

Evaluation and Categorization of Femur Morphometry with Digital Measurement Method

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ABSTRACT

BACKGROUND

Variational differences of the femur between populations like clinical, anthropological and forensic anthropology are important. These morphometric differences are influenced by factors such as race, heredity, climate and diet.

METHODS

With the descriptive and cross-sectional design of this study, we aimed to investigate the femur morphometry with digital image analysis program. In this study, 105 femur bones belonging to Cukurova University, Medicine Faculty, Anatomy Department, were used. This study which has a descriptive and cross-sectional design, was carried out in April 2018. For statistical analysis, "Statistical Package for Social Sciences for Windows 20.0" program was used.

RESULTS

The mean and standard deviation values of the parameters measured in femur were as follows- maximum femur length 431.42±36.2, physiological femur length 428±36.15, physiological trochanter length 403.3±34.3, anterior, posterior, superior and inferior aspects of collum femoris length 28±5.30, 25.5±5.4, 26.2±5.4, 39±7.5, caput femoris diameter 44±4, collum femoris width 34.2±7.15, collum femoris axis length 95.2±10, transverse and sagittal aspects of subtrochanteric diameter 30±3, 25.01±3, linea intertrochanterica length 68.1±8.22, transverse and sagittal aspects of mid-body diameter 27.03±3, 27.22±3, maximum proximal and distal width 86.1±13, 76.3±8, intercondylar width and depth 18.3±3.32, 25±4, condylar width and depth were 70.14±7.2, 57.4±7, midbody circumference was 85.5±9.03 mm. The mean weight of the femur was determined as 292.4±68.04 gr. Robustness, platymeria, pilastric, intercondylar width and depth indexes were calculated. Averages values of these indexes respectively were 13±2, 84.15±10, 101.22±10.4, 0.3±0.04, 0.43±0.05.

CONCLUSIONS

Although the mean morphometric data of the right femurs obtained from our study were higher than the left femurs, there was no significant difference ($p > 0.05$); There was a statistically significant difference between the right and left femurs in the intercondylar depth average ($p < 0.05$). When the studies in the literature were compared with our results, it was found that the nearest average values were the maximum femur length and physiological femur length. Studies suggest that differences in femur geometry may be caused by race-dependent characteristics. The anatomical structure and morphometric measurements of the femur are clinically important for femoral fractures and pathologies. In addition, the data obtained from this study will be used by anthropologists for various determinations in the field of forensic medicine. We think that the results of our study will help clinicians in surgical interventions.

KEY WORDS

Femur, Morphometry, Anthropology, Index, Population, Anatomy

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BACKGROUND

Human skeletal structure differs between populations. While the morphological values of the individuals living in different historical periods of a specific society may vary, the values of the societies living in the same period may be diverse. The femur, which is the longest and most powerful bone of the human skeleton, has a trajectory structure that can transfer the weight in the most appropriate way.^{1,2} Morphometric analysis should be done correctly to maintain this specific structure. Morphometric values of the femur are important for the determination of inter-racial features and differences. In this study, morphometric data of femur were obtained by digital image analysis program. Computerized analysis programs are becoming widespread through developing technology. In this way, the rate of efficient use of time increases and the materials are used for longer periods. In addition, these digital image analysis programs provide more precise and accurate results. For these reasons, it is preferred more frequently.³ We believe that this study will contribute to the database of our society by determining the morphometric differences between the populations. In addition, morphometric analysis of femur is of great importance in terms of postoperative success when prosthetic surgery is required. The main objective of total hip replacement implants is to provide stability without restricting movement.⁴ For this purpose, it is seen that proximal femur has morphometric importance especially in prosthesis design.⁵ In addition, by standardizing the data obtained, it is easier to identify possible risk factors for pathological conditions. The majority of the morphometric data in the literature were obtained by conventional (Manual) morphometric measurements. This study investigated that the femur morphometry with digital image analysis program.

METHODS

This descriptive and cross-sectional design, 105 (55 right, 50 left) femoral bone with unknown age and gender were used in Cukurova University, Faculty of Medicine, Department of Anatomy. The photographs of the bones were taken with a digital camera (Canon®, model 50D) at a distance of 70 cm under artificial light using a scale with a fixed length. The aperture is set to f/5, the exposure time is 1/ 60s and the ISO value is set to 100. Photos taken were transferred to computer. The photographs were examined using the digital image analysis program (Digimizer™, Japan) to determine the morphometric properties of the bones. In the photographs, the reference points of the parameters were determined, and the lines were drawn in the required directions. And the determined twenty-three parameters were measured. These parameters are generally used for sex determination. Measurements in the femur bone (Figure 1):

Maximum Femur Length

The linear distance between the tangent passing through the top point of the Caput Femoris and the tangent passing through the lowest point of the condylus medialis.

Physiological Femur Length

The linear distance between the tangent passing through the top point of caput femoris and the tangent passing through the lowest point of condylus medialis and condylus lateralis.

Physiological Trochanter Length

The linear distance between the tangent passing through the top point of the trochanter major and the tangent passing through the lowest point of the condylus medialis and condylus lateralis while maintaining the normal inclined position of the femur.

Anterior Collum Femoris Length

The linear distance between the midpoint of the epiphysis line and the midpoint of the linea intertrochanterica.

Superior Collum Femoris Length

The linear distance between the apex of the epiphysis line and the apex of the trochanter major.

Inferior Collum Femoris Length

The linear distance between the lower point of the epiphysis line and the apex of the trochanter minor.

Posterior Collum Femoris Length

On the posterior aspect, the linear distance between the midpoint of the epiphysis line and the midpoint of the crista intertrochanterica.

Collum Femoris Width

The length of the line taken vertically to the line connecting midpoint of the linea intertrochanterica and the midpoint of the epiphysis line.

Linea Intertrochanterica Length

The linear distance that passes through the peaks of the trochanter major and trochanter minor.

Maximum Proximal Width

The linear distance between the highest point of the caput femoris and the trochanter major.

Maximum Distal Width

The linear distance between the epicondylus medialis and epicondylus lateralis where they are most protruding to the sides.

Collum Femoris Axis Length

The linear distance between the outermost protrusion of the trochanter major and the highest point of the caput femoris.

Mid-Body Circumference

The mid-body circumference was measured with a tape measure.

Caput Femoris Diameter

The length that lies between the two points where the convexity of the caput femoris is highest in its vertical direction.

Subtrochanteric Sagittal Diameter

The distance measured from the approximately 3-6 mm bottom of the trochanter minor and the anterior-posterior direction.

Subtrochanteric Transverse Diameter

The distance measured from the approximately 3-6 mm bottom of the trochanter minor and the horizontal diameter which is taken vertically in line with the subtrochanteric sagittal diameter.

Mid-Body Sagittal Diameter

The diameter taken from the middle of the femur body in the anterior-posterior direction.

Mid-body Transverse Diameter

The diameter taken from the middle of the femur body in the horizontally at the same level perpendicular to the mid-body sagittal diameter.

Intercondylar Width

The distance between the lateral edge of the condylus medialis and the medial edge of the condylus lateralis in the distal part of the femur.

Intercondylar Depth

This is the distance between the deepest point of the posterior edge of the intercondylar region and the midpoint of the condylus medialis and condylus lateralis in the distal part of femur.

Condylar Width

At the lower end of the femur, the linear distance between the points at the condylus medialis-condylus lateralis are most protruding laterally.

Condylar Depth

At the lower end of the femur, the linear distance between the midpoint of the line joining the most extreme points of the posterior edges of the condylus medialis-the condylus lateralis and the midpoint of the line joining the most extreme points of the front edges.

Weight of Femur

Precision scale

In addition, robustness index, platymeria index, pilastric index, intercondylar width index and intercondylar depth index were calculated.⁶⁻⁹

Robustness Index

An index used to define the mass of bone. It is important in gender discrimination. Calculation method; midbody transverse length + midbody sagittal length ÷ physiological femoral length × 100.

Platymeria Index

Describes the flatness of the upper part of the femoral body. Calculation method; subtrochanteric sagittal diameter ÷ subtrochanteric transverse diameter × 100. Categorization values; hyperplatymeria/very flat (≤75),

platymeria/flat (75–84.9), eumeria/round (85–99.9), stenomeria/very round (≥100).

Pilastric Index

Defines the degree of development of linea aspera. Linea aspera provides support and stabilization of the femur during walking and running. Linea aspera, which started to emerge in pubertal period, becomes more prominent with age because of this feature. Calculation method; midbody sagittal diameter ÷ mid-body transverse diameter × 100. Categorization values; no pilastric (≤100), light pilastric/linea aspera weak (100–109.9), intermediate pilastric/linea aspera normal (110–119.9), advanced/strong pilastric/linea aspera prominent (≥120).

Intercondylar Width Index

Intercondylar width ÷ condylar width.

Intercondylar Depth Index

Intercondylar depth ÷ condylar depth.

For statistical analysis, "Statistical Package for Social Sciences for Windows 20.0" program was used. Descriptive Statistical methods (Mean, standard deviation, frequency%, minimum, maximum value) were used to evaluate the study data. Student's t-test was used to compare the right and left sides of the femur. The results were evaluated with a confidence interval of 95% and a significance level of p < 0.05.

RESULTS

The mean, standard deviation and minimum-maximum values of the determined parameters are shown in table 1. Mean values of robustness, platymeria, pilastric, intercondylar width and intercondylar depth indices were 13±2, 84.15±10, 101.22±10.4, 0.3±0.04 and 0.43±0.05 respectively. Platymeria index value belongs to eumeria (Round) and pilastric index value belongs to light pilastric (Linea aspera weak) classification. There was no significant difference between right and left femurs. Parameters were measured in mm, excluding femoral weight (gr).

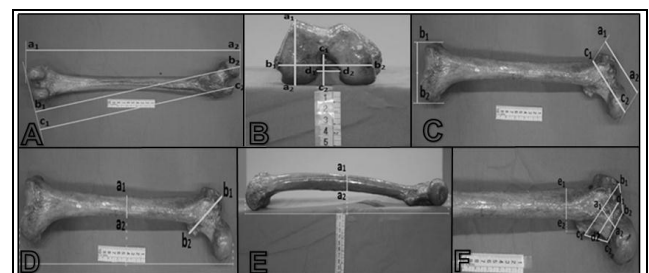


Figure 1. A. Maximum Femur Length (a1-a2), Physiological Femur Length (b1-b2), Physiological Trochanter Length (c1-c2). B. Condylar Depth (a1-a2), Condylar Width (b1-b2), Intercondylar Depth (c1-c2), Intercondylar Width (d1-d2). C. Maximum Proximal Width (a1-a2), Maximum Distal Width (b1-b2), Collum Femoris Axis Length (c1-c2). D. Mid-Body Transverse Diameter (a1-a2), Linea Intertrochanterica Length (b1-b). E. Mid-Body Sagittal Diameter (a1-a2). F. Collum Femoris Anterior Length (a1-a2), Collum Femoris Superior Length (b1-b2), Collum Femoris Inferior Length (c1-c2), Collum Femoris Width (d1-d2), Subtrochanteric Sagittal Diameter (e1-e2).

Parameters	Mean ± SD (mm)
Maximum femur length	431.42±36.2
Physiological trochanter length	403.3±34.3
Collum femoris anterior length	28±5.30
Collum femoris superior length	26.2±5.4
Collum femoris inferior length	39±7.5
Collum femoris width	34.2±7.15
Collum femoris axis length	95.2±10
Linea intertrochanterica length	68.07±8.22
Maximum proximal width	86.1±13
Maximum distal width	76.3±8
Collum femoris posterior length	25.5±5.4
Femur weight (gr)	292.4±68.04
Mid-body circumference	85.5±9.03
Caput femoris diameter	44±4
Physiological femur length	428±36.15
Subtrochanteric sagittal diameter	25.01±3
Subtrochanteric transverse diameter	30±3
Mid-body sagittal diameter	27.22±3
Mid-body transverse diameter	27.03±3
Intercondylar width	18.3±3.32
Intercondylar depth	25±4
Condylar width	70.14±7.2
Condylar depth	57.4±7

Table 1. Mean ± Standard Deviation Values of the Parameters

DISCUSSION

Maximum femur length is one of the most commonly used parameters in gender determination. Studies on gender determination of long bones have shown that the male femur is larger and larger than the female femur. In a study comparing the right and left femoral lengths, the left side values were found to be larger than the right side, but no significant difference was found.¹⁰ When the studies in which the maximum femur length is calculated are reviewed in the literature (Table 2), the values closest to our results belong to the study of Singh et al in the Indian population.^{6,10-16} Duthie et al. divided the population into two groups according to the time of death. The mean values of the femur length of the first group (Those who died in 1900-20, n: 71) were 457.3 mm in men and 422 mm in women calculated. The mean values of the femur length of the second group (those who died in 1980, n: 49) were 464.9 mm in men and 428.4 mm in women calculated. In the same study, mean values of collum femoris anterior length were in the first and second groups, respectively; 34.9 mm and 38.3 mm in males and 32.5 mm and 35 mm in females calculated. The mean values of collum femoris width in the first and second groups were, respectively; 34.1 mm and 35.8 mm in men and 30.6 mm and 32.1 mm in women calculated. As a result of the increase in these parameters; they think that the femur more susceptible to hip fracture due to biochemical reasons.¹⁷

Authors	Population	n	Mean ± SD (mm)
Isaac et al.	India	171	434.7±27.8
Khaleel et al.	India	50	437.44±31.44
Khan et al.	India	250	446.2±26.39
Manuel et al.	China	120	429.1±22.3
Strecker et al.	Germany	511	463±6.4
Pick et al.	USA	150	452.7
Silva et al.	Brazil	66	409±8.2
Singh et al.	India	200	432.6±26.7
The present study	Turkey	105	431.42±36.2

Table 2. Maximum Femur Length

In the study of Ziylan and Murshid, the mean of the trochanter length was 405.4±22.9 mm in the left femur and 402.6±28.1 mm in the right femur. When these data was compared to our study, the mean value of the left femur was found to be high, while the mean value of the right femur was found to be less.¹⁸ When the collum femoris anterior values in the literature were compared with our study, the results of the performed by Isaac et al. had the closest values to our study with 28.6±4.6 mm but the Silva et al. had the lower values with 22.3±3.3 mm. and Khanal et al. showed that the highest values with 37.8±5.3 mm. Collum femoris superior, inferior and posterior values showed that the similarity.^{11,15,19} In the study performed by separating the radiographic images into two groups, first group; 1958-60 and second group; 1989-91, collum femoris axis length was 81 mm in the first group and 90.2 mm in the second group. This increase was attributed to the fact that the population had better nutritional conditions over time.²⁰ In study conducted by the USA, the mean of the collum femoris axis length was calculated as 98.4 mm.¹⁴ The mean values of collum femoris width were right side and left side respectively, 33.53 mm and 27.86 mm in the American population, 33.91 and 28.92 mm in the Mexican population, and 35.09 and 30.85 mm in the French population.²¹ In a study in which two different populations were compared, mean values of collum femoris width; In the Caucasian population, the average was 45.1 cm and 43.7 cm in males and females, respectively. In the same study, in the Chinese population, an average of 43 cm for men and 39 cm for women were found. The results of the Caucasian population are the highest mean value compared to the literature.²² In a retrospective study of the population divided into two groups, 1950 and 1990, the width of the collum femoris was compared and it was found that the values were 38.1 mm in 1950 and 38.6 mm in 1960. The researchers investigating the reasons for the increase in hip

Authors	Population	n	Mean ± SD
Davis et al.	United States	57	16.2±2.3
Terzidis et al.	Greece	360	20.5±2.2
Charlton et al.	United States	48	♀ 17.4, ♂ 17.7
Chandrashekar et al.	United States	10	14.44±2.06
Murshed et al.	Turkey	100	19.1±2
Didia et al.	Nigeria	100	22.4±5.77
Muneta et al.	Japan	8	17.1±3.5
The present study	Turkey	105	18.3±3.32

Table 3. Intercondylar Width

Authors	Population	n	Mean ± SD.
Vaidya et al.	India	86	59.48-64.12-62.34
Chandrashekar et al.	United States	10	68.97±5.19
Davis et al.	United States	57	68.7±3.3
Murshed et al.	Turkey	100	74.4±4.3
Mahfouz et al.	North America	74	76.9±3.3
Berger et al.	United States	15	75.4±2.3
The present study	Turkey	105	70.14±7.2

Table 4. Condylar Width

Authors	Population		Robustness Index	Platymeric Index	Pilastric Index
Manuel et al.	Malaysia		12.6±0.7	82.26±6.5	107.46±9.4
Gözlük	Klazomenai Excavations	Female	11.93±0.49	82.04±8.48	102.04±13.15
		Male	13.06±0.54	85.27±8.7	100.19±10.57
	Chalcolithic Age	Male	12.47	77.41	111.53
		Mines Age	Female	13.19	77.71
	Male		13.1	73.02	103.6
	Hellenic Roman Byzantine Age	Female	-	83.95	103.08
Male		12.46	81.97	98.55	
Bolanowski et al.	Poland		20	83.4	102.4
Datta et al.	East Bengal	Right	12.36±0.99	93.94±14.95	-
		Left	12.50±0.83	89.76±9.57	-
The present study	Turkey		13±2	84.15±10	101±22

Table 5. Robustness, Platymeria and Pilastric Index Mean ± SD. Values

fracture formation with age stated that there was no significant difference in the width of the collum femoris.²³ When the literature data are examined, Khan et al. and Pick et al. studies showed that parallelism with our results.^{13,14} In a study conducted in Nepal, the mean value of linea intertrochanterica length was found to be 5.04 ± 0.70 cm.¹⁹ In 2004, Singh et al. showed that the value of linea intertrochanterica was 6.31 cm and the mean result for the same parameter in 2013 was 5.81 ± 5.80 cm. These values were found to be low compared to our study²⁴. The thickest and most important of the three major ligaments of the hip joint is iliofemoral ligamentum. Part of this ligament attaches to the linea intertrochanterica. Therefore, it is of great importance in hip joint operations¹. The intercondylar width value in our study was found to be low compared to the studies in Greece, Nigeria, and the USA and higher when compared to Japan, America and Turkey. The results are shown in table 3.²⁵⁻³¹

In addition, the intercondylar depth value calculated by Terzidis et al. In the same study was found to be 25.9 ± 2.25 this value is similar to the value obtained in our study 25 ± 4 . The intercondylar width of the femur is effective in the physiology and pathology of the anterior and posterior ligamentum cruciatum. Intercondylar width values have no effect on prosthesis design in patients with knee replacement. When the findings of our study were compared with the other studies, it was seen that the Indian population was smaller in the condylar width value and the studies in the US population had variable values. In studies conducted in North America and Turkey were higher values The condylar width is supported by most of the researchers for which it is largely accurate in gender determination (Table 4).^{24,27,28,32,33} These parameters are important in prosthesis production and surgical practice as well as in designing the size of knee implants.

In a study conducted in France, pilastric index values were calculated in a population of Neanderthal, Middle Palaeolithic modern people and European.

Upper Paleolithic modern people. The results were found to be 100.6 ± 9.6 in Neanderthals, 121.6 ± 15 in modern Middle Palaeolithic people and 116.9 ± 10.1 in modern Upper Palaeolithic people. As a result, Neanderthals were found to have pilastric deficiency and bone mass was higher³⁴. Comparison of the mean values of Robustness, platymeria and pilastric indexes with the literature data and periodic analysis are shown in Table 5.^{6,7,9,35}

In a study conducted in Istanbul, intercondylar width index was found to be 0.29 ± 0.03 and intercondylar depth index was found to be 0.40 ± 0.03 .³⁶ In a study conducted in athletes, the intercondylar width index were found to be 0.305 for female athletes and 0.311 for male athletes. They reported that female athletes experienced more ligamentum cruciatum anterior (ACL) injuries than male athletes. They think that the reason of these injury rates differ according to gender is body fat ratio, hamstring group muscles (m. biceps femoris, m. semitendinosus, m. semimembranosus) and m. quadriceps femoris strength and ACL size.³⁷ In a study conducted in Japan, individuals (healthy and patients with osteoarthritis) were compared. The intercondylar width index of healthy individuals was 0.22 ± 0.04 and the intercondylar depth index was 0.51 ± 0.11 . The same values were found to be 0.23 ± 0.04 and 0.55 ± 0.13 , respectively in

patients with osteoarthritis. They reported that the growth of osteophytes in intercondyles correlated with progression of osteoarthritis³¹. In our study, 0.3 ± 0.04 and 0.43 ± 0.05 , respectively. There is a statistically significant relationship between index values and anterior cruciate ligament rupture and it is thought to have an important role in gender determination even if there is no consensus. In a study conducted for the purpose of gender prediction from femur weight and mean femur weight was found to be in men and women; 389 ± 76.8 and 281 ± 53.9 on the right side, 380.2 ± 74.1 and 380.2 ± 59.8 g on the left side, respectively. Male femur was found to be heavier than female femur³⁸. Femur weight in our study; the minimum value was 134 gr, the maximum value was 466 gr, mean value was 292.4 ± 68.04 , while the mean of the right side was 302 ± 68 and the mean of the left side was 284 ± 67.55 g.

CONCLUSIONS

Although the mean morphometric data of the right femurs obtained from our study were higher than the left femurs, there was no significant difference ($p > 0.05$); There was a statistically significant difference between the right and left femurs in the intercondylar depth average ($p < 0.05$). When the studies in the literature were compared with our results, it was found that the nearest average values were the maximum femur length and physiological femur length. Studies suggest that differences in femur geometry may be caused by race-dependent characteristics. The anatomical structure and morphometric measurements of the femur are clinically important for femoral fractures and pathologies. In addition, the data obtained from this study will be used by anthropologists for various determinations in the field of forensic medicine. We think that the results of our study will help clinicians in surgical interventions.

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