Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2024;41:93-99

A Detailed Morphometric Characterization of Colombian Lower Limb Long Bones: Femur, Tibia and Fibula

Manuela Pineda[1], María A Barrera[1], Daniela Botero-González[2]

[1]Medical student, Faculty of Health Science, Technological University of Pereira, Pereira, Colombia
[2]Assistant professor, Department of Basic Medical Sciences, Faculty of Health Science, Technological University of Pereira, Pereira, Colombia

Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT

Introduction: morphometry enables a measurable analysis of the macroscopic structures of any part of the human body. Bone morphometry is essential for the performance of orthopedic surgeries as well as for the diagnosis and monitoring of certain pathologies. In this study, the three long bones of the lower limb - the femur, tibia and fibula - were measured employing a more comprehensive morphometry than conventional methods.

Methods: morphometric measurements were taken on dry human femurs, tibias and fibulae using anatomical landmarks to define proximal and distal epiphysis values in order to obtain lengths, widths and perimeters. Tibia and fibula weights were also taken.

Results: the morphometry of the lower limb long bones in the Colombian population is described. The tibias weighed 197.14±52.75 grams and 167.368±50.28 grams for the right and left tibias, respectively. The fibulae weighed 49.22±11.346 and 49.451±8.7 for the right and left, respectively. Distance from the femoral head to the greater trochanter p=0.0193, femoral neck perimeter p=0.0272, and tibia total length p=0.0433 were all statistically significant.

Conclusions: this paper is the first to present data regarding bone dimensions in lower limb long bones belonging specifically to the Colombian population.

Keywords: Anthropometry; Bone and bones; Femur; Leg bones; Osteology.

Introduction

The osteology of the lower limbs consists of three large bones: the femur, tibia and fibula. The femur is the largest and strongest bone in the human body, articulating proximally to the acetabulum of the coxal bone and distally to the patella and tibia forming the knee joint. The tibia is situated on the medial side of the leg and runs parallel to the fibula, connecting the knee joint to the ankle joint. The proximal epiphysis articulates with the femur bone to form the knee joint, while the distal epiphysis forms the inner part of the ankle joint. The fibula is located just behind the tibial head at the knee joint and it runs down the lateral side of the leg. The proximal epiphysis articulates with the tibia bone specifically inferior to its lateral condyle until it reaches the ankle joint with the distal epiphysis[1-3].

Morphological sciences determine the morphometric parameters of bones to establish limits between normality and pathology[4]. They enable a measurable analysis of the macroscopic structures of any part of the human body, contributing to the bone description precise numerical data on the analyzed structures[5,6]. In the scientific literature, morphological studies have been carried out in forensic anthropology, medicine and many of its multiple pathologies[7], and also in all research conducted in basic and clinical anatomy. Lower limb bone morphometry is essential in the performance of orthopedic surgeries for deformity or fracture correction using implants. It helps surgeons to plan and perform surgical procedures with precision. This quantitative information also contributes to the diagnosis and the monitoring of pathologies using information related not only to the bone length but also to certain specific anatomical features, in order to determine a deformity or a bone disease[6].

The aim of this study is to establish the morphometry of the long bones of the lower limbs from the Colombian population.

Materials and Methods

A total of 48 dried human adult bones of unknown ethnicity without any gross pathology or abnormality were analyzed. They comprised 16 femurs (eight left, eight right), 16 tibias (eight left, eight right) and 16 fibulae (six left, 10 right). Bones were obtained from the Laboratory of Anatomy at the Technological University of Pereira (UTP), in Risaralda, Colombia. The bones didn't belong to eight specific subjects, but were derived from multiple human cadaveric donors.

For bone morphometry, a digital caliper (Ubermann, Chile) was used to obtain lengths and widths, a measuring tape (Stanley Black & Decker, Inc., Seattle, USA) was used to calculate the perimeters, graph paper (Bico, Colombia) was used to establish lengths,

DOI: 10.51929/jms.41.93.2024
ISSN 2177-0298

a digital scale (Goldtech, India) was used to weigh tibias and fibulae, and an iPhone 13 camera (Apple Inc., California, USA) was used to take the photographs. All data was recorded in a Microsoft Excel® spreadsheet (version 2205).

The morphological measurements of the lower limb bones were taken from anatomical landmarks illustrated in Figures 1-3 and each measurement type was given an abbreviation that relates to a fuller description provided in the Tables. The femur data is presented in Figure 1 and Table 1, the tibia data in Figure 2 and Table 2, and fibula in Figure 3 and Table 3.

The data are expressed as mean ± standard deviation (SD). The student's t-test was used to compare mean values from the bones of each side of the body for all measurements and $p \leq 0.05$ was considered significant.

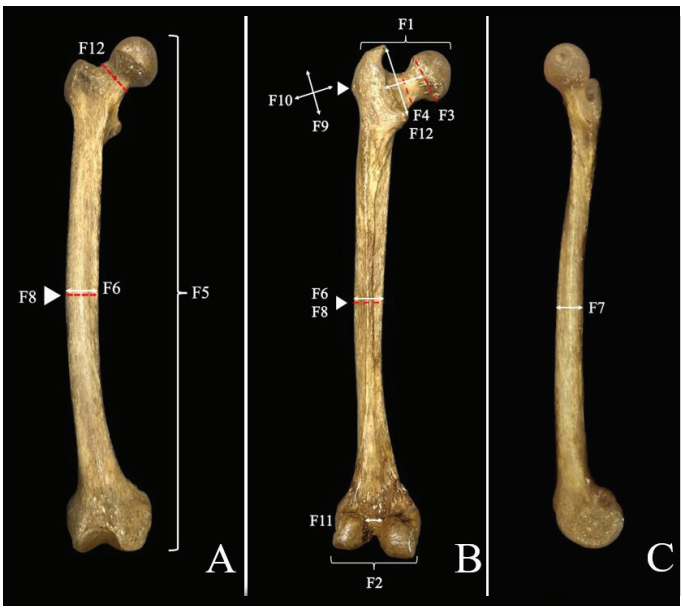

Figure 1. Femur morphometry. A: Ventral view. B: Dorsal view. C: Medial view.For abbreviations refer to table 1.

Figure 2. Tibia morphometry. A: Proximal epiphysis inferior view. B: Distal epiphysis superior view. C: Ventral view. D: Medial view. For abbreviations refer to table 2.

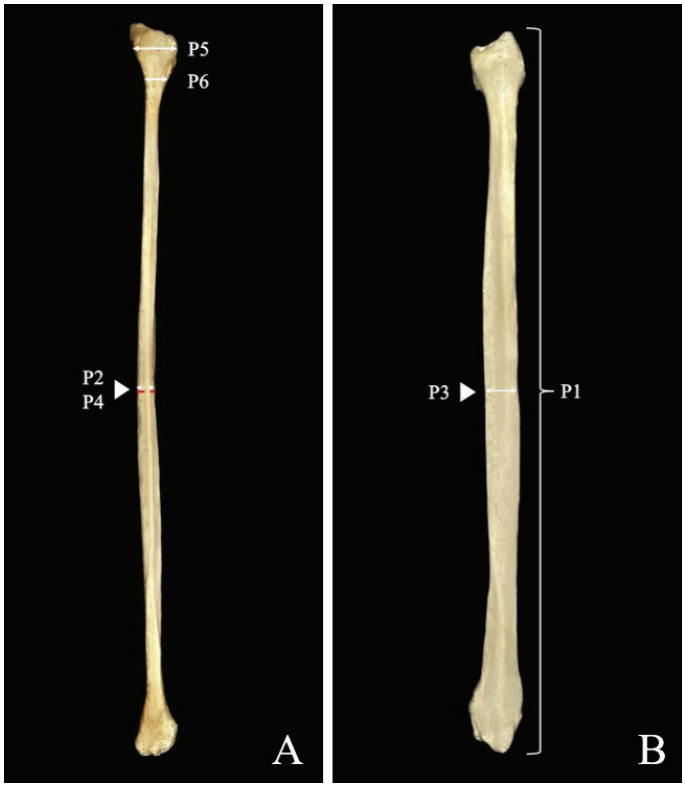

Figure 3. Fibula morphometry. A: Ventral view. B: Lateral view. For abbreviations refer to table 3.

Table 1. Femur morphometry.

Abbreviation	Measurement Description
F1	Distance from the femoral head to the greater trochanter
F2	Distance from medial to lateral condyle
F3	Femoral head width: measured from the most medial point to the most lateral point
F4	Femoral neck width: measured from medial to lateral
F5	Femur total length in ventral view: measured from the femoral head to the lower border of the medial condyle
F6	Femoral diaphysis width: measured in the middle of the axis from medial to lateral
F7	Femoral diaphysis width: measured in the middle of the axis from ventral to dorsal
F8	Femoral diaphysis perimeter: measured in the middle of the axis
F9	Intertrochanteric line distance in dorsal view
F10	Femoral neck length: measured from the midpoint of the intertrochanteric line to the midpoint of the femoral head total width (F3)
F11	Intercondylar fossa width: measured in the upper portion of the inner border from medial to lateral condyle
F12	Femoral neck perimeter

Table 2. Tibia morphometry.

Abbreviation	Measurement Description
T1	Distance from medial to lateral condyle
T2	Distance from the most caudal point of the medial malleolus to the fibular notch of the tibia
T3	Tibia total length: measured from the intercondylar eminence to the most caudal point of the medial malleolus, viewed dorsally
T4	Tibial diaphysis width: measured in the middle of the axis from medial to lateral
T5	Tibial diaphysis width: measured in the middle of the axis from dorsal to ventral
T6	Tibial diaphysis perimeter: measured at the midpoint of the axis
T7	Transverse diameter of the joint surface of the medial condyle
T8	Transverse diameter of the joint surface of the lateral condyle
T9	Middle transverse measure of intercondylar area

Table 3. Fibula morphometry.

Abbreviation	Measurement Description
P1	Fibular total length: measured from the apex to the most caudal portion of the lateral malleolus
P2	Fibular diaphysis width: measured in the middle of the axis from medial to lateral
P3	Fibular diaphysis width: measured in the middle of the axis from dorsal to ventral
P4	Fibular diaphysis perimeter: measured in the middle of the axis
P5	Fibular head width: measured from the most medial point to the most lateral point, in ventral view
P6	Fibular neck width: measured from medial to lateral

RESULTS

The descriptive statistics for the measurements are shown in Tables 4, 5 and 8 for the femurs, Tables 6 and 9 for the tibias, and Tables 7 and 10 for the fibulae. The tibias weighed 197.14 ± 52.75 grams (right tibias) and 167.368 ± 50.28 grams (left tibias). The fibulae weighed 49.22 ± 11.346 grams (right fibulae) and 49.451 ± 8.7

Table 4. Different studies regards femur morphometry.

Author	F2 Obtained Value (Mean ± SD in Milliliters)		F11 Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side	Right Side	Left Side
Present study	71.04 ± 3.33	70.58 ± 5.429	19.74 ± 2.41	20.3 ± 4.16
Santosh *et al.* 2022[23]	69.31 ± 6.72	70 ± 6.23	19.98 ± 3.24	19.82 ± 3.14
Phombut *et al.* 2021[24]	-	-	20.06 ± 2.72*	
Mahalakshmi *et al.* 2020[25]	72.82 ± 3.89	71.62 ± 5.67	21.66 ± 2.69	21.5 ± 4.64
Chavda *et al.* 2019[26]	69.6 ± 5.04	69.8 ± 4.96	20.4 ± 3.17	18.7 ± 2.52
Shweta *et al.* 2017[27]	73.1 ± 6.14	72.16 ± 6.58	20.82 ± 2.57	21.0 ± 3.13
Biswas *et al.* 2017[28]	71.71 ± 4.50	70.71 ± 5.25	20.86 ± 2.52	19.45 ± 2.57
Zalawadia *et al.* 2017[29] ♂	74.48 ± 1.90	74.59 ± 2.75	20.31 ± 2.94	20.91 ± 1.32
♀	67.42 ± 1.93	66.7 ± 2.59	19.42 ± 2.3	19.27 ± 2.74
Ameet *et al.* 2014[30]	72.5 ± 5.3	73.3 ± 5.3	18.0 ± 3.0	17.9 ± 2.5
Terzidis *et al.* 2012[31] ♂	88.6 ± 0.42*		22.0 ± 0.18*	
♀	78.5 ± 0.30*		18.7 ± 0.10*	
Ravichandran *et al.* 2010[32]	74.58 ± 0.57	73.97 ± 0.61	18.89 ± 0.29	18.65 ± 0.27
Murshed *et al.* 2005[33] ♂	-	-	21.3 ± 2.4*	
♀	-	-	19.1 ± 2.0*	

*Value without laterality

grams (left fibulae). For the femurs, F1 was statistically significant p=0.0193, as was F12 p=0.0272. For the tibias T3 was statistically significant p=0.0433.

Table 5. Different studies regards femoral head morphometry.

Authors	F3 Obtained Value (Mean ± SD in Milliliters)
Present study	45.02 ± 1.41
Verma *et al.* 2017[11]	42.32 ± 4.11
Umer *et al.* 2015[13]	45.50 ± 3.39
Menezes *et al.* 2015[14]	44.2 ± 4.4
Lin *et al.* 2014[12]	45.4
Polgug *et al.* 2013[10] ♂	43.7 ± 4.1
♀	40.9 ± 4.9
Baharuddin *et al.* 2013[34]	40.81 ± 3.43
Unnanuntana *et al.* 2010[35]	52.09 ± 4.43
Umer *et al.* 2010[36]	50.1 ± 3.8
Mahaisavariya *et al.* 2002[37]	43.98 ± 3.47

Table 8. Femur results.

Measurement	Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side
F1	81.74 ± 5.64	7.554 ± 8.54
F4	32.58 ± 1.56	29.66 ± 3.66
F5	452.83 ± 12.2	447.47 ± 27.4
F6	25.63 ± 1.2	25.29 ± 2.79
F7	27.71 ± 1.63	26.87 ± 2.23
F8	87.38 ± 5.01	85.1 ± 6.8
F9	59.79 ± 6.32	60.19 ± 7.14
F10	4.078 ± 0.317	39.16 ± 4.48
F12	100.92 ± 4.75	92.92 ± 7.85

Table 6. Different studies regards tibia morphometry.

Author	T1 Obtained Value (Mean ± SD in Milliliters)		T7 Obtained Value (Mean ± SD in Milliliters)		T8 Obtained Value (Mean ± SD in Milliliters)		T9 Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side
Present study	70.553 ± 5.069	66.99 ± 5.153	30.395 ± 2.493	29.423 ± 1.69	30.261 ± 2.843	28.084 ± 2.703	11.147 ± 2.905	11.82 ± 2.565
Gharehdaghi *et al.* 2018[9]	77.2 ± 3.5	77.3 ± 3.7	-	-	-	-	-	-
Lucena-Dos-Santos *et al.* 2018[20] ♂	-	-	30.24 ± 0,307*		34.05 ± 0,323*		11.67 ± 0,279*	
♀	-	-	27.02 ± 0,298 *		29.91 ± 0,281*		10.54 ± 0,262*	
Kang *et al.* 2017 [18]	70.70 ± 6.37*		-	-	-	-	-	-
Gandhi *et al.* 2014[19] ♂	65.98 ± 7.07	65.61 ± 7.21	30.18 ± 2.83	29.38 ± 3.14	28.62 ± 3.10	28.82 ± 3.12	7.18 ± 1.14	7.41 ± 0.95
♀	60.11 ± 6.62	59.34 ± 6.03	27.25 ± 3.05	26.96 ± 2.18	26.14 ± 2.51	26.00 ± 3.06	6.72 ± 1.06	6.38 ± 0.79

*Value without laterality

Table 7. Different studies regards fibula morphometry.

Authors	P1 Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side
Present study	396.926 ± 20.623	375.667 ± 9.638
Mukhia *et al.* 2022[38]	332.1 ± 14.2	330.6 ± 15.2
Albani *et al.* 2021[21]	358.6 ± 24.41	366.4 ± 25.37
Gharehdaghi *et al.* 2018[9]	367.4 ± 18.2	368.4 ± 17.9
Kaur *et al.* 2015[39]	355.8 *	

*Value without laterality

Table 9. Tibia results.

Measurement	Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side
T2	42.315 ± 4.008	40.169 ± 2.811
T3	368.083 ± 19.77	344.208 ± 24.317
T4	22.991 ± 3.29	20.769 ± 0.822
T5	28.212 ± 2.663	27.918 ± 2.707
T6	77.542 ± 6.387	74.208 ± 3.788

Table 10. Fibula results.

Measurement	Obtained Value (Mean ± SD in Milliliters)	
	Right Side	Left Side
P2	12.319 ± 1.226	11.582 ± 1.559
P3	16.039 ± 1.756	14.429 ± 1.245
P4	45 ± 3.849	41.444 ± 4.178
P5	26.137 ± 2.244	24.813 ± 3.14
P6	15.915 ± 1.701	14.399 ± 1.599

Discussion

The current study is the first to morphometrically measure the long bones of the lower limbs in Colombia, although the authors acknowledge the limitation of the small quantity of bones included in the sample. A further limitation is that such precise measurements can vary according to the individual researcher's experience, the instruments used, and the location of the bone-based landmarks.

In the case of the femur, the most commonly fractured bone in the human body[8], it is important for surgeons to be informed of the normal femur measurements in a population in order to perform reconstructive surgery. With this in mind, femur total length (measurement F5) was found to be similar to the results of Gharehdaghi *et al.* 2018 who reported right femur length to be 448.2±21.5 millimeters (mm) and the left length to be 448.9±22.2 mm[9]. Similar findings were reported by Polgug *et al.* 2013 for male bones (456.3±27.3 mm)[10]. In the present study, measurements are higher than those of the Polgug *et al.* 2013 study for female bones (421.1±33.7 mm)[10], and those of Verma *et al.* 2017 who report right femur lengths of 42.94±2.77 centimeters (cm) and left femur lengths of 42.70±3.01 cm[11]. The higher measurements in this current study could indicate that most of our samples were male bones (See Table 8).

Concerning the proximal epiphysis, femoral head width (measurement F3) is similar to those reported by Lin *et al.* 2014[12], and Umer *et al.* 2015[13] (See Table 5). Intertrochanteric line distance (measurement F9) measured by Menezes *et al.* 2015 had mean values of 47.9±6.2 mm[14] which are lower than the values found by the present study.

Total width of the femoral neck (measurement F4) are lower than the results of Lin *et al.* 2014 who reported values of 35.71±3.27 mm for male bones and 31.2±2.80 mm for female bones[12], and the results of Verma *et al.* 2017 who reported values of 34.23±4.395 mm for the right side and 31.73±3.662 mm for the left.[11] The measurements reported by Menezes *et al.* 2015 are similar to those obtained in the present study with an average of 3.10±0.35 cm[14]. It is likely that the measurements from Lin *et al.* 2014 and Verma *et al.* 2017 had higher results because the landmark was placed closer to the femoral head[11,12], while in the present study and the study conducted by Menezes *et al.* 2015, the measurements was taken establishing the landmark as the narrowest point of the neck[14], thus resulting in smaller values (See Table 8).

For the distal epiphysis, intercondylar fossa width (measurement F11) was found to be similar to most comparable studies. Distance from medial to lateral condyle (measurement F2) was also found to be similar to comparable results, such as those of Biswas *et al.* 2017[15] (See Table 4).

Of all the long bones, the tibia can be used in the estimation of stature as it displays marked inter-individual and sexual differences, and it is also very important in sex determination, orthopedic surgery and radiology for the knee joint[9,16]. For tibia total length (measurement T3), the mean results of 356.146±24.705 mm, without laterality discrimination, are similar to those of Kaloo *et al.* 2019 with 35.73±1.84 cm.[16] However, the results regarding laterality were statistically significant, which could be related to the sex of the bone samples. The present study results are lower than those from Gharehdaghi *et al.* 2018 which reported 377.4±20.2 mm for right tibias and 377.7±19.5 mm for the left[9], but were greater than the 302.64 mm reported by Robinson *et al.* 2008[17]. (See Table 9).

For the proximal epiphysis, the distance from medial to lateral condyle (measurement T1) was considerably lower than the findings of Gharehdahgi *et al.* 2018, a study in which only male bones were measured[9]. The results of the present study are similar to those obtained by Kang *et al.* 2017 for female bones but are markedly different from the results recorded for the male bones[18]. Finally, the results obtained by Gandhi *et al.* 2014 conducted in India[19] are lower than those of the present study. Transverse diameter of the joint surface of the medial condyle (measurement T7) and the middle transverse measure of intercondylar area (measurement T9) are similar to the measurements obtained by Lucena-Dos-Santos *et al.* 2018 for male bones[20], while T7 and Transverse diameter of the joint surface of the lateral condyle (measurement T8) are similar to the results of Gandhi *et al.* 2014 for male bones.[19] The results for T9 are higher than those reported by Gandhi *et al.* 2014 due to the difference in the landmarks used in each study. Gandhi measured specifically the narrowest part of the intercondylar area which could be the reason why lower values were obtained[19]. (See Table 6).

In relation to the distal epiphysis, distance from the most caudal point of the medial malleolus to the fibular notch of the tibia (measurement T2) was found to be lower than the distances measured by Gharehdaghi *et al.* 2018 (namely, 51.5±2.8 mm for the right, and 50.5±3 mm for the left)[9], and the mean measurement reported by Robinson *et al.* 2008 of 52.46 mm[17].

The fibula is the donor bone of choice for grafting

procedures for the subsequent reconstruction of skeletal, soft tissue and growth plate defects due to its anatomic accessibility, its independent blood supply, and the fact that its removal have minimal effects on the gross function of lower extremity[21]. Right fibular total length (measurement P1) values are greater than those reported by other authors. Left fibular lengths, however, are similar to the studies of Albani *et al*. 2021, and Gharehdaghi *et al*. 2018[9,21] (See Table 7).

For the weights and the remainder of the morphometric measurements shown in Tables 8, 9 and 10, no literature could be found to carry out comparisons. The weight between bones in this current study presented a large standard deviation, likely due to a combination of factors including gender, the bone conservation method, and the time that the bones have been in the laboratory.

Conclusions

The present study describes bone parameters for the femur, tibia and fibula, and provides data on bone dimensions in lower limb long bones from the Colombian population. Variations in the bone parameters obtained in this study can be helpful for future studies in orthopedic surgery, radiology, forensic science and anatomy. The present morphometry follows a simple and easily replicable method. For future studies, researchers are encouraged to weigh dry bones to establish a mean for this parameter.

Acknowledgements

The authors would like to acknowledge the Laboratory of anatomy of the Technological University of Pereira, the technical support of Jerónimo Vásquez-Gómez and Andres F Loaiza, the Infection and Immunity research group and its Immunology and Infectious Disease research team (SINI).

Ethics statement

The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research[22].

References

1. Bourne M, Sinkler MA, Murphy PB. Anatomy, Bony Pelvis and Lower Limb: Tibia. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK526053/
2. Cantrell AJ, Imonugo O, Varacallo M. Anatomy, Bony Pelvis and Lower Limb: Leg Bones. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK537024/
3. Gupton M, Munjal A, Kang M. Anatomy, Bony Pelvis and Lower Limb: Fibula. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470591/
4. Arias-Reina M. Morfología y morfometría ósea de la cadera en población adulta de la ciudad de Bogotá-Colombia. Bogotá, Colombia: Universidad Nacional de Colombia. 2022. Available at: https://repositorio.unal.edu.co/handle/unal/81140?show=full
5. Rohlf FJ, Marcus LF. A revolution morphometrics. Trends in Ecology & Evolution. 1993;8(4):129-132. doi: 10.1016/0169-5347(93)90024-J
6. True LD. Morphometric applications in anatomic pathology. Human Pathology, 1996;27(5):450–467. doi:10.1016/s0046-8177(96)90089-1
7. Vineetha C, Sarvani M, Ashwinirani SR, Sakshi S, Athira CP, Shilpa KS, *et al*. Morphometry As a Diagnostic Tool for Potentially Malignant Lesions. J Clin Diagn Res. 2015;9(12):ZC22-5. doi: 10.7860/JCDR/2015/15838.6959
8. Domínguez LG, Orozco SL. Frequency and types of fractures classified by the AO system at Hospital General de León for one year. Acta méd. Grupo Ángeles. 2017;15(4): 275-286. Available at: http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1870-72032017000400275&lng=es.
9. Gharehdaghi J, Baazm M, Ghadipasha M, Solhi S, Toutounchian F. Anthropometric measurements in Iranian men. Journal of Forensic and Legal Medicine. 2018;53:31–34. doi:10.1016/j.jflm.2017.10.013
10. Polguj M, Bliźniewska K, Jędrzejewski K, Majos A, Topol M. Morphological study of linea aspera variations - proposal of classification and sexual dimorphism. Folia Morphol. 2013;72(1):72-7. doi: 10.5603/fm.2013.0012
11. Verma M, Joshi S, Tuli A, Raheja S, Jain P, Srivastava P. Morphometry of Proximal Femur in Indian Population. J Clin Diagn Res. 2017;11(2):AC01-AC04. doi: 10.7860/JCDR/2017/23955.9210
12. Lin KJ, Wei HW, Lin KP, Tsai CL, Lee PY. Proximal femoral morphology and the relevance to design of anatomically precontoured plates: a study of the Chinese population. ScientificWorldJournal. 2014;2014:106941. doi: 10.1155/2014/106941
13. Umer M, Sepah YJ, Khan A, Wazir A, Ahmed M, Jawad MU. Morphology of the proximal femur in a Pakistani population. J Orthop Surg (Hong Kong). 2010;18(3):279-81. doi: 10.1177/230949901001800304
14. Menezes TM, Rocha TDS, de Oliveira BDR, de Albuquerque YML, Caiaffo V. Proximal Femoral Epiphysis: Manual Morphometry versus Digital Morphometry. Int. J. Morphol. 2015;33(3): 1114-1119. doi: 10.4067/S0717-95022015000300048
15. Biswas A, Bhattacharya S. A morphometric and radiological study of the distal end of femur in West Bengal population. Italian journal of anatomy and embryology. 2017;122:39-48. doi: 10.13128/IJAE-20925
16. Kaloo RA, Khurshid N. Study of correlation of length of the tibia with dimensions of the distal articular surfaces of the Tibia. International Journal of Contemporary Medical Research. 2019;6(9):I1-I3. doi: 10.21276/ijcmr.2019.6.9.37
17. Robinson C, Eisma R, Morgan B, Jeffery A, Graham EAM, Black S, Rutty GN.Anthropological Measurement of Lower Limb and Foot Bones Using Multi-Detector Computed Tomography. Journal of Forensic Sciences. 2008;53(6):1289-95. doi:10.1111/j.1556-4029.2008.00875.x
18. Kang KT, Son J, Kwon OR, Baek C, Heo DB, Park KM, *et al*. Effects of measurement methods for tibial rotation axis on the morphometry in Korean populations by gender. The Knee. 2017;24(1):23–30. doi:10.1016/j.knee.2016.09.012
19. Gandhi S, Singla RK, Kullar JS, Suri RK, Mehta V. Morphometric analysis of upper end of tibia. J Clin Diagn Res. 2014;8(8):AC10-3. doi: 10.7860/JCDR/2014/8973.4736
20. Lucena-dos-Santos ERS, Albuquerque PPF, Albuquerque PV, Oliveira BDR, Caiaffo V. Determination of Sex Based on the Morphometric Evaluation of the Proximal Tibia. International Journal of Morphology. 2018;36(1):104-108. doi: 10.4067/S0717-95022018000100104

21. Albani S, Linda JB, Hemalatha GJ. A Study of Morphometric and Topographic Anatomy of Nutrient Foramen in Fibula. International Journal of Anatomy Radiology and Surgery. 2021;10(4): AO14-AO16. doi: 10.7860/IJARS/2021/48630:2691
22. Iwanaga J, Singh V, Takeda S, Ogeng'o J, Kim HJ, Morys J, Ravi KS, *et al*. Standardized statement for the ethical use of human cadaveric tissues in anatomy research papers: Recommendations from Anatomical Journal Editors-in-Chief. Clinical Anatomy 2022:1–3. doi: 10.1002/ca.23849
23. Santosh KS, Sujita P, Dharma NM. Morphometric Analysis of Lower End of Human Adult Dry Femur in the Zone of Eastern Odisha – An Observational Study. Int. J. Pharm. Sci. Rev. Res. 2022;74(2):63-67. doi: 10.47583/ijpsrr.2022.v74i02.009
24. Phombut C, Rooppakhun S, Sindhupakorn B. Morphometric Analysis and Three-Dimensional Computed Tomography Reconstruction of Thai Distal Femur. Appl. Sci. 2021;11:1052-66. doi: 10.3390/app11031052
25. Mahaisavariya B, Sitthiseripratip K, Tongdee T, Bohez EL, Vander Sloten J, Oris P. Morphological study of the proximal femur: a new method of geometrical assessment using 3-dimensional reverse engineering. Med Eng Phys. 2002;24(9):617-22. doi: 10.1016/s1350-4533(02)00113-3
26. Chavda HS, Jethva NK, Gupta S. A study of Morphometric analysis of condyles of adult femur of humans in Gujarat region. International Journal of Anatomy, Radiology and Surgery. 2019; 8(3): AO01-AO05. doi: 10.7860/IJARS/2019/40703:2474
27. Shweta J, Renu C. Morphometric analysis of Condyles and Intercondylar notch of femur in North Indian population and its Clinical significance. J Evolution Med Dent Sci. 2017;6(32): 2605-08. doi: 10.14260/Jemds/2017/563
28. Biswas A, Bhattacharya S. A morphometric and radiological study of the distal end of femur in West Bengal population. Italian Journal of Anatomy and Embryology 2017;122(1):39- 48. doi: 10.13128/IJAE-20925
29. Zalawadia AZ, Parekh DH, Patel S. M. Morphometric study of lower end of dry femur in Gujarat region and its Clinical implication. Int J Anat Res. 2017; 5(4.2):4595-99. doi: 10.16965/ijar.2017.406
30. Ameet, K. J., Murlimanju, B. V. A Morphometric Analysis of Intercondylar Notch of Femur with Emphasis on Its Clinical Implications. Med and Health. 2014; 9(2): 103-08.
31. Terzidis I, Totlis T, Papathanasiou E, Sideridis A, Vlasis K, Natsis K. Gender and side-to-side differences of femoral condyles morphology: osteometric data from 360 caucasian dried femori. Anatomy Research International. 2012; 2012:679658. doi: 10.1155/2012/679658
32. Ravichandran D, Melanie R. Morphology of the intercondylar notch and its clinical significance. IJAS. 2010;1:26–30.
33. Murshed KA, Çiçekcibaşi AE, Karabacakoğlu A, *et al*. Distal femur morphometry: a gender and bilateral comparative study using magnetic resonance imaging. Surg Radiol Anat. 2005;27:108–112. doi: 10.1007/s00276-004-0295-2
34. Baharuddin, M. Y., Zulkifly, A. H., Lee, M. H., Kadir, M. R. A., Saat, A., & Aziz, A. A. Three dimensional morphometry of the femur to design the total hip arthroplasty for Malay population. Advanced Science Letters. 2013;19(10):2982-87. doi: 10.1166/asl.2013.5085
35. Unnanuntana A, Toogood P, Hart D, Cooperman D, Grant RE. Evaluation of proximal femoral geometry using digital photographs. J Orthop Res. 2010;28(11):1399-404. doi: 10.1002/jor.21119
36. Umer M, Sepah YJ, Khan A, Wazir A, Ahmed M, Jawad MU. Morphology of the proximal femur in a Pakistani population. J Orthop Surg (Hong Kong). 2010;18(3):279-81. doi: 10.1177/230949901001800304
37. Mahaisavariya B, Sitthiseripratip K, Tongdee T, Bohez EL, Vander Sloten J, Oris P. Morphological study of the proximal femur: a new method of geometrical assessment using 3-dimensional reverse engineering. Med Eng Phys. 2002 Nov;24(9):617-22. doi: 10.1016/s1350-4533(02)00113-3
38. Mukhia R, Poudel PP, Mansur DI, Wahekar K. Morphological and Morphometrical Study of Dry Fibula at Medical college of Western Nepal. Journal of Karnali Academy of Health Sciences. 2022;5(1). Available at: https://jkahs.org.np/jkahs/index.php/jkahs/article/view/258/328
39. Kaur J, Srivasatava D. Morphometric analysis of fibular graft dimensions for placement of dental implants. Journal of the Anatomical Society of India. 2015;64(1):67-72. doi: 10.1016/j.jasi.2015.04.016

Mini Curriculum and Author's Contribution

1. Manuela Pineda - Medical student. Contribution: Effective scientific and intellectual participation for the study; technical procedures; data acquisition; preparation and draft of the manuscript; critical review and final approval. ORCID 0009-0003-3471-7843

2. María A Barrera - Medical student. Contribution: Effective scientific and intellectual participation for the study; technical procedures; data acquisition; preparation and draft of the manuscript; critical review and final approval. ORCID 0009-0008-0569-9494

3. Daniela Botero-González – DDS; M.Sc; PhD. Contribution: Guiding professor; effective scientific and intellectual participation for the study; technical procedures; data acquisition; data interpretation; data statistical analysis; preparation and draft of the manuscript; critical review and final approval. ORCID 0000-0002-0156-4997

Received: October 27, 2023
Accepted: December 12, 2023

Corresponding author
Daniela Botero-González
E-mail: dbotero@utp.edu.co