Sex determination using Radiographic Anthropometric dimensions of the Clavicle in an Igbo population of Nigeria

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ABSTRACT

Introduction: The clavicle varies between the sexes, being more curved, thicker, less smooth and longer in males than in females. The purpose of this study was to predict the sex of an individual from the clavicle dimensions in the West Niger Igbo population of Nigeria.

Materials and Methods: This retrospective study involved subjects, 25 to 69 years old, who visited the Radiology Department of Federal Medical Centre, Asaba, for plain chest X-ray, from January to December, 2017. A total of 140 posterior-anterior chest X-ray films, 58 males and 82 females, were used. The Linear horizontal length (LHL), Sternal end diameter (SED), Acromial end diameter (AED) and Mid-length diameter (MLD) were measured. Students' t-test was used to assess the mean gender difference and the mean side difference, while the Pearson's correlation was used to ascertain the relationship between right and left clavicles. The level of statistical significance was fixed at p-value <0.05.

Results: There were significantly higher mean values of LHL, SED, AED and MLD on both sides in males than in females (p<0.001). There was significant, strong positive paired samples correlation of all parameters (p<0.001. The accuracy of sex estimation was 80.7% (LHL), 63.6% (SED), 65.7% (AED), 67.9% (MLD), 80.7% (combined parameters) on the right and 74.3% (LHL), 70.7% (SED), 56.4% (AED), 62.1% (MLD) and 80.7% (combined parameters).

Conclusion:The results have further shown that sex can be estimated from the dimensions of the adult clavicle and therefore, will be useful to the forensic anthropologists in human identification.

Key words: Anthropology, Clavicle, Discriminant function analysis, Nigeria, Sex determination

INTRODUCTION

Biological profile is the unique physical features of a person which can be ascertained from the from the records of an individual or the remains after death. Establishing the biological profile of an individual is very crucial to the success of a forensic human identification. [1] This usually involves the determination of sex, age, stature and ancestry or ethnicity. There are many situations in which human identification may become necessary: road traffic accidents, air crashes, natural disasters, homicides, murder and so forth. In our environment, the spate of killings as a result of religious insurgency on the one hand and local militia groups on the other hand is a common knowledge. In these situations, sex determination reduces the number of possible searches of an unknown individual by half. [2]

Bones such as the skull, pelvis, long bones of the upper and lower limbs, such as the clavicle, humerus and femur have been employed in the identification of unknown persons.[3] The clavicle is the first bone to start ossification, at about the 5th– 6th week of intrauterine life, and the last to complete the process, at about 25th year of life.[4] Anatomically, the features of the clavicle vary between the sexes; being more curved, thicker, less smooth and longer in males than in females.[5] The clavicle as a bone, is a durable anatomical structure that can withstand taphonomic degradation after the individual has died, even long after the soft tissues have decomposed, making it suitable for human and indeed sex determination. [6]

Different studies on sex determination have focused more on the dry bones. [7–10] There is a paucity of studies that employed the plane radiographic method for sex determination. Similarly, various studies have been conducted in different populations of the world, using different methods on the morphology and morphometry of the clavicle. Those that used dry clavicle were conducted in India [7, 10–17] and South Africa. [8] Those that used plane chest radiographs are scarce, except the study conducted in Southern Nigeria. [18] Among the studies that used computed tomography images are those conducted in China [19] and Cape Town, South Africa. [20, 21] However, the anthropometric dimensions of bones in one population or geographic area may be different from those of another. [3] Furthermore, it has been rightly noted that the design and fixation of devices for fractured clavicle depends on the anatomy and morphology of this bone. [21] Lack of baseline data for a particular population or ethnic group can militate against the effective management and provision of appropriate devices for fixation of fractured clavicle, which are lacking in the population under consideration.

The study will provide discriminant formulae for sex determination that will be used as a tool by the forensic anthropologist. It will also provide a database of anthropometric dimensions of the clavicle which will serve as a guide to the orthopaedic surgeons in the effective surgical management of patients involving the clavicle. This study will be relevant to Biological Anthropologist for population studies. The purpose of this study is to predict the sex of an individual from the clavicle dimensions in the West Niger Igbo population of Nigeria.

MATERIALS AND METHODS

Study Design and Population

The retrospective cross-sectional method for the quantitative design was used in this study. Subjects 25 to 69 years of age who visited the Radiology Department of Federal Medical Centre Asaba, for plain chest X-ray, from January to December, 2017 constituted the study population.

Sample and Sampling Technique

The sample comprised 140 posterior-anterior (PA) chest X-ray radiographs, 58 males and 82 females, which constituted all films for that period less those excluded from the study.

Selection Criteria

All technically adequate radiographs were included in the study. Those indicative of clavicular disorder or fracture as confirmed by the radiologist were excluded. In addition, radiographs showing clavicles short of complete secondary ossification were excluded.

Ethical Consideration

The principles of Helsinki Declaration [22] are considered in this study. Accordingly, the approval for this study was obtained from the Research and Ethical Committee of the Federal Medical Centre, Asaba, with reference number: FMC/ASB/A81 VOL. XII/96.

Method of Data Collection

Each film was placed in a well illuminated X-ray viewing box and the following parameters of the clavicle were measured using the digital sliding vernier caliper (Mitutoyo, Japan):

Linear horizontal length (LHL): The horizontal distance between parallel lines drawn at the most medial part of the Sternal end and most lateral part of the acromial end of the clavicle (Figure 1).

Sternal end diameter (SED): The vertical distance between the highest point and the lowest point of the medial border of Sternal end of the clavicle (Figure 1).

Acromial end diameter (AED): The vertical distance between the highest point and the lowest point of the lateral border of acromial end of the clavicle (Figure 1).

Mid-length diameter (MLD): The vertical distance between the highest point and the lowest point of the middle of the linear horizontal length of the clavicle (Figure 1).

Estimation of error of measurements

Fifteen Chest X-ray films from a population other than the one for the main study were obtained and the LHL, SED, AED and MLD were measured on two different days of one week apart. Technical error of measurement (TEM) was calculated based on a standard formula shown below: Absolute TEM= $\sqrt{(\sum D^2 \div 2N)}$. [23, 24] 'D' is the difference between the two measurements; N is the total number of subjects measured in the two days. The TEM was transformed into the relative TEM (rTEM); this was to express the error in percentage corresponding to the total average of the variable according to the following formula: Relative TEM= (TEM/VAV) ×100. [23] Where VAV = Variable average value (arithmetic mean of the mean between double measurements). The Absolute TEM was found to be 0.48 for the LHL, 0.18 for SED, 0.19 for AED and 0.16 for MLD while the Relative TEM was 0.3%, 1.1%, 1.3% and 1.1% for the LHL, SED, AED and MLD respectively. The errors observed were minimal and hence had no effect on the study results.

Data Analysis

The raw data were analysed with the aid of IBM SPSS version 23. Independent samples t-test was used to test the mean difference between males and females, and paired sample t-test was used to test the mean difference between right and left side. Pearson's correlation was also conducted to ascertain the level of relationship between right and left side. Discriminant function analysis was also done to determine the accuracy of each parameter for sex determination. The level of statistical significance was fixed at p-value <0.05

RESULTS

Demographic data of subjects revealed 41.4% (58) and 58.6% (82) of all study subjects were males and females respectively. Data also showed that the mean ± SD age of the study subjects was 43.7 ± 12.94 years.

Table 1: Comparison of parameters studied in males and females on the left and right side.

Side	Parameter	Sex	N	Range	Mean±SD	t	Df	p-value
Left	LHL (mm)	F	82	95.19-175.43	134.54±13.64			
		M	58	128.07-170.90	148.73±10.13	6.718	138	<0.001
	SED (mm)	F	82	17.58-34.64	23.36±3.34			
		M	58	19.05-30.52	25.46±2.74	3.932	138	<0.001
	AED (mm)	F	82	7.15-20.51	13.62±2.77			
		M	58	9.82-20.14	14.81±2.49	2.601	138	<0.001
	MLD(mm)	F	82	10.37-26.83	14.92±2.63			
		M	58	12.48-24.90	16.77±2.59	4.116	138	<0.001
Right	LHL (mm)	F	82	60.53-177.27	132.65±15.73			
		M	58	128.07-171.86	152.01±9.59	9.024	138	<0.001
	SED (mm)	F	82	16.21-31.84	22.63±3.37			
		M	58	17.05-31.55	24.93±3.23	4.049	138	<0.001
	AED (mm)	F	82	7.72-21.05	13.25±2.91			
		M	58	8.39-24.05	15.53±3.20	4.393	138	<0.001
	MLD(mm)	F	82	9.26-22.03	14.23±2.15			
		M	58	11.45-22.24	15.70±2.11	3.990	138	<0.001

LHL= Linear horizontal length, SED= Sternal end diameter, AED= Acromial end diameter, MLD= Mid-length diameter, F=female, M=male, Df= degree of freedom.

Table 1 shows the comparison of clavicular parameters studied on the left and right side between males and females. In all the parameters, the mean ± SD in males were statistically significantly higher than those in females on both sides: p< 0.001 each for LHL, SED and MLD on the left; LHL, SED, AED and MLD on the right; while p= 0.010 for left AED.

Table 2: Paired samples t-test between right and left clavicles (N=140).

Pair	Parameter	Mean±SD difference	t	Df	p-value
Pair 1	Linear horizontal length on right side - Linear horizontal length on left side (mm)	0.25±8.75	0.339	139	0.735
Pair 2	Sternal end diameter on right side - Sternal end diameter on left side (mm)	-0.64±2.49	-3.060	139	0.003
Pair 3	Acromial end diameter on right side - Acromial end diameter on left side (mm)	0.08±2.35	0.411	139	0.682
Pair 4	Mid-length diameter on right side - Mid-length diameter on left side (mm)	-0.85±2.02	-4.979	139	<0.001

Table 2 shows paired samples t-test of the combined data of all parameters studied between the right and left sides. In SED and MLD, the mean ± SD were significantly higher on the left than the right side (p=0.003 and p < 0.001 respectively). However, there were no significant side differences in LHL (p=0.735) and AED (p=0.682).

Table 3: Paired samples t-test between right and left clavicles in males (n=58) and females (n=82).

Sex	Pair	Parameter	Mean±SD	t	Df	p-value
Female	Pair 1	Linear horizontal length on right side - Linear horizontal length on left side (mm)	-1.89±9.94	-1.720	81	0.089
	Pair 2	Sternal end diameter on right side - Sternal end diameter on left side (mm)	-0.73±2.72	-2.419	81	0.018
	Pair 3	Acromial end diameter on right side - Acromial end diameter on left side (mm)	-0.37±2.01	-1.682	81	0.096
	Pair 4	Mid-length diameter on right side - Mid-length diameter on left side (mm)	-0.69±2.20	-2.839	81	0.006
Male	Pair 1	Linear horizontal length on right side - Linear horizontal length on left side (mm)	3.27±5.54	4.506	57	<0.001
	Pair 2	Sternal end diameter on right side - Sternal end diameter on left side (mm)	-0.53±2.13	-1.876	57	0.066
	Pair 3	Acromial end diameter on right side - Acromial end diameter on left side (mm)	0.72±2.65	2.080	57	0.042
	Pair 4	Mid-length diameter on right side - Mid-length diameter on left side (mm)	-1.07±1.72	-4.753	57	<0.001

Table 3 shows the paired samples t-test of clavicular parameters in females and males between the right and left sides. In females, the mean ± SD in SED and MLD were significantly higher on the left than the right (p=0.018 and p=0.006 respectively); while in LHL and AED there was no significant side difference (p= 0.089 and 0.096 respectively). In males, the mean ± SD in LHL and AED were significantly higher on the right side than the left (p< 0.001 and 0.042 respectively), while MLD was significantly higher on the left side than the right (p< 0.001). In contrast, there was no significant side difference in the case of SED (p=0.066).

Table 4: Paired samples correlations between right and left parameters(N=140).

Pair	Parameter	r	p-value
Pair 1	Linear horizontal length on right side & Linear horizontal length on left side (mm)	0.848	<0.001
Pair 2	Sternal end diameter on right side & Sternal end diameter on left side (mm)	0.731	<0.001
Pair 3	Acromial end diameter on right side & Acromial end diameter on left side (mm)	0.698	<0.001
Pair4	Mid-length diameter on right side & Mid-length diameter on left side (mm)	0.692	<0.001

r= Correlation coefficient.

Results of paired sample correlations of the combined data of clavicular parameters studied between the right and left sides are shown in table 4. All the paired sample correlations showed very strong, highly significant and positive correlations (p< 0.001, r ≈ 0.7– 0.8).

Discriminant analysis was done to separate the genders, the independent variable, and the clavicular dimensions measured were the predictor variables. The derived model is in this form: $S= k + b_1x_1 + b_2x_2 + \ldots\ldots + b_nx_n$; where S is the predictor or discriminant score, k is the Y-intercept, b is the discriminant coefficient, x is the predictor and n is the number of discriminant variable. Discriminant analyses showed that Wilk's lambda was significant for the Linear horizontal length; Sternal diameter; Mid-length diameter and combined data ($p<0.001$) on both sides, and Acromial diameter ($p<0.001$ on the right and 0.010 on the left). Canonical correlation of all the predictor variables were significant, with the LHL on the right and combined data on both sides as the highest (6.00-6.27) and the lowest was AED on the left (0.216).

Table 5. Discriminant analyses for sex determination using clavicular dimensions.

Side	Parameter	Canonical correlation	Model	Male accuracy	Female accuracy	Overall accuracy	Sectioning point
Right	LHL	0.60	S= -10.395 + 0.074(LHL)	84.5%	78.0%	80.7%	-0.0002
	SED	0.32	S= -7.127 + 0.302(SED)	62.1%	64.6%	63.6%	-0.00007
	AED	0.35	S= -4.685 + 0.330(AED)	60.3%	69.5%	65.7%	-0.006
	MLD	0.32	S= -6.955 + 0.469(MLD)	60.3%	73.2%	67.9%	-0.0021
	LHL+SED+ AED+MLD	0.63	S= -12.993 + 0.061(LHL) + 0.075(SED) + 0.010(AED) + 0.170(MLD)	84.5%	78.0%	80.7%	-0.00003
Left	LHL	0.50	S= -0.478 + 0.675(LHL)	74.1%	74.4%	74.3%	-0.00033
	SED	0.32	S= -7.789 + 0.321(SED)	67.2%	73.2%	70.7%	-0.032
	AED	0.22	S= -5.311 + 0.376(AED)	50.0%	61.0%	56.4%	-0.00023
	MLD	0.33	S= -6.004 + 0.383(MLD)	56.9%	65.9%	62.1%	-0.0001
	LHL+SED+ AED+MLD	0.60	S= -14.662 + 0.072(LHL) + 0.086(SED) – 0.064(AED)	86.2%	76.8%	80.7%	-0.006

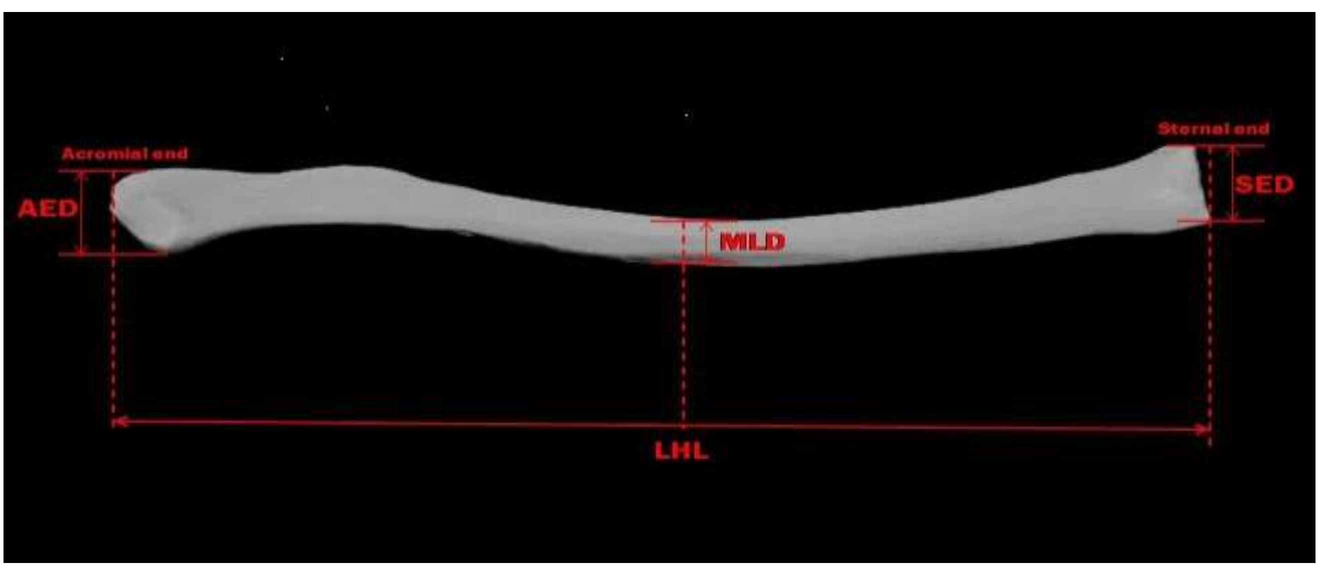
LHL= Linear horizontal length; SED= Sternal end diameter; AED = Acromial end diameter; MLD= Mid-length diameter.

Discriminant analyses for sex determination using clavicular dimensions is shown in Table 5. The overall accuracy of correct classification was higher in LHL on the right and combined data on both sides (80.7%) and the lowest was AED on the left (56.4%).

Figure 1: Measurements of clavicle taken.

LHL= Linear horizontal length; AED= Acromial end diameter; MLD= Mid length diameter;

***SED= Sternal end diameter*.**



DISCUSSION

In the present study, the higher mean value of linear horizontal length on both sides in males compared to that of females could be as a result of wider shoulder than hip in males after puberty, but wider hip than shoulder in females since the length of clavicle contributes to the width of the shoulder. [10] Males attain four-fifth of the total length of their clavicle later at about the age of 12 years than females who attain theirs at about the age of 9 years. [25] This implies that the longer period the clavicle had to grow in males compared to females could be a contributing factor to the sex difference observed. [25]

This sex difference in clavicle is analogous to the higher stature in males compared to females as a result of a long time the males had to grow compared to females since females attain puberty about two years earlier than males. [26, 27] Height as well as diet are known to influence the length of the clavicle. [28] Besides, it has been opined that the proportion of the skeleton is about 20% shorter in females compared to males. Hence, the skeleton in males is expected to be more robust and longer than those in females. [12, 29, 30]

Longer clavicle in males than females has been stated by many authors. [5, 31] Some studies reported higher mean length of the clavicle in males than females, they did not subject their data to test of significant difference. [11, 13, 14, 16, 17, 20] The statistically significant higher mean linear horizontal length value in males in comparison to females in the current study is in tandem with the findings of previous studies that reported similarly. [7, 8, 10, 12, 19] As previously enunciated, this could be ascribed to the wider shoulder than hip in males after puberty and the longer period the clavicle had to grow in males compared to females.

In the present study, there was no significant side difference in the linear horizontal length of the clavicle as similarly reported in a prior study. [15] The reason for this observation in the present study is not clear. It is important to state that despite the aforesaid observation, [15] mean length of the clavicle in the present study is greater. Genetic factors and environmental factors such as nutrition and geographic location that affect population could be attributed to the differences observed.

On Sternal end diameter and Acromial end diameter, the statistically significantly higher values in males than females on both sides may be due to differences in skeletal growth and maturity time, the different time at which puberty is reached, hormones, more stress loadings on male clavicle from more laborious task, as the difference in biomechanical loadings on a bone and activity one engages in may lead to a higher degree of sexual dimorphism. [32] Yang *et al*. [19] used only right clavicle, while Sehrawat & Pathak [12] used both clavicles in their respective studies and both reported statistically significant higher mean SED and AED in males compared to females. However, in a similar study using only the left clavicle, [18] statistically significant higher mean SED in males was observed, but the mean gender difference in AED was not significant. While another study that used both clavicles [8] observed the mean gender difference was statistically significant for both sides. Population differences due to genetic and environmental factors are possible reasons for the varied results in different studies.

On mid-length diameter, in the present study, there was higher value in males than females. The differences were statistically significant for both sides. The differences observed may be as a result of more mechanical stress on male clavicle from more strenuous work as the length of the clavicle is less sensitive to the effect of loading than shaft breadth. [33] The statistically significantly higher value of the mid-length diameter in males than females was also reported in other studies. [7, 18]

The significant strong positive correlations in corresponding samples on right and left sides may suggest that clavicles on both sides were affected equally by factors such as nutrition, hormone, and so forth. It may also indicate that both were equally affected by factors affecting anthropometric measurements.

Doshi et al. [7] in a related study in Maharashtra, India, using dry bones, also reported a similar very high overall percentage of accuracy (87.0%) as well as for male (87.0) as well as for male (87.8) and female (85.6%) when the full length of the clavicle was used. Similar very high level of accuracy was also noted in the mid length.

In a study that utilized dried clavicle in North Karnataka, India, [10] percentage accuracy of sex determination by discriminant analysis of the length of the clavicle was greater (right: male (62%); female (63%); left: male (76%); female (67.5%)) than the values of the present study. Ishwarkumar et al. [8] conducted a study on sex determination using the dried clavicles in the Kwazulu-Natal population, South Africa. Although they used Logistic regression analysis to determine the sex, they reported that the percentage accuracy of sex prediction for the full length was 89%. This is comparable with the result of the present study, which percentage accuracy of sex prediction using the full length of clavicle is 80.7% on both sides.

In a study in a modern Spanish sample utilizing dried clavicle, Alcing et al. [9] reported discriminant function percentage accuracy of 90.99% and 88.3% for right and left clavicle respectively, which are similar to that of present result.

The present study focused only on adults of 25-69 years, and did not involve age below 25 and above 69 years. This is a limitation of the study; hence, further studies of the clavicle involving individuals of the latter ages are recommended.

Conclusion

This study has further established that there is sexual dimorphism in the linear horizontal length, sternal end diameter, acromial end diameter and mid-length diameter of the clavicle with the males being higher than the females. It has also established that there is significant strong positive correlation between the right and left linear horizontal length, Sternal end diameter, acromial end diameter and mid-length diameter of the clavicle. The accuracy of sex determination is 80.7% (LHL), 63.6% (SED), 65.7% (AED), 67.9% (MLD) and 80.7% (combined parameters) on the right; 74.3% (LHL), 70.7% (SED), 56.4% (AED), 62.1% (MLD) and 80.7% (combined parameters). The results of this study have shown that sex can be determined from the dimensions of the clavicle using discriminant function analysis; hence, its usefulness in forensic anthropology.

REFERENCES

1. Austin D, King RE. The biological profile of unidentified human remains in a forensic context. Acad Forensic Pathol. 2016;6(3):370-390.
2. Sen J, Kanchan T, Ghosh A, Mondal N, Krishan K. Estimation of sex from index and ring finger lengths in an indigenous population of Eastern India. J Clin Diagn Res. 2015;9 (11): HC01-5.
3. Akhlaghi M, Moradi B, Hajibeygi M. Sex determination using anthropometric dimensions of the clavicle in Iranian population. J Forensic Leg Med. 2012; 19(7):381-385.
4. Singh I. Textbook of human osteology. 3rd ed. Jaypee Brothers Medical publishers (P) Ltd; New Dehli, India. 2008.
5. Birch R. Pectoral girdle and upper limb. In Gray's Anatomy: the Anatomical basis of clinical practice, S. Standring S (ed). Elsevier, London, U.K, 2016, pp 776-894.
6. Buran F, Can IO, Ekizoglu O, Balci A, Guleryuz H. Estimation of age and sex from bimastoid breadth with 3D computed tomography. Rom J Leg Med. 2018; 26:56–61.
7. Doshi MA, Reddy BB. Determination of sex of adult human clavicle by discriminant function analysis in Marathwada region of Maharashtra. Int J Res Med Sci. 2017;5:3859-3864.
8. Ishwarkumar S, Pillay P, Haffajee MR, Rennie C. Sex determination using morphometric and morphological dimensions of the clavicle within the KwaZulu-Natal population. Int J Morphol. 2016; 34(1):244-251.
9. Alcina M, Rissech C, Clavero A, Turbón D. Sexual dimorphism of the clavicle in a modern Spanish sample. Eur J Anat. 2015; 19(1): 73-83.
10. Shobha, Math SC, Jatti VB, Murthy CRV. Identification of Sex of Human Clavicles from North Karnataka Zone. Anthropologist. 2014; 17(3): 917-920.
11. Thulasi MS, Vrijakumari CR, Kumar KV, Indira MV. Clavicle, a tool for sex determination- a study in South India. J Dent Med Sci. 2017; 16(2):54-58.
12. Sehrawat JS, Pathak RK. Variability in anatomical features of human clavicle: its forensic anthropological and clinical significance. Translational Research in Anatomy, 2016; 3 (4): 5-14.
13. Bagal G, Takale S. Sex determination from the clavicle. J Med Sci Clin Res. 2016; 4(6):11162-11165.
14. Khaleel N, Jayachandra P, Shaik HS, Khalid B, Mohammad A. Morphometry of clavicle. J Pharm Sci Res. 2014; 6(2):112-114.
15. Ashish K, Gayatri SAR, Krishnaiah M, Chaitanaya K. Morphometric parameters and sex determination of clavicle in Telangana Region. J Dent Med Sci. 2014; 13(10):1-5.
16. Rani Y, Naik S, Singh AK, Murari A. Correlation of stature of adult with the length of clavicle. J Indian Acad Forensic Med. 2011; 33(3):194-196.
17. Arvinder PS, Anupama M, Seema, Balijit SK. Sex determination from clavicle bone for Punjab zone. Indian Internet J Forensic Med Toxicol. 2010; 8(1):1-8.
18. Udoaka AI, Nwokediuko AU. Radiologic evaluation of clavicular morphology in Southern Nigerians. International Journal of Morphology. 2013; 31(1):94-99.
19. Yang JC, Lin K, We H, Tsai C, Lin K, Lee P. Morphometric analysis of the clavicles in Chinese population. Biomed Res Int. 2017;2017:1-5.
20. King PR, Scheepers S, Ikram A. Anatomy of the clavicle and its medullary canal: a computed tomography study. Eur J Orthop Surg Traumatoly. 2014; 59(12):1130-1139.
21. Walters J, Solomons M, Roche S. A morphometric study of the clavicle. SA Orthop J. 2010; 9(3):47-52.
22. World Medical Association Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects. Bull World Health Organ 2001. 79:373-374.
23. Arroyo M, Freire M, Ansotegui L, et al. Intraobserver error associated with anthropometric measurements made by dietitians. Nutr Hosp. 2010. 25:1053-1056.
24. Ulijaszek SJ, Lourie JA. Intra- and inter-observer error in anthropometric measurement. In Anthropometry:

the individual and the population, SJ Ulijaszek, CG Mascie-Taylor (eds). Cambridge University Press, Cambridge, 1994. pp. 30-55.
25. McGraw MA, Mehlman CT, Lindsell CJ, Kirby CL. Postnatal growth of the clavicle: birth to 18 years of age. J Pediatr Orthop. 2009; 29(8):937-943.
26. Eboh DE, Igbigbi PS. Stature estimation from cephalometric parameters of young adults in five Nigerian ethnic groups. Ital J Anat Embryo. 2017; 122(2):98-107.
27. Yamada K, Ohta M, Yoshimura K, Hasekura H. A possible association of Y chromosome heterochromatin with stature. Hum Gen. 1981; 58:268-270.
28. Kaur H, Harjeet SD, Jit I. Length and curves of the clavicle in Northwest Indians. J Anat Soc India. 2002; 51(2):199-209.
29. Ross AH, Ubelaker DH, Kimmerie EH. Implications of dimorphism, population variations and secular changes in estimating population affinity in Iberian Peninsula. Forensic Sci Int. 2011; 206:214-215.
30. Humphrey LT. Growth patterns in the modern human skeleton. Am J Phy Anthropol. 2008; 105:57-72.
31. Sinnatamby CS. Last's Anatomy. Regional and applied. 12th ed. Elsevier, London. 2011.
32. Charisi D, Eliopoulos C, Vanna V, Koilias CG, Manolis SK. Sexual dimorphism of the arm bones in a modern Greek population. J Forensic Sci. 2011; 56:10-8.
33. Auerbach BM, Raxter MH. Patterns of clavicular bilateral asymmetry in relation to the humerus: variations among humans. Journal of human evolution. 2008; 54(5):663-674.