

# RADIOGRAPHIC ANATOMY OF THE PROXIMAL FEMUR: CORRELATION WITH THE OCCURRENCE OF FRACTURES

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## ABSTRACT

**Objective:** To evaluate the correlation between radiographic parameters of the proximal femur anatomy and fractures. **Methods:** Three hundred and five digital x-rays of the pelvis were analyzed in the anteroposterior view. Of these x-rays, twenty-seven showed femoral neck or transtrochanteric fractures. The anatomical parameters analyzed were: femoral neck width (FNW), femoral neck length (FNL), femoral axis length (FAL), cervicodiaphyseal angle (CDA), acetabular tear-drop distance (ATD) and great trochanter-pubic symphysis distance (GTP-

SD). The analysis was performed by comparing the results of the x-rays with and without proximal femoral fracture, to establish a correlation between them. **Results:** No differences were found between the anatomical parameters of the groups with and without proximal femoral fracture. **Conclusion:** There was no association between anatomical changes in the proximal femur and greater susceptibility to fractures. **Level of evidence IV, Cross-sectional Study.**

**Keywords:** Femur. Femoral fractures. Femur neck. Radiography.

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## INTRODUCTION

Proximal femoral fractures in elderly patients are considered severe and have a direct and negative impact on the life expectancy and quality of life of these patients. The diagnosis of fractures of the proximal extremity of the femur is usually carried out objectively with a careful physical examination and radiographs of the pelvis and of the coxofemoral joint in the anteroposterior and lateral views.<sup>1</sup>

According to US statistics, more than 250,000 hip fractures occur every year and this number will be doubled in about 30 years' time.<sup>2</sup> Advanced age, female sex, osteoporosis, Caucasians, smoking, alcoholism, previous fracture, history of falls and low estrogen level are the main risk factors for the occurrence of hip fractures.<sup>2</sup> In the elderly, minor falls from the orthostatic position are responsible for approximately 90% of proximal femoral fractures. In young patients the rate of hip fractures is low, and when present, is associated with high-energy trauma.<sup>2</sup>

The overload on the proximal extremity of the femur generates

deforming forces that result in fracture occurrence. The treatment of proximal femoral fractures aims to allow the fast mobilization of the patient and the reestablishment of hip function.<sup>3-5</sup> The characteristic morphology of the proximal extremity of the femur and the muscle balance of the hip are factors that make weight bearing possible among patients.<sup>4</sup> Recent studies have been conducted with the intention of showing the relationship between fracture of the proximal extremity of the femur and the anatomical configuration of the hip.<sup>3,4</sup>

The objective of this study is to evaluate, through digital radiography of the pelvis, whether there is any correlation between the occurrence of proximal femoral fractures and morphometric alterations of the hip.

## MATERIAL AND METHOD

Three hundred and five (305) digital radiographs of the pelvis of patients treated in the emergency room of an Orthopedic and Traumatology clinic of a general hospital were evaluated in the

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Study conducted at the Orthopedic and Traumatology Clinic of Hospital Felício Rocho - Belo Horizonte - MG.

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anteroposterior view, between February and April 2010. The radiographs were selected at random, by active search in the hospital's image bank. Inclusion criterion: digital panoramic radiographs of the pelvis of skeletally mature patients. Exclusion criterion: radiographs of skeletally immature patients, bilateral fracture of the hips and presence of tumor-like or infectious lesions that could alter the anatomy of the proximal region of the femur.

We analyzed the distribution with regards to sex, stratification by ages (under 35 years; between 31 and 65 years and over 65 years) and compared the data between the groups with and without proximal femoral fracture.

The pelvic radiographs were taken in the anteroposterior view, with the tube at a distance of 1 meter from the chassis. The patient was positioned in horizontal supine position and the lower limbs internally rotated 20°.

In the morphometric evaluation of the normal hips, i.e., without fractures, the right side was chosen, while in patients with fractures, the measurement was taken on the normal side (contralateral to the fracture).

#### The analyzed measurements were:

femoral neck width - (FNW),  
 femoral neck length - (FNL),  
 femoral axis length - (FAL),  
 cervicodiaphyseal angle - (CDA),  
 acetabular tear-drop distance - (ATD),  
 great trochanter-pubic symphysis distance - (GTPSD).

The choice of these measurement indexes was based on previous studies of morphometric analysis of the proximal region of the femur.

All the measurements were obtained by two examiners, with the help of the measurement tools of the *PACS Vepro Medimage software, version 7.2 (SP 1)\**. (Figure 1)

In comparing the means and medians of the six variables (FNW, FNL, FAL, CDA, ATD, GTPSD), according to fracture occurrence, we used the Student's t-test for independent samples, in cases of normality of data, and the Mann-Whitney test, in cases of non-normality.

In comparing the means and medians of the six variables according to age bracket, we used ANOVA in cases of normality and the Kruskal-Wallis test in cases of non-normality.

The differences between the pairs of age brackets were verified by means of Dunn's post-test.

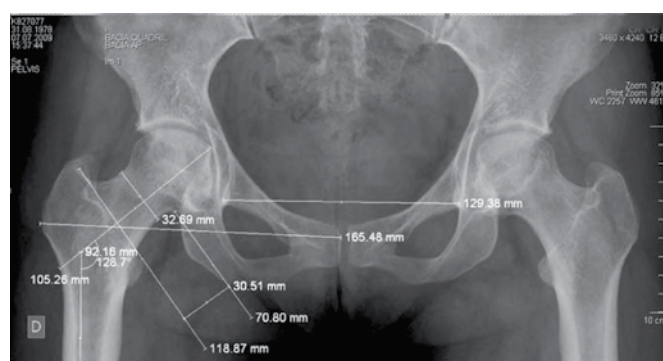
The statistical programs used were *SPSS for Windows 15.0*, *Minitab 14.0* and *GraphPad Prism 4*.

The significance level ( $\alpha$ ) considered was 0.05.

## RESULTS

Table 1 presents the patients' distribution according to sex, age bracket and fracture occurrence. The group is made up of 61.3% (187) women and 38.7% (118) men. As regards age bracket: 29 (9.5%) were up to 30 years of age; 148 (48.5%) from 31 to 65 years and 128 (42%) 66 years or over. Twenty-seven (8.9%) radiographs presented proximal femoral fracture.

As regards age distributed in years, the mean was 59.2 years (SD=20), minimum of 18 and maximum of 100 years. (Table 2) Table 3 presents the distributions of the variables FNW, FNL, FAL, CDA, ATD and GTPSD. The mean femoral neck width



FNW	Femoral Neck Width	32.69 mm
FNL	Femoral Neck Length	30.51 mm
FAL	Femoral Axis Length	105.26 mm
CDA	Cervicodiaphyseal Angle	128.7°
ATD	Acetabular Tear-Drop Distance	129.38 mm
GTPSD	Great Trochanter-Pubic Symphysis Distance	165.48 mm

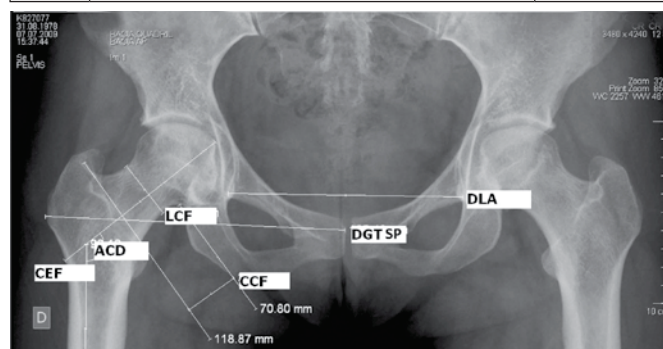


Figure 1. Measurements analyzed in the AP radiographs of the pelvis.

was 36.6 millimeters (SD=4.8), minimum 26 and maximum 53 millimeters. The third quartile was equal to 40 millimeters, meaning that 25% of the patients had a femoral neck width of 40 millimeters or above. The interpretation of the other variables is similar to this interpretation of the femoral neck width.

Table 4 presents the verification of normality of variables FNW, FNL, FAL, CDA, ATD and GTPSD according to the age bracket. The variables FNW, FNL, FAL and CDA do not follow normal distribution according to the age bracket, while the variables ATD and GTPSD do follow this distribution.

The median of the femoral neck width for the patients aged up to 30 years was 41 millimeters; for the patients aged from 31 to 65 years it was 35 millimeters and for the patients aged 66 years or over it was 36 millimeters. This difference was statistically significant (Kruskal-Wallis Statistic=9.758; p-value =0.008) (Table 5). Based on the post-test, it was concluded that the differences are between and among the brackets "up to 30 years" and "31 to 65 years" and up to 30 years" and "66 years or over", while the patients from the "up to 30 years" bracket have a statistically higher median than the patients from the "31 to 65 years" bracket (p-value < 0.05), and higher than the patients from the "66 years or over" bracket (p-value p < 0.01). The median of the femoral axis length for the patients aged up to 30 years was 118 millimeters; for the patients aged from 31 to 65 years it was 111 millimeters and for the patients aged 66 years or over it was 112 millimeters. This difference was

**Table 1.** Distribution of the patients according to sex, age bracket and occurrence of fracture.

Variable	N	%
Sex		
Female	187	61.3%
Male	118	38.7%
Total	305	100.0%
Age bracket		
Up to 30 years	29	9.5%
31 to 65 years	148	48.5%
66 years or over	128	42.0%
Total	305	100.0%
Fracture		
No	278	91.1%
Yes	27	8.9%
Total	305	100.0%

**Table 2.** Distribution of age (in years) of the patients.

Variable	N	Mean	S-D	Minimum	Maximum	1 <sup>st</sup> quartile	Median	3 <sup>rd</sup> quartile
Age (in years)	305	59.2	20.0	18.0	100.0	44.0	59.0	76.0

S-D: standard deviation

**Table 3.** Distribution of the Variables FNW, FNL, FAL, CDA, ATD, GTPSD.

Variable	N	Mean	S-D	Minimum	Maximum	1 <sup>st</sup> quartile	Median	3 <sup>rd</sup> quartile
Femoral Neck Width	305	36.6	4.8	26.0	53.0	33.0	36.0	40.0
Femoral Neck Length	305	35.7	6.4	17.0	60.0	32.0	36.0	40.0
Femoral Axis Length	305	113.4	9.7	92.0	147.0	107.0	113.0	120.0
Cervicodiaphyseal Angle	305	129.2	5.5	111.0	144.0	126.0	129.0	132.0
Acetabular tear-drop distance	305	133.4	11.1	104.0	169.0	125.5	133.0	141.0
Great trochanter-pubic symphysis distance	305	176.9	11.5	144.0	209.0	169.0	177.0	185.0

S-D: standard deviation

statistically significant (Kruskall-Wallis Statistic=9.743; p-value =0.008). (Table 5) Based on the post-test, it was concluded that the differences are between and among the brackets "up to 30 years" and "31 to 65 years", "and up to 30 years" and "66 years or over", while the patients from the "up to 30 years" bracket have a statistically higher median than the patients from the "31 to 65 years" bracket (p-value < 0.01), and higher than the patients from the "66 years or over" bracket (p-value < 0.01). The median of the cervicodiaphyseal angle for the patients aged up to 30 years was 132 degrees; for the patients aged from 31 to 65 years it was 129 degrees and for the patients aged 66 years or over it was 129 degrees. This difference was statistically significant (Kruskall-Wallis Statistic =8.903; p-value =0.012) (Table 5). Based on the post-test it was concluded that

**Table 4.** Verification of normality of the variables FNW, FNL, FAL, CDA, ATD, GTPSD according to age bracket.

Variable	Age bracket	Statistic K-S	p-value
Femoral Neck Width	Up to 30 years	0.205	0.003*
	31 to 65 years	0.119	0.000*
	66 years or over	0.066	>0.200
Femoral Neck Length	Up to 30 years	0.108	>0.200
	31 to 65 years	0.080	0.021*
	66 years or over	0.060	>0.200
Femoral Axis Length	Up to 30 years	0.113	>0.200
	31 to 65 years	0.109	0.000*
	66 years or over	0.073	0.088*
Cervicodiaphyseal angle	UP to 30 years	0.161	0.054*
	31 to 65 years	0.105	0.000*
	66 years or over	0.094	0.008*
Acetabular tear-drop distance	Up to 30 years	0.143	0.135
	31 to 65 years	0.051	>0.200
	66 years or over	0.053	>0.200
Great trochanter-pubic symphysis distance	Up to 30 years	0.134	0.197
	31 to 65 years	0.058	>0.200
	66 years or over	0.072	0.175

\*:Does not follow normal distribution.

K-S: Kolmogorov-Smirnov test

the differences are between and among the brackets "up to 30 years" and "31 to 65 years" and "up to 30 years" and "66 years or over", while the patients from the "up to 30 years" bracket have a statistically higher median than the patients from the "31 to 65 years" bracket (p-value < 0.01), and higher than the patients from the "66 years or over" bracket (p-value < 0.05). Table 6 presents the verification of normality of variables FNW, FNL, FAL, CDA, ATD and GTPSD according to the occurrence of fracture. The only variable that follows normal distribution, in keeping with the two categories of the fracture variable (yes, no), was the acetabular tear-drop distance.

Statistically significant difference was detected in the median of the femoral neck length in keeping with the fracture (Mann-Whitney U test =2729.5, p-value =0.019). For the non-fractured femurs, the median of this variable was equal to 36 millimeters and for the fractured femurs it was equal to 33 millimeters. At this point, the normality of the femoral neck length was verified according to sex, and was not normal for the male sex. Such being the case, the median of the femoral neck length was compared by means of the Mann-Whitney nonparametric test. Statistically significant difference was also detected in the femoral neck length between the sexes. It was concluded that the median of the femoral neck length for men (37) is statistically higher than the median of the women (35).

Due to the results obtained, comparisons were made between the femoral neck length of the men and of the women, separately, according to the occurrence of fracture.

Normality of the femoral neck length variable was verified both for the men and for the women, separately, according to the occurrence of fracture. For the women, the variable followed normal distribution for the two categories of fracture, while for the men, the variable was not normal for the fractured femurs.

**Table 5.** Distribution of the variables FNW, FNL, FAL, CDA, ATD, GTPSD according to age bracket.

Variable	Age bracket	N	Mean	S-D	Minimum	Maximum	1 <sup>st</sup> quartile	Median	3 <sup>rd</sup> quartile	Statistic	p-value
Femoral Neck Width**	Up to 30 years	29	39.2	4.7	30.0	47.0	34.5	41.0	42.5	9.758	0.008*
	31 a 65 years	148	36.2	4.6	28.0	53.0	33.0	35.0	39.0		
	66 years or over	128	36.3	4.9	26.0	49.0	33.0	36.0	39.0		
Femoral Neck Length**	Up to 30 years	29	37.2	6.4	23.0	48.0	33.0	37.0	42.5	4.315	0.116
	31 a 65 years	148	36.3	6.3	17.0	60.0	32.0	36.0	41.0		
	66 years or over	128	34.8	6.5	17.0	50.0	31.0	35.0	39.0		
Femoral Axis Length**	Up to 30 years	29	118.3	9.3	94.0	134.0	113.0	118.0	126.0	9.743	0.008*
	31 a 65 years	148	113.1	9.6	92.0	147.0	106.0	111.0	120.8		
	66 years or over	128	112.7	9.6	92.0	140.0	107.0	112.0	118.8		
Cervicodiaphyseal angle**	Up to 30 years	29	131.7	5.1	120.0	144.0	129.0	132.0	134.0	8.903	0.012*
	31 to 65 years	148	129.3	5.4	111.0	144.0	126.3	129.0	132.0		
	66 years or over	128	128.6	5.7	116.0	143.0	125.0	129.0	132.0		
Acetabular tear-drop distance ***	Up to 30 years	29	134.7	10.9	119.0	169.0	128.5	134.0	139.0	0.279	0.756
	31 to 65 years	148	133.0	11.1	104.0	162.0	126.0	132.5	141.8		
	66 years or over	128	133.5	11.2	106.0	159.0	125.0	133.5	142.0		
Great trochanter-pubic symphysis distance ***	Up to 30 years	29	179.6	11.5	152.0	194.0	173.0	182.0	189.0	0.927	0.397
	31 to 65 years	148	176.9	10.8	153.0	205.0	169.0	178.0	184.0		
	66 years or over	128	176.4	12.3	144.0	209.0	168.3	176.0	184.0		

\* Statistically significant. \*\* Kruskal-Wallis test carried out \*\*\* ANOVA carried out.

**Table 6.** Verification of normality of the variables FNW, FNL, FAL, CDA, ATD, GTPSD according to the occurrence of fracture.

Variable	Fracture	Kolmogorov-Smirnov Statistic	p-value
Femoral Neck Width	No	0.095	0.000*
	Yes	0.105	>0.200
Femoral Neck Length	No	0.065	0.006*
	Yes	0.092	>0.200
Femoral Axis Length	No	0.074	0.001*
	Yes	0.110	>0.200
Cervicodiaphyseal angle	No	0.087	0.000*
	Yes	0.126	>0.200
Acetabular tear-drop distance	No	0.037	>0.200
	Yes	0.079	>0.200
Great trochanter-pubic symphysis distance	No	0.055	0.043*
	Yes	0.093	>0.200

\*Does not follow normal distribution.

Such being the case, the mean femoral neck length variable was compared among the women, and the median among the men. No statistically significant difference was detected in the femoral neck length according to the occurrence of fracture, either for the men (median for the non-fractured femurs=38, for the fractured femurs=33.5) or for the women (median for the non-fractured femurs=35, for the fractured femurs=33).

Such being the case, for the femoral neck length variable, it is concluded that sex is a "confusing factor", as it influences the size of the femoral neck length with statistically significant difference in relation to the fracture, when not considered in the analysis. In performing the comparison of this variable according to the occurrence of fracture separately for each sex, this difference does not appear significant. The great trochanter-pubic symphysis distance was also statistically greater in the non-fractured patients (Mann-Whitney U test =2863.0, p-value =0.042).

We also verified the normality of the great trochanter-pubic symphysis distance variable according to sex. The result found was not normal for the male sex. Such being the case, we compared the median of the great trochanter-pubic symphysis distance by means of the Mann-Whitney nonparametric test.

Statistically significant difference was detected in the great trochanter-pubic symphysis distance according to sex. It was concluded that the median of the great trochanter-pubic symphysis distance for the men (183) is statistically higher than the median of the women (175).

Due to the results obtained, comparisons were made between the great trochanter-pubic symphysis distance of the men and of the women, separately, according to the occurrence of fracture. Normality of the great trochanter-pubic symphysis distance variable was verified both for the men and for the women, separately, according to the occurrence of fracture. For the women, the variable followed normal distribution for the two categories of fracture, while for the men, the variable was not normal for the non-fractured femurs. Such being the case, the mean great trochanter-pubic symphysis distance variable was compared among the women, and the median among the men.

No statistically significant difference was detected in the great trochanter-pubic symphysis distance in relation to the occurrence of fracture, either for the men (median for the non-fractured femurs = 183, for the fractured femurs=177) or for the women (median for the non-fractured femurs =175, for the fractured femurs=173).

Thus it is concluded that sex is a "confusing factor" that influences the size of the great trochanter-pubic symphysis distance. There is statistically significant difference in relation to the fracture, when the sex is not considered in the analysis. In performing the comparison of this variable according to the occurrence of fracture separately for each sex, this difference does not appear significant.

The normality of the cervicodiaphyseal angle variable was ve-



rified at this point. It was concluded that this angle does not follow normal distribution.

The median of the cervicodiaphyseal angle ( $129^\circ$ ) is statistically lower than  $135^\circ$  (Wilcoxon Statistic=2840.5; p-value =0.000) and  $130^\circ$  (Wilcoxon Statistic=16333; p-value=0.005).

## DISCUSSION

Proximal femoral fractures represent a serious public health problem in Brazil and in the world due to the high morbimortality and the massive expenses resulting from their treatment. The prevention of the occurrence of fractures due to osteoporosis becomes the principal plan of action against this problem that affects about 250,000 new patients per year.<sup>2</sup> Nutritional guidance, the encouragement of the practice of impact exercises, exposure to morning sunlight, adaptation of the homes of elderly patients with fall prevention measures and, in some cases, treatment with medications, are important strategies that can reduce the risk of fractures resulting from osteoporosis.

The treatment of proximal femoral fractures is, as a rule, surgical. The methods range from osteosynthesis of the fracture with plates, screws or locked intramedullary nails to hip arthroplasty. The aim of this study is to observe whether there is any morphometric parameter in the proximal region of the femur able to predict greater risk of occurrence of proximal femoral fractures. We achieved a larger sample size than that observed in previous studies (305 radiographs) and the distribution in terms of sex was similar to that found in the literature. The racial factor was not covered on account of the difficulty in stratifying groups due to the considerable racial miscegenation of the Brazilian population.<sup>5-10</sup>

The analysis of the measurements of the radiographic parameters by two examiners and the use of digital radiography with a tool able to correct distortions resulting from the patient-tube distance of the radiography device (PACS Vepro Medimage system, version 7.2 SP 1) minimized the risk of erroneous data acquisition.

Canto et al.<sup>4</sup> analyzed 126 radiographs of the coxofemoral joint, of which 42 had no fracture, 42 had transtrochanteric fracture and 42 had femoral neck fractures. In their series, the authors observed: significant correlation comparing the acetabular tear-

-drop distance and the great trochanter distance in the groups of patients with fractures; significant correlation between the increase of the cervicodiaphyseal angle and the incidence of proximal femoral fracture; significant correlation between the acetabular tear-drop distance and the incidence of femoral neck and transtrochanteric fractures. There was no significance between the axial length of the hip and the incidence of proximal femoral fracture. The author emphasizes that he did not find any explanation for valgism of femoral neck being considered a risk factor, since the greater the values of varism, the greater the lever arm between the abductor muscles and the center of rotation of the hip and, therefore, the more vulnerable the patient to the occurrence of fractures. This finding was also corroborated by other studies.<sup>5,11</sup> Other authors, however, did not encounter such an association.<sup>12,13</sup> According to Sisk,<sup>14</sup> the fact that the femoral neck of women is more horizontal would explain the higher occurrence of proximal femoral fractures in the female sex.

In the present study, the number of women was almost twice that of the men - ratio: 2:1, and the average age of these patients, whose radiographs were analyzed, was 59.2 years. Twenty-seven (8.9%) of the 305 radiographs analyzed presented fractures.

The increase in femoral neck axis length is apparently related to a higher occurrence of fractures, according to some trials.<sup>5-7</sup> In our series of 305 pelvic radiographs in the anteroposterior view, of which 27 presented proximal femoral fractures, no association was found between the radiographic parameters measured and higher risk of fractures. It should be emphasized that, initially, the femoral neck length and the great trochanter-pubic symphysis distance presented statistically significant correlation for occurrence of fractures. However, when the abovementioned variables were analyzed according to distribution by sex, there was no statistically significant correlation, which indicates that the parameter "sex" was a "confusing factor" in the analysis of such variables.

## CONCLUSION

No correlation was found between radiographic parameters of the proximal femur and the occurrence of fractures.

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