



An Osteometric Study of Proximal and Distal Femur Morphology

Proksimal ve Distal Femur Morfolojisinin Osteometrik Değerleri

Sema Özandaç¹, Pınar Göker¹, Ahmet Hilmi Yücel¹, Memduha Gülhal Bozkır¹

¹Çukurova University Faculty of Medicine, Department of Anatomy, ADANA

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ABSTRACT

Purpose: The current study was undertaken to determine the surgically relevant parameters of proximal and distal femur from right and left femora in our population.

Methods: These measurements were taken from 400 adult femora (200 right, 200 left) from Department of Anatomy laboratory of Çukurova University, Faculty of Medicine using an electronic digital caliper and goniometer. The mean values of the neck of the length (NL), maximum femoral length (FL), the length of femoral shaft (FSL), intertrochanteric apical axis length (ITAAL), maximum vertical diameter of the femoral head (VDH), neck shaft angle (NSA), superior-inferior femoral neck diameter (SID) and intercondylar notch width (ICNW) were taken.

Results: The mean values of these measurements were found to be 22.2 ± 3.0 mm, 429.5 ± 35.0 mm, 306.5 ± 26.7 mm, 61.9 ± 5.7 mm, 44.2 ± 3.8 mm, $121.1^\circ \pm 4.0^\circ$, 30.8 ± 3.1 and 2.4 ± 0.2 cm in the right side respectively. However, in the left side same dimensions were 22.5 ± 4.4 mm, 431.3 ± 26.2 mm, 299.5 ± 59.4 mm, 61.4 ± 5.1 mm, 44.2 ± 3.3 mm, $121.2 \pm 4.0^\circ$, 30.0 ± 2.9 and 2.3 ± 0.2 cm respectively.

Conclusion: The observations presented in the report have defined anatomic parameters that need to be taken into consideration when surgical procedures are performed in hip and knee area for this population.

Key words: Femur morphometry, Proximal femur and Distal femur.

ÖZET

Amaç: Çalışmamızda, popülasyonumuzdaki sağ ve sol distal ve proksimal femurun cerrahi olarak ilgili ölçüm değerlerinin belirlenmesi amaçlanmıştır.

Materyal ve Metod: Laboratuvarımızda bulunan 400 adet femurda milimetrik bir kumpas ve goniometre yardımıyla collum femoris ve femur'un maksimum uzunluğu ortalaması, femur shaftı uzunluğu ortalaması, linea intertrochanterica ile fovea capitis arasındaki uzaklık (intertrokanterik apikal aks uzunluğu) ortalaması, caput femoris'in maksimum vertikal uzunluk ortalaması, femur boyun shaft açısı ortalaması, collum femoris'in supero-inferior uzunluk ortalaması ve intercondylar mesafe uzunluğu ortalaması ölçülmüştür.

Bulgular: Ölçümlerimize ait değerler sırasıyla; sağda 22.2 ± 3.0 mm, 429.5 ± 35.0 mm, 306.5 ± 26.7 mm, 61.9 ± 5.7 mm, 44.2 ± 3.8 mm, 121.1 ± 4.00 , 30.8 ± 3.1 ve 2.4 ± 0.2 cm bulunurken, aynı değerler sol tarafta 22.5 ± 4.4 mm, 431.3 ± 26.2 mm, 299.5 ± 59.4 mm, 61.4 ± 5.1 mm, 44.2 ± 3.3 mm, 121.2 ± 4.00 , 30.0 ± 2.9 ve 2.3 ± 0.2 cm olarak bulunmuştur.

Sonuç: Çalışmamızda elde edilen değerlerin popülasyonumuzda yapılacak olan kalça ve diz ile ilgili cerrahi girişimlerde yardımcı olacağını düşünmekteyiz.

Anahtar kelimeler: Femur morfometrisi, proksimal femur ve distal femur.

INTRODUCTION

Antropometric measurements of long bones, provide important information including gender, race, age and stature of subjects and the length of the bone effects stature of subjects¹. It has been thought that femur is the good predictor for stature¹. The femur, bone of the thigh is the longest and most strongest of human body. It consists of a body (shaft) and two ends; proximal and distal^{2,3,4}. Moreover, knowledge of proximal femur anatomy is essential for hip joint. The femur morphometry is crucial for orthopedists, anatomists, anthropologists and forensic scientists. Femur morphometry could be used in treatment including osteotomy of proximal femur, hip and femur pathological situations^{1,5}. Furthermore, neck shaft angle (NSA) effects the adaptation of the acetabulum to the femoral head, distribution forces and hip joint function⁵. The femoral neck is a flat surface of bone and it interconnects femoral head with femoral shaft⁶. It has been demonstrated that the measurements including femoral head diameter, bicondylar width are practical to use to sex identification⁷. Furthermore, proximal femur geometry has been defined as an important parameter of hip fracture and longer neck length would be an indicator for hip fracture^{8,9}.

NSA is used in diagnosis and treatment of the hip illness by orthopedists and radiologists. This angle decreases gradually. It is approximately $125 \pm 5^{\circ}$ in normal adult population^{5,10}. While this angle increases in congenital subluxation and dislocation of hip, poliomyelitis, cerebral palsy and idiopathic scoliosis. It decreases in some situations including congenital-posttraumatic coxa vara and Perthes' disease⁵. The neck length which is the good indicator of NSA, helps collar-diaphyseal angle correction, prosthesis design^{5,11}. The measurements such as neck shaft angle and intertrochanteric apical axis length, maximum vertical diameter of the head affect each other and could be used in designing hip prostheses⁵.

Additionally, distal femur morphometry is substantial for total joint replacement and internal fixation material (12-16) and it can be used as the reference point for measuring patellar height¹⁷. Intercondylar notch width is important in injury of anterior cruciate ligament (ACL) and stenosis of the intercondylar notch in athletes^{3,18,19,20}. As a result, femoral morphometric measurements have a great value in diagnosis and treatment of the congenital or post-traumatic deformity.

The current study aimed to document the normal values of a set of the neck length (NL), maximum femoral length (FL), the length of femoral shaft, intertrochanteric apical axis length (ITAAL), maximum vertical diameter of the femoral head (VDH), neck shaft angle (NSA), superior-inferior femoral neck diameter (SID) and intercondylar notch width (ICNW) in our population.

MATERIALS and METHODS

The study was carried out from the 400 adult femora (200 right, 200 left). The data were collected from Department of Anatomy Laboratory of Çukurova University Faculty of Medicine in this study. The following 8 parameters were measured using an electronic digital caliper and goniometer. These measurements shown in Table 1 were as follows:

- Femoral neck length (NL) (the distance between base of the femoral head and the intertrochanteric line at the junction of the front of the neck with the shaft) (Figure 1)
- Maximum femoral length (FL) (measured the upper point of femur head and the lowest point of femoral condyle of femur) (Figure 2)
- The length of femoral shaft (from lower point of the lesser trochanter to the upper end of the medial supracondylar ridge of femur) (Figure 2)

- Intertrochanteric apical axis length (ITAAL) (the distance taken from fovea capitis to intertrochanteric line) (Figure 1)
 - Maximum vertical diameter of the femoral head (VDH) (the distance between the upper point of femoral head and the lowest point of femoral head) (Figure 1)
 - Collo-diaphysial or Neck shaft angle (NSA) (measured between the long axis of the femoral shaft with the axis of the femoral neck) (Figure 1)
 - Superior-inferior femoral neck diameter (SDI) (The distance taken from the narrowest part of the femur neck in superior-inferior direction) (Figure 1)
 - Intercondylar notch width (ICNW) (The distance between $\frac{1}{2}$ the antero-posterior diameter of the lateral surface of the medial condyle of femur and $\frac{1}{2}$ the antero-posterior diameter of the medial surface of the lateral condyle of femur). (Figure 2)
- The data were divided into two groups: right and left. The SPSS 10.0 program was used for statistical analysis of the measurement results. From these measurements, means, standard deviations (SD), and minimum and maximum (min.-max) values were calculated.

Table 1.Characteristics of proximal and distal femur from 400 (200 right, 200 left) adult femora from Cukurova University in Turkey

Measurements		Minimum- Maksimum	Mean	SD
Femoral neck length (NL)	Right	17 mm-31 mm	22.2 mm	3.0 mm
	Left	18 mm -42 mm	22.5 mm	4.4 mm
Maximum femoral length (Max.FL)	Right	361 mm-508 mm	429.5 mm	35.0 mm
	Left	366 mm-485 mm	431.3 mm	26.2 mm
Length of femoral shaft (FSL)	Right	251 mm-367 mm	306.5 mm	26.7 mm
	Left	240 mm-380 mm	299.5 mm	59.4 mm
Intertrochanteric apical axis length (ITAAL)	Right	47 mm-73 mm	61.9 mm	5.7 mm
	Left	48 mm-77 mm	61.4 mm	5.1 mm
The maximum vertical length of head (VDH)	Right	35 mm- 51 mm	44.2 mm	3.8 mm
	Left	35 mm-51 mm	44.2 mm	3.3 mm
Collo-diaphysial angle-Neck Shaft Angle (NSA)	Right	117 ⁰ -132 ⁰	121.1 ⁰	4.0 ⁰
	Left	118 ⁰ -132 ⁰	122.2 ⁰	4.0 ⁰
Superior-inferior femoral neck diameter (SDI)	Right	24 mm-37 mm	30.8 mm	3.1 mm
	Left	25 mm-38 mm	30.0 mm	2.9 mm
Intercondylar Notch Width (ICNW)	Right	2.0 cm-3.2 cm	2.4 cm	0.2 cm
	Left	1.7 cm-2.9 cm	2.3 cm	0.2 cm

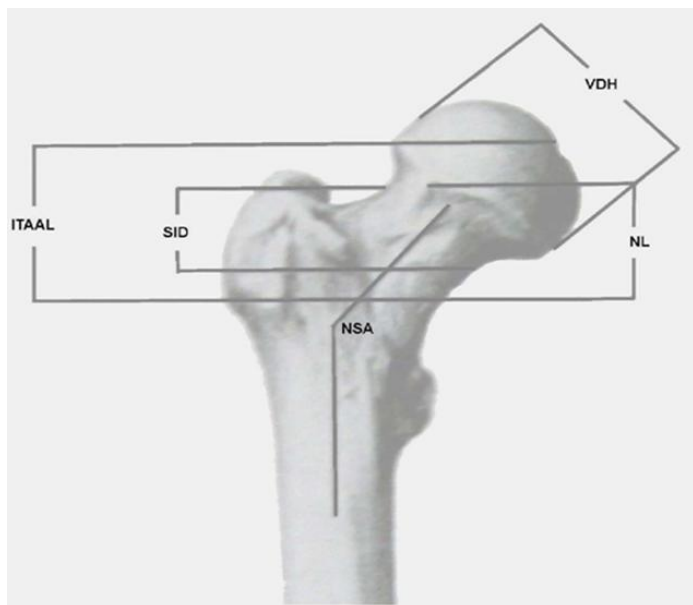


Figure 1.-VDH- Maximum vertical diameter of the femoral head, NL- Neck Length, SID-Superior-inferior femoral neck diameter, ITAAL- Intertrochanteric apical axis length, NSA-Neck Shaft Angle

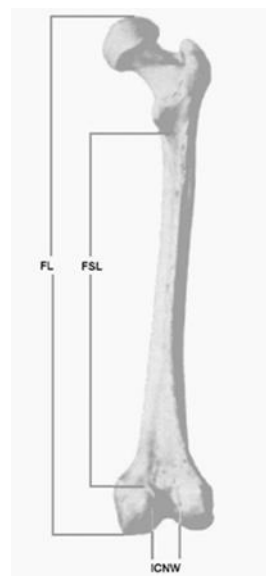


Figure 2.-FL- Maksimum Femoral Length, FSL- The length of the femoral Shaft, ICNW- Intercondylar notch width.

RESULT

The minimum-maximum, mean and SD values of the measurements from the right and left femora are shown in Table 1. From the 400 adult femora, neck of the length (NL), maximum femoral length (FL), the length of femoral shaft (FSL), intertrochanteric apical axis length (ITAAL), maximum vertical diameter of the femoral head (VDH), neck shaft angle (NSA), superior-inferior femoral neck diameter (SID) and intercondylar notch width (ICNW) were evaluated. The mean values of neck of the length (NL), maximum femoral length (FL), the length of femoral shaft (FSL), intertrochanteric apical axis length (ITAAL), maximum vertical diameter of the femoral head (VDH), neck shaft angle (NSA), superior-inferior femoral neck diameter (SID) and intercondylar notch width (ICNW) were found to be 22.2 ± 3.0 mm, 429.5 ± 35.0 mm, 306.5 ± 26.7 mm, 61.9 ± 5.7 mm, 44.2 ± 3.8 mm, $121.1 \pm 4.0^\circ$, 30.8 ± 3.1 mm and 2.4 ± 0.2 cm in the right side respectively. However, in the left side same dimensions were

22.5 ± 4.4 mm, 431.3 ± 26.2 mm, 299.5 ± 59.4 mm, 61.4 ± 5.1 mm, 44.2 ± 3.3 mm, $121.2 \pm 4.0^\circ$, 30.0 ± 2.9 mm and 2.3 ± 0.2 cm respectively in the left side respectively. According to our last measurement result, minimum-maximum corresponding values for right femora were found to be 17 mm-31 mm, 361 mm-508 mm, 251 mm-367 mm, 47 mm-73 mm, 35 mm- 51 mm, 117° - 132° , 24 mm-37 mm and 2.0 cm-3.2 cm in the right side respectively, and 18 mm-42 mm, 366 mm-485 mm, 240 mm-380 mm, 48 mm-77 mm, 35 mm- 51 mm, 118° - 132° , 25 mm-38 mm and 1.7 cm-2.9 cm in left side respectively.

DISCUSSION

The femur is the longest and strongest bone of individual body. It consists of a body (shaft) and two ends; proximal and distal^{2,3,21,22}. Studies about long bones explain the data including race, gender, age and stature. Especially, race, hereditary, climate and nutritional status of population impress length of long bones and

stature¹. Our study included of the various parameters of the femur and comparing them with other populations.

Proximal femur anatomy provide information about the hip joint mechanism⁵. Thus, proksimal femur geometry can be used in estimation of the hip fracture^{8,9}. Moreover, loss of bone mineral density in proksimal femur increases inclination to fall. Many factors play role in hip fracture. Poor nutritional status, lower body weight, lean body mass, fat content and lifestyle including live by oneself, use of psychotropic drugs- alcohol and some diseases such as, senile dementia, neurologic disorders, hemiplegia are reasons of hip fracture^{8,9}. If impact stres increases and bone strength decreases, this fracture will occur easily. Furhermore, it has been shown that impact stres of proksimal femur leads to longer femoral neck length (NL) and smaller crosssectional area of the femoral neck^{8,9}. It has been also determined that the racial differences in NL affect the differences in fracture risk incidence. Additionally, It was revealed that NL could be the important predictor of the NSA with FL and used for the NSA correction, prosthesis design. When only a fragment of the femur is available, it can be useful in estimating maksimum FL too^{1,5,8,11}. Maximum femoral length which depends on the stature is 27% of the stature. In a study consisting of Indians, the mean values of NL and FL were 28.6 mm and 434.9 mm in right side, and 28.1 mm and 435.3 mm in left side respectively⁵. Whereas, same values were 38.3 and 464.9 mm in males and 35.0 and 428.4 mm in females respectively in Scotland population²³. According to Gujarat region, the mean value of the maksimum length of femur was 451.81 mm (right) and 453.35 mm (left) in males and 417.48 mm (right) and 420.44 mm (left) in females respectively²⁴. The mean of the NL was found as 48.8 mm in chinese population⁸. Corresponding values were found to be 22.2 mm and 429.5 mm in the right side and 22.5 mm and 431.3 mm respectively in this study.

Moreover, intertrochanteric apical axis length (ITAAL) which is the distance between the summit of the head and the mid-point of the intertrochanteric line, can be used for determining neck shaft angle and maksimum femoral length^{1,5}. Also, it was determined that ITAAL and maksimum vertical diameter of head (VDH) might be useful parameters in estimating femoral length and sex identification. Furthermore, VDH measurement is taken from the upper point of head to inferior point of head^{1,22}. Isaac et al reported that the mean values of ITAAL and VDH were 58.7 mm and 41.2 mm in right side respectively, and 57.1 mm and 41.2 mm in left side respectively⁵. Additionally, it was identified the mean value of VDH as 39.85 mm in males and 41.75 mm in females of South Indian population²². The mean values of same measurements were found to be 61.9 mm and 44.2 mm in the right side and 61.4 mm and 44.2 mm in the left side respectively for our population. Our results are different from Indians;having lower than Turkish group.

Hip disorders such as coxa vara or coxa valga affect femoral shaft angle (NSA). this angle changes as, she-he grows older. While the angle is aproximately 150⁰ in early infancy, it is 140⁰ in childhood, 125⁰ in adult life and 120⁰ in older^{5,10}. When this value exceeds 130⁰, coxa valga is seen. Controversely, it is defined as coxa vara, when the angle is less than 120⁰ 10,14,25. The NSA affects the adjusment of the femoral head in the acetabulum and forces dispersion and function hip joint. It is important for the surgeon during the internal fixation of fractured neck femur. Furthermore, it was estimated that femoral head diameters documented the variations of the bone in different populations^{5,11,14}. According to Indian study, the mean value of NSA was 126.5⁰ in right side and 126.9⁰ in left side⁵. Additionally, same dimension was 122.64⁰ for healthy females, and 125.53 mm for fractured females in Italian population⁹. However, this angle was reported as 126.65⁰ in females and 136.70⁰ in males in Nigerian region¹¹. Moreover, in several papers from different

countries it has been reported the NSA value as 126° in American population, 127.5° in Sweden, 122.4° in Belgium, in 132.1 in Chinese population^{8,26,27,28,29}. Owing to Finland, the same value was found to be 128.3° in healthy group, and 133.7° in fractured groups³⁰. However, this dimension was measured as 121.1° in right femur and 122.2° in left femur in our group. We found significant differences in the mean value of NSA of Indians, Nigerians, Americans, Sweden, Chinese and Finland population with our population; having greater value than Turks. From this data, our results are more similar to Belgium and Italian healthy group.

Superior inferior femoral neck diameter is practical to use for sex identification^{7,13}. It was evaluated as 33.53 mm and 27.86 mm in American Indians, 33.91 mm and 28.92 mm in Mexican population and 35.09 mm and 30.85 mm in French population for males and females respectively¹³. Whereas, according to our data, corresponding value was found to be 30.8 mm in right side and 30.0 in left side.

Distal Femur anatomy is crucial determinant for total joint replacement design and internal fixation and patellar height measurement. It is associated with anterior cruciate ligament (ACL) rupture^{12,17}. Moreover accurate knowledge of distal femur can be used for total knee prostheses design. Smaller intercondylar notch have been associated with smaller ACL width and this will increase the ACL rupture. It is also related with knee osteoarthritis^{3,12,18,20}. Total knee arthroplasty is a reliable and cheap method for knee osteoarthritis treatment and it alters the mechanical loading of knee joint. The loss of bone in the distal anterior femur is also a risk factor for supracondylar fractures of the femur^{31,32}. It was found that the mean value of femur intercondylar width was 2.05 cm (right) and 2.05 cm (left) in Greek population¹². Additionally, according to Nigerian population, the ICNW value was measured as 2.21 cm in left side and 2.27 cm in right side³. In this paper this value was 2.4 cm in

right side and 2.3 cm in left side. Our results are higher than other studies values.

In summary, when comparing the literature findings with this study, we observe that there are differences between Indians, Nigerians, Americans, Sweden, French, Mexican Finlands and our population about proximal femur data. However there are similarities between Belgiums, Italians and our population. We consider that these discrepancies could be a result of such factors like race, genetic variables, nutritional status, lifestyle, climate and socioeconomic status.

In conclusion, we think that precise knowledge of the femur anatomy is essential for safe and accurate surgical interventions. Especially, neck shaft angle is important for the surgeon during the internal fixation of fractured neck femur. Moreover, the differences of mean value of maximum femoral length between populations could be a result of factors impressing bone morphology including heredity, diet, nutrition status, environment. Therefore, the observations presented in this study have defined anatomic parameters that need to be taken in consideration for performing safe surgical procedures such as total hip-knee replacement or prostheses design and guidelines for the use of devices in hip and knee. As a result, we believe that the data obtained in this study can provide crucial information for femur morphometry and may help the surgeon for having a successful surgery and minimize the related problems.

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Yazışma Adresi / Address for Correspondence:

Dr. Sema Özandaç
Cukurova University Faculty of Medicine
Department of Anatomy
ADANA
E-mail : sezaoz@hotmail.com
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