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Comparison of Femoral Geometry Among Cases with and without Hip Fractures

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Hip fractures have high morbidity and mortality rate for the people as a complication of osteoporosis and is generally seen in old age. It is known that femoral geometric measurements are important in the assessment of hip fracture risks. This study aimed to examine the association between hip geometry and hip fracture in post-menopausal elderly females.

In the present study, 232 hip X-rays were taken from women with no hip fractures (Group 1) and 29 post-menopausal women with hip fractures (Group 2) after a minor trauma. After standard anterior-posterior plain pelvic X-ray radiographs were obtained, various radiographic measurements were performed in all cases, including the hip axis length (HAL), femoral neck axis length (FAL), acetabular width (AW), femoral head width (HW), femoral neck width (FW), femoral shaft width (FSW), intertrochanteric width (TW), lateral and medial cortical thickness of the femoral shaft (LCT, SMCT), femoral neck cortical thickness (NMCT) and femoral neck-shaft angle (Q-angle).

In group 1, the mean age, weight and height were 62.5 ± 7.4 years, 70.8 ± 12.5 kg, and 157.5 ± 6.7 cm, respectively. In group 2, these values were 70.17 ± 6.8 years, 64.7 ± 11.5 kg, and 158.3 ± 2.7 cm, respectively. There were no statistically significant differences in the measurements of HAL, FAL, AW and HW between the two groups. In group 2, the mean FW value was significantly higher than in group 1 (p= 0.01). The mean values for FSW, TW, NMCT, SMCT, LCT were statistically lower in group 2 than those in group 1 (p= 0.01, p=0.038, p=0.001, $p<0.001$, $p<0.001$, respectively). Q-angle was also significantly higher in cases with hip fracture than in cases with no hip fracture (p=0.01).

The values of FW, FSW, TW, NMCT, SMCT, LCT and Q-angle seem to be important parameters in the evaluation of hip fracture risks. However, further studies are needed to clarify this conclusion.

Key Words: Femoral geometry, hip fracture, osteoporosis

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INTRODUCTION

As a result of minor trauma, excluding any falls, osteoporotic hip fractures are observed especially in elderly people and women at the proximal region of the femoral bone. This is an important health problem regarding disability, death and medical costs. It is suggested that the bone mineral density (BMD), femoral geometry, and various individual and genetic features affect bone durability at the proximal region of the femoral bone.[1-3] Therefore, it is important to find the physical characteristics that predict hip fracture. Although BMD is one of the primary determinants of bone strength, femoral geometry and genetic features are additional indicators of femoral bone durability. On the other hand, hip geometry is an indicator for hip fractures and is not dependent on age nor the BMD.[4] In turn, geometric variables are related to bone production during growth. In contrast to the BMD, these variables are more stable and do not change with age or other factors.[5] As a result, geometry is one of the major determinants of femoral durability in all ages.

Some studies have indicated that femoral geometric measurements, such as higher HAL and decreased cortical thickness, are related to the risk of hip fracture.[4,6,7] Therefore, we aimed to investigate whether there were differences for femoral measurements between patients with and without hip fractures by looking at their standard antero-posterior plain pelvic radiographs.

MATERIALS AND METHODS

A total of 261 post-menopausal women over 50 years of age were included in the present study. Group 1 included pelvic radiographs of 232 women without hip fractures, and group 2 included 29 cases with femoral neck fractures due to minor trauma. All patients were examined in the Department of Physical Medicine and Rehabilitation, Istanbul Univ., by the Cerrahpasa Medical Faculty.

Baseline values were obtained by anamnesis and recorded for all cases, including age, weight, height, age at menopause, duration of menopause, presence of additional diseases and history of fractures due to minor trauma or osteoporosis. Cases with metabolic bone diseases, terminal diseases, malignancy, renal failure and coxarthrosis were not included in the study.

Pelvic radiographs were obtained from both groups using the same standardized protocol;[6,8-11] 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 symphisis pubis. Geometric measurements were performed bilaterally in cases without hip fracture. In addition, such measurements were performed in cases with hip fracture, but in the opposite side from the healthy hips.

After the radiographs, all measurements were performed by the same physician (H.T.Ç.) on the same day. Afterwards, the same measurements were performed 1 week later by the same investigator and the results were averaged.

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, AW, HW, FW, FSW, TW, LCT, SMCT, NMCT and Q-angle on the radiographs were as follows; (Fig. 1).

1. HAL: length of the femoral neck axis from the base of the lateral part of the greater trochanter to the inner pelvic brim;
2. FAL: length of the femoral neck axis from base of the lateral part of the greater trochanter to the caput femoris;
3. AW: line from the caput femoris to the inner pelvic brim;
4. HW: broadest cross-section of the femoral head;
5. FW: narrowest cross-section of the femoral neck;
6. FSW: width 3 cm below the centre of the lesser trochanter;
7. TW: cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter;
8. LCT: lateral cortical thickness of the shaft at the level of the width measurement at the femoral shaft;
9. SMCT: medial cortical thickness of the shaft

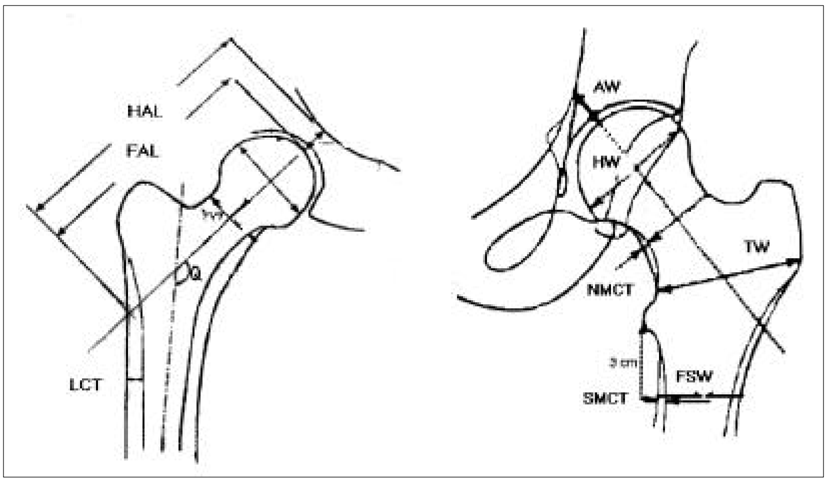

Fig. 1. Geometrical measurements of the femur on plain radiographic film. (HAL: Hip axis length, FAL: Femoral neck axis length, AW: Acetabular bone width, HW: width of the femoral head, FSW: Femoral shaft width, FW: Femoral neck width, NMCT: thickness of the medial cortex at the centre of the femoral neck, TW: intertrochanteric width, SMCT: Medial cortical thickness of the femoral shaft, LCT: Lateral cortical thickness of the femoral shaft, Q-angle: Femoral neck-shaft angle).

at the level of the width measurement at the femoral shaft;
10. NMCT: femoral neck cortical thickness at the level of the width measurement at the femoral neck;
11. Q-angle: (in degrees) angle between the femoral neck and shaft of the femur.

In addition, we studied whether there was a correlation between body mass index (BMI) and HAL as well as between BMI and FAL in both groups.

Statistical analysis: SPSS for the Windows program was used for descriptive analyses. Student's T-test and Pearson's correlation coefficient were used as indicated. $p<0.05$ (95% confidence intervals) was considered significant.

RESULTS

In group 1, the mean age, weight and height were 62.5 ± 7.4 years, 70.8 ± 12.5 kg and 157.5 ± 6.7 cm, respectively. In group 2, these values were 70.1 ± 6.8 years, 64.7 ± 11.5 kg and 158.3 ± 2.7 cm, respectively The mean post-menopausal year was significantly higher in group 2 than in group 1. Menopausal age was similar between the two groups. The mean age was statistically higher, and BMI was lower in cases with hip fracture (group 2) in comparison to those without hip fracture (group 1) (p=0.014 and p=0.005, respectively) (Table 1). There were no significant correlations between BMI and HAL as well as between BMI and FAL (r=0.09, r=0.03 respectively) (Fig. 2 and 3).

Because there may be geometric differences between either side of the hip, measurements were performed bilaterally in cases with no fractures. Femoral geometric measurements revealed no significant differences between the right and left sides (Table 2).

The mean values for HAL, FAL, AW and HW were similar between these groups (Table 3). The mean values for FW were significantly higher (p= 0.01) whereas FSW, TW, NMCT, SMCT and LCT were significantly lower in cases with hip fracture (group 2) in comparison to those cases without hip fracture (group 1) (p=0.01, p=0.038, p=0.001, $p<0.001$ and $p<0.001$, respectively). Q-angle was also significantly higher in cases with hip fracture (group 2) (p=0.01) (Table 4).

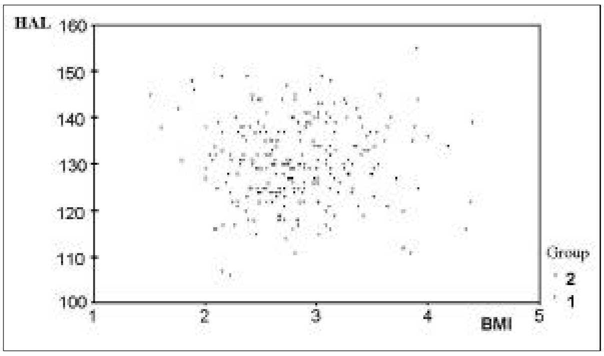

Fig. 2. Relationship between HAL and BMI (r=0.09). Group 1: No hip fracture cases. Group 2:Hip fracture cases.

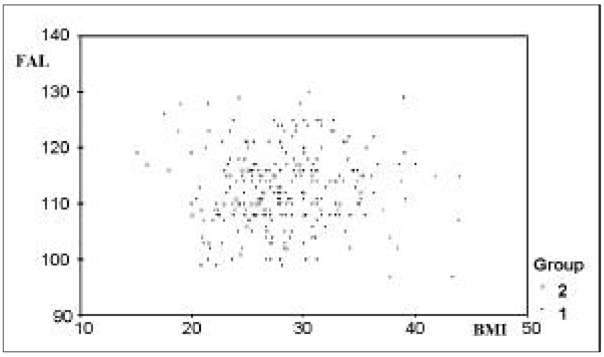

Fig. 3. Relationship between FAL and BMI (r=0.03). (Group 1: Cases without hip fracture, Group 2: Cases with hip fracture)

Table 1. Demographic Characteristics of the Study Subjects

Parameters	Cases with hip fracture (N=29)	Cases with no hip fracture (N=232)	p-value
Mean Age	70.1 ± 6.8	62.5 ± 7.4	0.005
BMI	25.8 ± 4.4	28.5 ± 4.9	0.005
Mean Age at Menopause	48.7 ± 6.5	46.6 ± 4.7	0.130
Duration of Postmenopausal Years	21.5 ± 7.7	15.8 ± 9.6	0.001

BMI, body mass index.

Table 2. The Results for Bilateral Radiographic Measurements of Cases with No Hip Fractures

Parameters	Right (N=232)	Left (N=232)	*p*-value
HAL (mm)	130.5 ± 8.9	130.1 ± 9.0	0.695
FAL (mm)	112.7 ± 6.9	112.5 ± 6.9	0.741
AW (mm)	17.8 ± 3.8	17.7 ± 4.1	0.848
HW (mm)	53.3 ± 3.2	53.0 ± 3.41	0.234
FW (mm)	35.8 ± 2.8	35.9 ± 2.79	0.787
FSW (mm)	37.6 ± 3.0	37.7 ± 3.1	0.706
TW (mm)	62.5 ± 5.3	63.0 ± 3.97	0.291
NMCT (mm)	2.1 ± 0.7	2.0 ± 0.68	0.403
SMCT (mm)	7.8 ± 1.4	8.0 ± 1.44	0.247
LCT (mm)	7.0 ± 1.3	7.1 ± 1.31	0.622
Q-angle (degree)	128.9 ± 5.9	128.9 ± 5.8	0.975

HAL, hip axis length; FAL, femoral neck axis length; AW, acetabular width; HW, femoral head width; FW, femoral neck width; FSW, femoral shaft width; TW, intertrochanteric width; NMCT, femoral neck cortical thickness; SMCT, medial cortical thickness of femoral shaft; LCT, lateral cortical thickness of femoral shaft; Q-angle, femoral neck-shaft angle.

Table 3. Outcomes of HAL, FAL, AW and HW in Cases with and without Hip Fractures

Parameters	Cases with hip fracture (N=29)	Cases with no hip fracture (N=232)	*p*-value
HAL (mm)	130.3 ± 5.7	130.5 ± 8.9	0.921
FAL (mm)	111.7 ± 5.5	112.7 ± 6.9	0.461
AW (mm)	18.2 ± 3.0	17.8 ± 3.8	0.536
HW (mm)	53.3 ± 2.3	53.3 ± 3.2	0.895

HAL, hip axis length; FAL, femoral neck axis length; AW, acetabular width; HW, femoral head width.

Table 4. Outcomes of FW, FSW, TW, NMCT, SMCT, LCT and Q-angle in Cases with and without Hip Fractures

Parameters	Cases with hip fracture (N=29)	Cases with no hip fracture (N=232)	*p*-Value
FW (mm)	37.3 ± 2.7	35.8 ± 2.8	0.01
FSW (mm)	35.6 ± 3.1	37.6 ± 3.0	0.001
TW (mm)	60.4 ± 3.5	62.5 ± 5.3	0.038
NMCT (mm)	1.6 ± 0.5	2.1 ± 0.7	0.001
SMCT (mm)	5.8 ± 1.2	7.8 ± 1.4	<0.001
LCT (mm)	5.3 ± 1.2	7.0 ± 1.3	<0.001
Q-angle (degree)	132.8 ± 5.5	128.9 ± 5.9	0.01

FW, femoral neck width; FSW, femoral shaft width; TW, intertrochanteric width; NMCT, femoral neck cortical thickness; SMCT, medial cortical thickness of femoral shaft; LCT, lateral cortical thickness of femoral shaft; Q-angle, femoral neck-shaft angle.

DISCUSSION

Recent studies have shown that the geometry of the femoral neck is associated with the risk of hip fracture in the elderly. Indeed, HAL deserves particular attention and is independent of age and BM, which is not affected by the femoral BMD and body size.[4,6,8-12]

Different ethnicities play an important role in the distribution of hip fractures. The difference of incidences between ethnic groups is attributed to different geometric measurements.[13-15] In England, with many northern Europeans, the incidence of hip fracture in people over 50 years of age was found to be higher when compared with those living in New Zealand, Scandinavian and South Africa.[16] This incidence is quite low amongst the Maori people and amongst the Bantus in New Zealand and in South Africa, respectively but is relatively high amongst the Hindus in Singapore.[17-19]

Femoral neck fractures occur less frequently in blacks who are American-born or of African origin than in Caucasians living in northern Europe.[20,21] This is explained on the basis of the BMD since peak bone density is higher in blacks with a slower ossifluence. However, the Bantus in South Africa are different in this respect because they have been reported to have a lower incidence of fracture whereas the values for BMD are lower than that of Caucasian in Johannesburg.[22] This inconsistency is associated with a much lower frequency of falling down as it has been reported for black women.[23-25] Similarly, this inconsistency has also been related to such geometric femoral measurements as the increased HAL or Q-angle.[13,14] Indeed, the risk of fracture is higher in cases with increased HAL values. Because black women have shorter HAL, TW and a thicker cortical bone in geometric femoral measurements, less frequent femoral neck fractures occur in blacks of African origin than in Caucasians in northern Europe.[11]

As expected, the average age of cases with fracture was higher than those without hip fractures due to the increase in frequency of hip fracture. However, such a difference of age between our groups is not important because it has been reported that the geometry of the hip, an indicator for hip fractures, is independent of age and BMD.[4] In addition, The BMI of the cases with hip fracture was lower. When falling down, although the femur is expected to be exposed to greater forces in taller and heavier individuals, it is known that the body weight plays a preventative role in hip fractures.[26]

In a study involving 8074 white women, Faulkner et al.[4] found that the risk of hip fracture for HAL was nearly twice the mean value for each standard deviation. On the other hand, Karlsson et al.[10] could not find any relationship between the risk of fracture and FAL in their measurements among the Swedish population. On the contrary, they even found shorter FAL values in cases with no fracture. Although Nelson et al.[27] reported that there was not a difference for HAL between black and white males, there are also some clinical studies showing a lower risk of hip fracture in black males. As a result, femoral geometry in women is thought to be clinically important.[28]

All the cases in our study were post-menopausal women, and we could not find any significant differences in terms of HAL, FAL, AW, HW and FW in cases with or without hip fractures (Table 4). There are some controversial reports in the literature on this regard. Faulkner et al.[5] have reported that the relationship between a fracture and HAL is likely to be ensured through AW, which is associated with only femoral neck fracture.[9] However, Peacock et al.[6] have proposed that AW is not associated with any type of fracture. All our patients with fractures had femoral neck fracture and we could not find any significant differences with respect to AW between the patients with and without fractures.

We found that FSW and TW values were lower in patients with fractures. We also demonstrated that NMCT, LCT and SMCT were much lower in cases with fractures. These results were similar with those found by Theobald et al.[11] that demonstrated the group with fractures having lower NMCT and SMCT. Gluer et al.[9] have claimed that SMCT and NMCT are strong parameters in trochanteric and femoral neck fractures, respectively. In the present study, all cases in group 2 had femoral neck fractures, and we thought that the risk in femoral neck fractures was more associated with cortical thickness. We found that Q-angle measurements were higher in cases with fractures than those in cases with no fractures. On the other hand, Karlsson et al.[10] observed that Q-angle was much lower in cases with fractures. Although there was no significant statistical difference in the cases with fractures, Q-angle was found to be higher in cases with hip fracture by another study of Peacock et al.[6]

In conclusion, femoral geometry can account for the differences in the incidence of fracture in populations that is not explained by density. We think that FW, FSW, TW, NMCT, SMCT, LCT and Q-angle measurements are important parameters in the assessment of tendency toward hip fractures.

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