between different populations or within the same population. Moreover, skeletal measurements and the shape of bones can offer a guide to clinicians for the determination of risk factors for fractures.

Fractures are an important health burden as regards disability, death, and medical costs (Faulkner et al., 1993; Boonen et al., 1995; Gregory et al., 2004). In particular, hip fractures are a major problem for elderly people. The shape of the proximal femur is known to be an important risk factor for hip fracture of the femoral neck, regardless of bone mass or bone strength (Gregory et al., 2004). A bone fractures when it is subjected to stresses

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greater than its ultimate strength. The stress within a bone depends on the geometric arrangement and the material of which the bone is made, as well as on the direction and size of the force applied (Ravn et al., 1999; Testi et al., 2001; Liu et al., 2004).

Many studies have been carried out to define risk factors for hip fracture in order to identify those at risk and hence to prevent fractures (Hawker et al., 2002; Munaisinghe et al., 2002). The risk of hip fracture can be predicted by some factors, such as body mass index (BMI), bone mineral density (BMD), the direction and severity of the fall, muscle strength, body habitus, femoral morphometry, family history or lifestyle factors (Glüer et al., 1994; Pande et al., 2000; Calis et al., 2004). There are substantial variations in hip fracture incidence rates worldwide, which suggest the existence of important environmental factors that could be manipulated to reduce hip fracture occurrence. This substantial variation may be related to genetic factors and environmental conditions (climate, lifestyle factors, etc.) influencing BMI, BMD and the morphometry of the proximal femur (Glüer et al., 1994; Munaisinghe et al., 2002; Gnudi et al., 2002; Greendale et al., 2003).

The femoral heads support the entire weight of the body, suggesting that the morphometry of the proximal femur may contribute to femoral neck strength. The proximal femur acts as a brace, and its biomechanical properties depend on the width and length of the femoral neck (Cheng et al., 1997). Femoral morphometric parameters including hip axis length (HAL), femoral neck axis length (FAL), femoral neck width (FW), femoral head width (HW), intertrochanteric width (TW), and femoral neck-femoral shaft angle (Q angle) have been related to the mechanical strength of the proximal femur. These parameters are also involved in the resistance of bone to impact, the highest values being found in races with a higher incidence of hip fracture (Faulkner, 1995; Karlsson et al., 1996; Pinilla et al., 1996; De Laet et al., 1998; Rosso and Minisola, 2000; Bergot et al., 2002; Gregory et al., 2004; Pulkkinen et al., 2004). Some of the most frequently described measurements that have been associated with an increased risk of fracture include a longer hip axis length (Faulkner et al., 1993; Boonen et al., 1995; Gnudi et al., 1999; Gregory et al., 2004), a larger neck-shaft angle (Boonen et al., 1995; Gnudi et al., 1999; Alonso et al., 2000; Testi et al., 2001; Gregory et al., 2004) and a larger neck width (Boonen et al., 1995; Gnudi et al., 1999; Alonso et al., 2000; Gregory et al., 2004). In addition to the morphometry of proximal femur, it has been found that body weight and the body mass index (BMI) are associated with fracture risk (Felson et al., 1993; Ravn et al., 1999; Hawker et al., 2002; Munaisinghe et al., 2002; McGuigan et al., 2002; Liu et al., 2004).

In this study, our aim was to obtain measurements of the proximal femoral morphometry and body mass index in Turkish women. We compare our results with those of previous studies and attempt to provide information about the morphometric characteristics of the proximal femur and body mass index for Turkish women.

Materials and Methods

This study included 190 women aged over 50 years (mean age ± SEM; 61.86 ± 0.64 years). Baseline values were recorded for all women, including age, weight, height and the presence of additional disease. In addition, body mass index (BMI) was calculated as weight (kilograms) divided by the square of height (meters). Women with metabolic bone diseases, terminal diseases, malignancy, renal failure or coxarthrosis were not included in the study.

Pelvic radiographs were obtained using the standardized protocol: in 15-30 degrees of internal rotation of the hips in the supine position with a film-focus distance of 100 cm, and the beam centered on the symphysis pubis. Morphometric measurements were performed unilaterally and all measurements were performed by I. Ari. The definitions of the measurements were taken from the literature and were selected on the basis of their being good discriminators in previous studies. These are clearly defined in the available literature (Glüer et al., 1994; Pande et al., 2000; Alonso et al., 2000; Gnudi et al., 2002; Greendale et al., 2003; Calis et al., 2004).

A transparent film with one longitudinal line and several perpendicular lines was placed over the hip radiograph and on the femoral head in order to facilitate accuracy and consistency of the measurements. The measurements of HAL, FAL, HW, FW, TW and

Q-angle on the radiographs were as follows (Fig. 1):

1. HAL (C-D): length of the femoral neck axis from the base of the lateral part of the greater trochanter to the inner pelvic brim;

2. FAL (A-B): length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris;

3. HW (E-F): broadest cross-section of the femoral head;

4. FW (G-H): narrowest cross-section of the femoral neck;

5. TW (I-J): cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter;

6. Q-angle (between BKL): angle between the femoral neck and shaft of femur.

Statistical analyses were performed on these measurements. We calculated the mean ± standard error for each BMD, anthropometric and morphometric parameters. The Pearson linear correlation was performed using the SPSS 10.0 software. In all tests, p values of less than 0.05 were considered statistically significant.

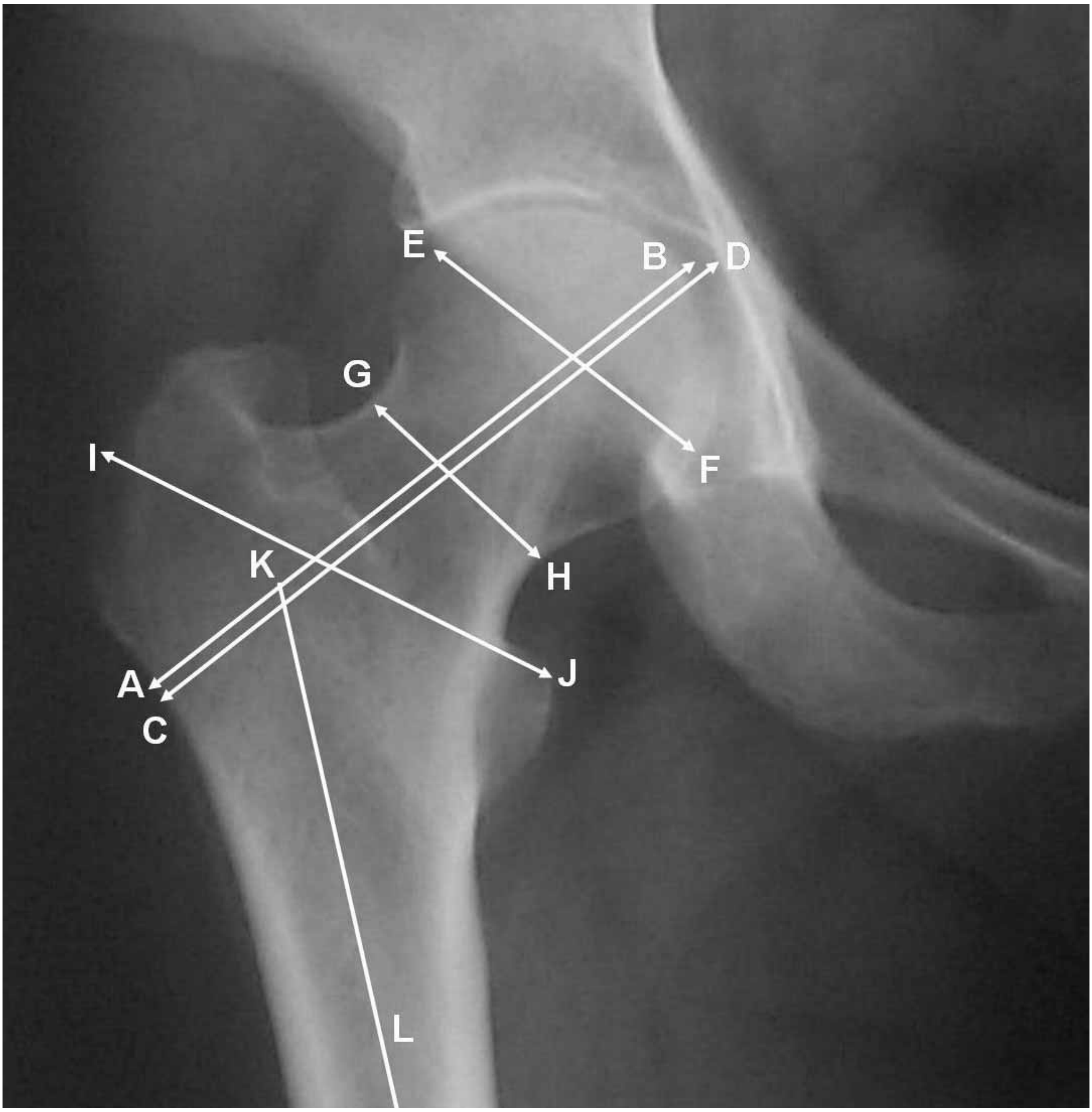

Figure 1. Definition of the parameters measured from the anteroposterior roentgenograms of the proximal femur. **A-B** (FAL): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris; **C-D** (HAL): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the inner pelvic brim; **E-F** (HW): Broadest cross-section of the femoral head; **G-H** (FW): Narrowest cross-section of the femoral neck; **I-J** (TW): Cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter; **BKL** (Q-angle): Angle between the femoral neck and shaft of femur.

Results

The mean ± SEM values of the anthropometric indices of 190 Turkish women (age, weight, height and BMI) were found to be 61.86 ± 0.64 years, 66.47 ± 0.82 kg, 153.98 ± 0.45 cm, 28.02 ± 0.32 kg/m^2, respectively (Table 1). The averages of the proximal femur morphometric measurements were HAL: 10.80 ± 0.04 cm, FAL: 10.14 ± 0.04 cm, HW: 5.21 ± 0.02 cm, FW: 3.54 ± 0.01 cm, TW: 8.42 ± 0.03 cm, Q angle: 131.52 ± 0.30 degree (Table 1).

Table 1. Averages of the measurements of femoral morphometrics and anthropometrics in Turkish women.

Measurements n = 190	Mean	± SEM
Age (years)	61.86	0.64
Height (cm)	153.98	0.45
Weight (kg)	66.47	0.82
BMI (kg/m^2)	28.02	0.32
HAL (cm)	10.80	0.04
FAL (cm)	10.14	0.04
HW (cm)	5.21	0.02
FW (cm)	3.54	0.01
TW (cm)	8.42	0.03
Q Angle (deg.)	131.52	0.30

In this study, Pearson's linear correlation coefficients between the BMI and femoral morphometric parameters were calculated (Table 2) to evaluate the relationship of BMI and proximal femoral morphometry. The strongly positive correlations were found between BMI and TW (r= 0.230; p= 0.002), BMI and FW (r= 0.169; p= 0.023), BMI and HW (r= 0.175; p= 0.018). Moreover, there were strongly positive correlations among the femoral morphometric parameters (Table 2). These results show that there are relationships among HAL, FAL, TW and the Q angle (Table 2). In addition, both FW and HW were related to HAL, FAL and TW. However, neither FW nor HW had a relationship with the Q angle (Table 2).

Table 2. Pearson correlation coefficients of femoral morphometric measurements and BMI values in Turkish women. (***= p<0.001; **= p<0.01; *= p<0.05).

Variables *(r and p values)*	HAL	FAL	TW	FW	HW	Q Angle	BMI
BMI	0.04 0.53	0.03 0.64	0.23 0.00***	0.16 0.02*	0.17 0.01**	0.11 0.12	
Q Angle	-0.18 0.01**	-0.18 0.01**	0.16 0.02*	0.07 0.30	0.05 0.49		
HW	0.44 0.00***	0.42 0.00***	0.55 0.00***	0.68 0.00***			
FW	0.38 0.00***	0.38 0.00***	0.47 0.00***				
TW	0.29 0.00***	0.25 0.00***					
FAL	0.97 0.00***						
HAL							

Discussion

Recent studies have shown that both the morphometry of the proximal femur and the BMI are associated with the risk of hip fracture in the elderly. In this study, we found positive correlations between some measurements of the proximal femur (HW, FW and TW) and the body mass index (BMI). In other words, as the values of the body mass index increase, the values of HW, FW and TW increase accordingly.

The results of previous studies have shown that there is a relationship between hip fracture risk and HAL, FAL, FW, and Q angle (Faulkner et al., 1993; Boonen et al., 1995; Alonso et al., 2000; Testi et al., 2001; Gnudi et al., 2002). A longer hip axis length, a larger neck-shaft angle and a larger neck width are associated with an increased risk of hip fracture (Faulkner et al., 1993; Faulkner et al., 1994; Boonen et al., 1995; Karlsson et al., 1996; Schwartz et al., 1999; Alonso et al., 2000; Gnudi et al., 2002). The precise physical mechanism of this is unknown, since it contradicts data from ex vivo biomechanical tests showing a positive correlation between hip axis length and femoral neck strength (Cheng et al., 1997; Schwartz et al., 1999). To the best of our knowledge, the hypothesis that a longer hip axis length leads to a higher probability of impacting the great trochanter and to a lower impact absorption after a fall (Faulkner, 1995; Schwartz et al., 1999; Rosso and Minisola, 2000) is reliable, but is yet to be documented. Ex vivo biomechanical tests have shown that the neck-shaft angle does not correlate with femoral neck strength (Pinilla et al., 1996; Schwartz et al., 1999), and hence its correlation with fracture risk may involve other mechanisms. It could be hypothesized that the width of the neck-shaft angles or of the anteversion angles interacts with the direction of the fall, thus affecting the femoral neck loading angle (Pinilla et al., 1996). This angle is inversely related to fracture load and its variation may therefore be associated with different fracture risks (Pinilla et al., 1996; Schwartz et al., 1999). The anteversion angle affects the width of the neck shaft-angle. The greater neck-shaft angle found in fractured subjects may therefore be caused by the effective greater width of this angle or the greatly anteverted femoral neck axis, since its foreshortening results in an overestimation of the neck-shaft angle (Calis et al., 2004).

Body mass index is associated with bone mineral density (BMD) and fracture risk (Felson et al., 1993; Ravn et al., 1999; McGuigan et al., 2002). Decreased body weight is one of the independent predictors of low bone mass in premenopausal women, and the BMI is low in generalized osteoporotic patients (Hawker et al., 2002; Munaisinghe et al., 2002; Liu et al., 2004). Follow-up studies in peri- and postmenopausal women have also found that there is a beneficial effect of higher BMI on bone (Liu et al., 2004).

In this study the average results of proximal femoral morphometry were HAL: 10.8 cm, FAL: 10.1 cm, FW: 3.5 cm, TW: 8.4 cm, HW: 5.2 cm and the Q Angle: 131.5 degree, respectively. These results are higher than those of previous studies addressing different populations (Gnudi et al., 1999; Alonso et al., 2000; Gnudi et al., 2002; Bergot et al., 2002; Crabtree et al., 2002; Gregory et al., 2004; Pulkkinen et al., 2004) (Table 3). In addition, the results of the present study as regards BMI were higher than those of similar studies (Table 3).

Several studies carried out in different societies have found that the incidence of hip fracture differs from country to country (Rosso and Minisola, 2000). This evidence suggests that other factors such as proximal femoral morphometry, may be equally important in determining hip fracture risk. However, there are discrepancies concerning the effect of proximal femoral morphometry on fractures (Hoaglund and Low, 1980; Beck et al., 1990; Faulkner et al., 1993; De Laet et al., 1998; Schwartz et al., 1999). These discrepancies may be due to racial differences in proximal femoral morphometry among populations. It is well known that the features and variability of the human skeleton determine the racial characteristics of populations and that they may exhibit substantial differences in different societies. The variations in skeletal morphometric measurements are associated with genetic and environmental factors (geography, diet, life style…). In this study, we found that the Q angle was not associated with FW and HW but was closely related to HAL, FAL and TW. On the other hand, HAL, FAL and the Q angle had no correlations with the BMI. In contrast, TW, FW and HW had positive correlations with the BMI. In this respect, it may be considered that the BMI may influence the thickness of the femoral neck but not its length or its angulation. In conclusion, the BMI and the proximal femoral morphometry should not be evaluated as independent risk factors and should be taken together into consideration in cases of fracture. Also, femoral morphometric measurements related to different populations are worth to obtain the validity of risk factors in hip fractures and hence further studies are required in different populations to collecting more data about proximal femoral morphology.

Table 3. Comparison of the parameters (anthropometric and femoral morphometric) in women without hip fracture in different studies.

	Anthropometric Measurements				*Femoral Morphometric Measurements (cm)*					
Studies, year, country, n	age *years*	height *cm*	weight *kg*	BMI *kg/m²*	HAL	FAL	FW	TW	HW	Q Angle *(deg)*
Gnudi et al. 1999, Italy, n= 329	62.8	159.5	62.5	24.5	10.6	—-	3.1	—-	—-	122.6
Gomez et al. 2000, Spain, n= 310	70.3	153.7	65.4	27.6	6.3	—-	3.2	—-	—-	124.6
Crabtree et al. 2002, UK, n= 568	69	159	68	26.8	10.3	—-	—-	—-	—-	—-
Bergo et al. 2002, France, n= 49	68.2	160.1	59.2	23.1	10.5	9.3	3.1	—-	—-	125.6
Gnudi et al. 2002, Italy, n= 366	77	157.6	60.8	24.4	10.7	—-	—-	—-	—-	132.0
Gregory 2004, UK, n= 24	69.1	158.6	63.3	25.1	—-	—-	—-	—-	—-	—-
Pulkkinen et al. 2004, Finland, n= 40	73.7	—-	—-	—-	10.4	9	2.9	5.2	4.3	128.3
Present study, Turkey, n= 190	61.8	153.9	66.4	28.0	10.8	10.1	3.5	8.4	5.2	131.5

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