OPEN ACCESS

Saudi Journal of Medicine
Abbreviated Key Title: Saudi J Med
ISSN 2518-3389 (Print) | ISSN 2518-3397 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Assessment of Age from Morphometric Analysis of the Tibia Bone

Clinton David Orupabo[1]*

[1]Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University

DOI: https://doi.org/10.36348/sjm.2026.v11i05.001 | **Received:** 27.02.2026 | **Accepted:** 20.04.2026 | **Published:** 01.05.2026

***Corresponding Author:** Clinton David Orupabo
Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University

Abstract

Much recent studies in trying to discover a more accurate and reliable method in age estimation have been ongoing. The study aimed at estimating age using the metrical parameters of the tibia bone. Long bones adjudged to be reliable also offer researchers an easy-to-use approach for its robustness and uniqueness. The cadaveric samples included bones of the right tibia of 78 males (53 profiled and 25 non-profiled for age) who are within the age range of 21 and 60 years. A convenience sampling technique was utilized for the bone collection. Two to three bone sections were collected from the mid-shaft of the right tibia using a hacksaw. The data was analyzed with SPSS 25. The findings showed that the mean of the marrow cavity diameter (MCD), marrow area (MA), radius, and area of cortex were 2.15 ± 0.07, 4.10 ± 0.27, 0.36 ± 0.01, and 0.45 ± 0.04, respectively. ANOVA test for variation shows a statistically significant (P=0) variation in the MCD and MA between the different age groups studied. The variation in the area of cortex was not statistically significant (P>0.05). The MCD, MA, and the radius of the cortex show weak correlation with age (r= 0.264, 0.363, and 0.031), and are hence poor assessors of age in males using the tibia.

Keywords: Age, Cortex of bone, Males, Marrow cavity area, Marrow cavity diameter, Tibia bone.

INTRODUCTION

Several studies have been done to try to elucidate a more scientific and logical approach to determining the identity of skeletal remains. These studies range from older macroscopic analyses to more current and very reliable approaches. [1-15] In fact, it has been postulated that once the age and sex are determined, the identity of any skeletal remain is almost about 80% established. [16-18] Again, population-specific studies have been conducted to decipher if variations in these anthropological features exist. Although it is logically expected that such variations could exist with gross anatomical features, hinged on genetic and geographical differences. Our research stems from a challenging reality to bridge the already existing gap with the African population. In fact, most African countries, including Nigeria, are grossly lagging in investigating and solving criminal cases for cases of questionable deaths and identification of missing victims from remains. This is, however, due to a lack of a forensic database, a lack of contemporary forensic equipment, and poor training of personnel, as well as police officers. [19]

The unique anatomy of the long bones makes them a common tool in the hand of forensic experts for their easy-to-study approach and possession of several features for sex and age estimation. Although research has shown that some bones other than the long bones serve for distinction in age estimation. However, because of their length and robustness, they appear to be some of the skeletal remnants found at crime scenes. In fact, most studies requiring compact bones have utilized the long bones. [20, 21, 14, 22]. Again, because long bones provide researchers with the means to study their various regions, some authors have also investigated the effect of physical and mechanical stressors on these different regions to investigate if variations exist following remodeling rates at different levels. [23-25] We intend, therefore, to examine the midshaft of the tibia for various age distributions.

Gross anatomical approaches for age estimation differ across age groups, so that the findings on skeletal remains vary with children, adults, and the elderly. [26, 27] As early as 1955, Brooks [1] analyzed the pubic bone and cranium and demonstrated age indicators with relevant sexual dimorphic variables. Also, Brooks *et al.,* (1990) [28] examined two methods with the assessment of the os pubis and documented that the application of these methods to an area of the skeleton offered more accurate results. The auricular surface of the Ilium was further examined for age changes, which offered new advances at that time when several controversies prevailed. [3] In an earlier work to determine age from combined morphology and histology, Thomas *et al.,* (2000) [21] looked at some femoral features, including total subperiosteal area, periosteal, and endosteal perimeter. They concluded that most of the parameters studied were independent predictors of age and that a larger medullary cavity with age [29, 30] was observed. Takeuchi *et al.,* (1998) [31] demonstrated marrow cavity enlargement with age and documented a positive correlation with circumference and area of marrow cavities in male and female subjects. They reported that in male subjects over 60years and those between 40 and 60years, the difference in marrow cavity enlargement was marked. Takahashi *et al.,* (1966) [32] reported in their study on the mid-shaft of the ribs that the size of the cortical area of the bone peaks between 15 and 25 years, and declines afterwards in both sexes. They also documented that the ratio of the cortical to the total cross-sectional area of the bone decreases throughout life. Thomas *et al.,* (2005) [33] also studied the medullary and cortical areas of the femur of an Australian population and discovered that with increasing age, the porosity in the inner cortex, posterior and anterolateral regions increase. Thus, while the porosity in the male samples increases steadily, that of females had much different patterns from those of the younger age group to the older groups. Therefore, with increasing porosity, the cortical area could decrease and subsequently lead to larger marrow cavities.

MATERIALS AND METHODS

Bone samples were collected from individuals who are all Nigerians, though of poor socioeconomic background. The age, sex, and ethnic origin of the cadavers were documented, except for a very few whose bio data was missing from the hospital records. The cadaveric samples included bones of the right tibia collected from the Mortuary Unit, Pathology Department of the University of Port Harcourt Teaching Hospital, from 78 males (53 profiled and 25 non-profiled for age) who are within the age range of 21 and 60 years. A convenience sampling technique was utilized for the bone collection. 2-3 bone sections were collected from the mid-shaft of the right tibia using a hacksaw with the cadaver in supine position. Cross sections were made to a thickness of about 0.5mm to 1.0cm. The sections were cut within 5 to 15 degrees perpendicularly to the longitudinal axis of the long bone. Direct measurements were done for the marrow cavity diameter (MCD) and cortical radius or thickness using a centimeter rule and a sliding digital vernier caliper (Kales Industry and Trade Co., Ltd, Jinhua, Zhejiang, China) to the nearest 0.1mm. The marrow cavity diameter was taken at the maximum ends of the concentric circle, from one end to the opposite end of the circle and/or sphere. The cortical thickness was taken from the inner edge of the cortical plate to the outer edge of the cortical plate. The marrow cavity diameter is obtained by measuring the distance from one end of the cavity at its maximum point to the opposite end. The cortical thickness is obtained by measuring the distance from the inner border of the cortex to the outer border of the cortex or periosteal border, and is designated as r [1]. The marrow or medullary area is a derived parameter and first obtained by dividing the marrow cavity diameter by 2 to obtain the radius, and is designated as r^2. This is then inserted into the formula for the area of a circle πr [2], in order to calculate the marrow area. The cortical area is obtained by using the cortical thickness, r [1], and then inserted into πr^2. Data was analyzed with SPSS 25.

RESULTS

Table 1 shows the mean value for the various metric parameters taken for the tibia bone of Nigerian males. This is the mean for all ages studied.

Table 1: Descriptive statistics for the metric parameters of the tibia

Parameters (Cm)	Mean ±Sem (N= 78)
MCD	2.15 ± 0.07
Radius of cortex	0.36 ± 0.01
Area of cortex	0.45 ± 0.04
Radius of MC	1.10 ± 0.04
MA	4.10 ± 0.27

MCD-marrow cavity diameter, MA-marrow area, SEM-standard error of mean

Table 2: Descriptive statistics of the various age distributions

Age Range	MCD (cm)	Radius of cortex(cm)	Area of cortex(cm)	Radius of MC (cm)	MA (cm)
20-22	2.16 ± 0.21	0.28 ± 0.04	0.25 ± 0.07	1.10 ± 0.10	4.03 ± 0.69
23-25	2.31 ± 0.20	0.32 ± 0.03	0.36 ± 0.06	1.17 ± 0.10	4.80 ± 0.85
26-28	2.36 ± 0.16	0.32 ± 0.04	0.34 ± 0.08	1.20 ± 0.08	4.60 ± 0.63
29-31	2.44 ± 0.13	0.31 ± 0.03	0.33 ± 0.07	1.24 ± 0.07	4.93 ± 0.50
32-34	2.20 ± 0.00	0.20 ± 0.00	0.10 ± 0.00	1.10 ± 0.00	3.80 ± 0.00
35-37	1.20 ± 0.00	0.30 ± 0.00	0.30 ± 0.00	0.60 ± 0.00	1.10 ± 0.00
38-40	1.20 ± 0.00	0.50 ± 0.00	0.80 ± 0.00	0.60 ± 0.00	1.10 ± 0.00
41-43	2.30 ± 0.00	0.30 ± 0.00	0.30 ± 0.00	1.20 ± 0.00	4.50 ± 0.00

Age Range	MCD (cm)	Radius of cortex(cm)	Area of cortex(cm)	Radius of MC (cm)	MA (cm)
44-46	1.80 ± 0.00	0.30 ± 0.00	0.30 ± 0.00	0.90 ± 0.00	2.50 ± 0.00
50-52	3.33 ± 0.03	0.35 ± 0.05	0.40 ± 0.10	1.70 ± 0.00	9.10 ± 0.00
59-61	2.90 ± 0.30	0.30 ± 0.10	0.35 ± 0.25	1.45 ± 0.15	6.78 ± 1.23

MCD-marrow cavity diameter, MA-marrow area, SEM-standard error of mean

Table 2 shows the MCD, MA, Radius and Area of cortex for the different male age groups. The marrow cavity and marrow area is seen to increase with age but for some isolated reductions at ages 35 to 40. The area of cortex does not show a definite pattern.

Table 3: Test of variation between Age groups using ANOVA

Parameters		Sum of Squares	Df	Mean Square	F	Sig.
MCD	Between Groups	16.519	11	1.502	5.174	.000**
	Within Groups	23.801	82	.290		
	Total	**40.320**	**93**			
Radius cortex	Between Groups	.425	11	.039	2.808	.004**
	Within Groups	1.128	82	.014		
	Total	**1.553**	**93**			
Area cortex	Between Groups	2.545	11	.231	2.411	.012
	Within Groups	7.869	82	.096		
	Total	**10.413**	**93**			
	Within Groups	5.726	82	.070		
	Total	**10.010**	**93**			
MA	Between Groups	228.492	11	20.772	4.749	.000**
	Within Groups	358.656	82	4.374		
	Total	**587.148**	**93**			

MCD-marrow cavity diameter, MA-marrow area, ** - very significant

Table 3 shows a statistically significant (P=0) variation in the MCD and MA between the different age groups studied. The variation in the area of cortex was not statistically significant (P>0.05) whereas that of the radius was statistically significant (P=0.004).

Table 4 shows a post hoc test to see which variable shows the most significant variation between the age groups studied. Hence it was observed that the MCD shows the most statistical variation and can be suitable for age determination in males using the tibia.

Table 4: Post hoc t-Test: Two-Sample Assuming Equal Variances

	MCD	*MA*
Mean	2.204	4.321
Variance	0.448004	5.992543
Observations	10	10
Pooled Variance	3.220274	
Hypothesized Mean Difference	0	
Df	18	
t Stat	-2.63791	
P(T<=t) one-tail	0.008355	
t Critical one-tail	1.734064	
P(T<=t) two-tail	0.01671	
t Critical two-tail	2.100922	

Table 5: Correlation coefficient for Age and MCD/Radius of cortex

Parameters	Correlation coefficient (r)
MCD	0.264
MA	0.363
Radius of cortex	0.031
Area of cortex	0.185

MCD-marrow cavity diameter, MA-marrow area
Correlation coefficient (r) values were determined using Pearson correlation.

Table 5 shows a weak positive correlation between age and the MCD. This suggests that as age advances, the MCD also increases but fairly. There is also a very weak positive correlation between age and radius of cortex. This suggests that age has little or no impact on the radius of the cortex.

DISCUSSION

The use of the long bones in age estimation as well as in other anthropological parameters have been document to be very reliable by several researchers [34-38], although only a very few have studied on the tibia as most of the studies sourced and found were done on the femur.[39, 30, 21] Some studies on the tibia focused on the use of histology to determine age. [40, 41] It is however postulated that gross anatomical approaches for age estimation differ across age groups so that the findings on skeletal remains vary with children, adults and the old. [26, 27] Hence it is likely the findings with the tibia could infer close results to previous studies.

Our findings show the mean of the marrow cavity diameter, marrow area, radius, and area of cortex as 2.15 ± 0.07, 4.10 ± 0.27, 0.36 ± 0.01, and 0.45 ± 0.04, respectively (Table 1). The marrow cavity and marrow area are observed to increase with age, but some isolated reductions at ages 35 to 40 (Table 2). The area of the cortex does not show a definite pattern. However, the ANOVA test for variation (Table 3) shows statistically significant (P=0) variation in the MCD and MA for the different age groups studied. The MCD shows stronger statistical variation among male age groups using a post-hoc test (Table 4). The variation in the area of cortex was not statistically significant (P>0.05), whereas that of the radius was statistically significant (P=0.004). Bonicelli *et al.,* (2021) [35] work on age-related changes in the rib cortical bone matrix documented that the cortical bone porosity was seen to increase linearly with age, showing a robust correlation (P<0.001). This implies that as age increases, the cortical thickness decreases as the bone becomes more porous. The findings were more precise, though, showing that there truly is an age difference in the radius and area of the cortex, but the variation with age is more statistically significant (P<0.05) for the cortical radius. Also, Feik *et al.,* (1997) [30] documented on the midshaft of the femur and noted that the total subperiosteal area was significantly higher in the 7th decade than in the 3rd decade of life for males. There were no significant differences beyond the age of 70. It is possible that since our study population was all before their 7th decade of life, the variation in the area of cortex was not significant as reported by Feik *a* 1997, [30]. Although our study was on the tibia, there appear to be some relevant similarities with other long bones previously studied.

Feik and associates [30] also reported that the medullary area decreased from early childhood to middle age, although not significantly. The study discovered age variation, which was statistically significant in the marrow cavity diameter and medullary or marrow area. Our findings concur with Takahashi & Frost (1966), [32] who reported that the marrow area and marrow cavity enlarge with age, but become temporarily stable between 20 and 40 years. In the present study, however, the marrow cavity diameter and marrow area increase steadily from age 20 to 30 years, but fall surprisingly between 30 and 40 years, and increase rapidly again from 40 to 55 years, then become stable beyond this age. Whether this inconsistency seen in this study is common with the tibia bone, or with the prevailing socioeconomic class of our study population, is yet to be ascertained. We hope this will be unraveled with further studies on the tibia bone. Table 5 shows a weak positive correlation between age and the marrow cavity diameter, and even a much weaker correlation with the radius of the cortex. Although the marrow cavity enlarges with age, our findings show a weak correlation. This could affect the reliability of the tibia in age estimation using the marrow cavity diameter and the radius of the cortex. However, the marrow area, though showing a weak correlation (r=0.363), is more positively correlated with age compared to the other parameters. The marrow area in our study is a better assessor of age.

CONCLUSION

The findings in this study show that the marrow cavity diameter and the radius of the cortex show weak correlation with age, although variation between age groups was shown to be statistically significant (P<0.05) with the MCD, MA, and radius of cortex. The MCD also shows a stronger variation among male age groups after a post-hoc test. It therefore infers that these parameters, though they can be used to determine age, are weak assessors of age in males when the tibia is used.

Conflict of Interest: There is no conflict of interest.

Ethical Approval: Ethical approval was sought from the University of Port Harcourt Research Ethics Committee and was granted with the ethical number UPH/CEREMAD/REC/MM83/012

Acknowledgement

Special appreciation to the Head of Pathology Department and the Mortuary unit head, and as well the Chief Medical Director of UPTH for providing the specimen for this work and granting permission to go ahead with the skeletal collections.

REFERENCES

1. Brooks ST. Skeletal age at death: the reliability of cranial and pubic age indicators. Am J Phys Anthropol. 1955; 13:567–597.
2. Redfield A. A new aid to ageing immature skeletons, development of the occipital bone. American Journal of Physical Anthropology. 1970; 33:207-220.

3. Lovejoy CO, Meindl RS, Pryzbeck TR, *et al.,* Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. Am J Phys Anthropol. 1985a; 68:15–28.
4. Krogman WM, İşçan MY. The Human Skeleton in Forensic Medicine. American Journal of Physical Anthropology. 1987; 74 (1):136 – 137.
5. Stout SD, Dietze WH, İşçan MY, Loth SR. Estimation of age at death using the cortical histomorphometry of the sternal end of the fourth rib. Journal of Forensic Sciences. 1994; 39(3):778-784.
6. Smith KJ. Standards of human tooth formation and dental age assessment. In Kelley, M. A, Larson, C. S. (Eds), Advances in Dental Anthropology, New York: Wile Liss.1991; pp. 143-168.
7. John KL. Forensic anthropology: What bones can tell us. Laboratory Medicine, Vol.29. no.7. Journal of Physical Anthropology. 1998; 23:149-164.
8. Loth SR, İşçan MY. Morphological age estimation. In: Siegal, J, Saukko, P, Knupfer, G (Eds). Encyclopedia of Forensic Science. Academic. 2000; 242-252.
9. Scheuer L, Black S. Developmental Juvenile Osteology London: Academic Press. 2000
10. Oettle AC, Steyn M. Age estimation from the sternal ends of ribs by phase analysis in South African blacks. Journal of Forensic Sciences. 2000; 45(5):1071-1079.
11. Scheuer L. Application of osteology to forensic medicine. Clinical Anatomy. 2002; 15:297-312.
12. Buckberry JL, Chamberlain AT. Age estimation from the auricular surface of the ilium: a revised method. American Journal of Physical Anthropology. 2002; 119:231-239.
13. Yuriko I, Kagumi U, Tetsuaki W, Eisaku K. New method for estimation of adult skeletal age at death from the morphology of the auricular surface of the ilium. American Journal of Physical Anthropology. 2005; 128(2):324-339.
14. Sobol J, Ptaszyńska-Sarosiek I, Charuta A, Oklota-Horba M, Żaba1 Cz, & Niemcunowicz-Janica A. Estimation of age at death: examination of variation in cortical bone histology within the human clavicle Folia Morphol. 2015; Vol. 74, No. 3, pp. 378–388.
15. Ubelaker DH, Khosrowshahi H. Estimation of age in forensic anthropology: Histological perspective and recent methodological advances. Forensic Science Res. 2019; 4(1):1-9.
16. Lynnerup N, Thomsen JL, Frohlich B. Intra- and Inter-observer variation in histological criteria used in age at death determination based on femoral cortical bone. Forensic Science International. 1998; 91(3):219-230.
17. Maat GJR, Maes A, Aarents MJ, Nagelkerke NJD. Histological age at death prediction from the femur in a contemporary Dutch sample* The decrease of non-remodeled bone in the anterior cortex. Journal of Forensic Sciences. 2006; 51:230-237.
18. Kosior W. Age and Notions related to it in Greek Non – legal sources – The contribution to the Research of Roman law 1. Roc2niki Administracji prawa nr. 2016; XVI (1), S.85 – 96.
19. Ladapo OA. ISSN 1554-3897 African Journal of Criminology and Justice Studies: Effective Investigations, A Pivot To Efficient Criminal Justice Administration: Challenges In Nigeria. 2008; AJCJS, Vol.5, #s1 &279.
20. Keough N. Estimation of age at death from the microscopic structure of the femur. MSc Thesis submitted to the School of Medicine, Faculty of Health Sciences, University of Pretoria, South Africa. 2007
21. Thomas CDL, Steyn MS, Feik SA, Wark JD, Clement JG. Determination of age at death using combined morphology and histology of the femur. Journal of Anatomy. 2000; 196, Pp 463 – 471.
22. Simone L. Sex Estimation in Forensic Anthropology Using the Radius, Femur, and Scapula. Honour Thesis, Texas State University, San Marcos, Texas. 2015.
23. Ingraham MR. Histological age estimation of the midshaft clavicle using a new digital technique. M.Sc Thesis (Biology), University of North Texas. 2004
24. Tersigni MA. Serial Long Bone Histology: Inter-and Intra-Bone Age Estimation. PhD diss., University of Tennessee. 2005.
25. Gocha TP, Agnew AM. Spatial variation in osteon population density at the human femoral midshaft: histomorphometric adaptations to habitual load environment. J. Anat. 2016; 228, pp733—745.
26. Ubelaker DH. Human skeletal remains: Excavation, analysis, interpretation. Washington (DC): Taraxacum; 1999.
27. Rogers TL. Skeletal age estimation. In: Blau S, Ubelaker DH, editors. Handbook of forensic anthropology and archaeology. New York City (NY): Routledge; 2016; 273–292.
28. Brooks' S, Suchey JM. Skeletal age determination based on the os pubis: a comparison of the Acsadi-Nemeskeri and Suchey-Brooks methods. J Hum Evol. 1990; 5:227–238.
29. Feik SA, Thomas CDL, Clement JG. Age trends in remodeling of the femoral midshaft differ between the sexes. Journal of Orthopaedic Research. 1996; 14, 590–597.
30. Feik SA, Thomas CDL, Clement JG. Age-related changes in cortical porosity of the midshaft of the human femur. Journal of Anatomy. 1997; 191, 407–416.
31. Takeuchi S, Kageyama I, Awatake T, Kato S, Yamashita H. Enlargement of the femoral marrow cavity with aging. Kaibogaku Zasshi. 1998; 73(3):259-64.
32. Takahashi H, Frost HM. Age and Sex Related Changes in the Amount of Cortex of Normal Human Ribs, Acta Orthopaedica Scandinavica. 1966; 37:2, 122-130, DOI: 10.3109/17453676608993272

33. Thomas CDL, Feik SA, Clement JG. "Regional variation of intracortical porosity in the midshaft of the human femur: age and sex differences," Journal of Anatomy. 2005; vol. 206, pp. 115-125.
34. Kranioti EF, Michalodimitrakis M. Sexual dimorphism of the humerus in contemporary Cretans--a population-specific study and a review of the literature*. J Forensic Sci. 2009 Sep; 54(5):996-1000. doi: 10.1111/j.1556-4029.2009.01103. x.
35. Bonicelli A, Zioupos P, Arnold E, Rogers KD, Xhemali B, Kranioti EF. Age related changes of rib cortical bone matrix and the application to forensic age-at-death estimation. Sci Rep. 2021; 22; 11(1):2086. DOI: 10.1038/s41598-021-81342-0.
36. Gupta A, Billings BK, Hummel S, Grosskopf B. Evaluating Morphological Methods for Sex Estimation on Isolated Human Skeletal Materials: Comparisons of Accuracies between German and South African Skeletal Collections. Forensic Sci. 2022, 2, 574–584. https://doi.org/10.3390/forensicsci2030042
37. Didia BC, Nduka EC, Adele O. Stature estimation formulae for Nigerians. Journal of Forensic Sciences. 2008; 54 (1): 20-21.
38. Oghenemavwe LE, Agi CE. Stature estimation from humeral length amongst Nigerians: A radiographic approach. World Journal of biology pharmacy and health sciences. 2022; 09(03), 030–035
39. Smith RW, Walker HR. Femoral expansion in aging women: implications for osteoporosis and fractures. Science. 1964; 145, 156-157.
40. Thompson DD. Core technique in the determination of age at death in skeletons. Journal of Forensic Sciences. 1979; *24*:902-915.
41. Orupabo CD, Oghenemavwe LE, Diamond TE. Histomorphometric estimation of age from bone samples of Nigerians. International Journal of Medicine and Medical Research. 2020; 6(2): 67-76.