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**Original research article**

# Morphometric Parameters for Determination of Sex by Adult Human Clavicle

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**Abstract**

**Background**: The determination of sex of an individual is primary criterion of identification, but this is very difficult problem and becomes even morechallenging when only a single bone like clavicle is available. The traditionalmethods of sexing bone are subjective and not of much help in medico-legal cases where 100% accuracy is needed. Hence metrical analysis of clavicles for determination of sex by various morphometric measurements is done.

**Methodology**: The total 155 dried clavicles of adult human bodies of known sexes were obtained from the dept. of Anatomy, at Indira Gandhi Institute of medical sciences, Patna. And various medical colleges in Bihar. The present study was conducted at dept. of Anatomy, by measuring the various morphological data of adult human clavicles like their length, mid-shaft circumference, weight, volume, incidenceof rhomboid fossa and its length and breadth, and medial and lateral angles.

**Conclusion:** The clavicular parameters like length, mid-shaft circumference, robustness index, weight, volume, rhomboid fossa length and breadths have been found to be statistically highly significant with high probability of prediction of correct sex. While, clavicular angles were less significant. When a clavicle exhibits a rhomboid fossa, it was likely from a male**.**

**Keywords**: Anthropology, human identification, morphometric, skeletalremains, rhomboid fossa, mid-shaft circumference.

## Introduction

Determination of sex is an important and essential step towards establishing identity of unknown human from skeletal remains.[1] The correct determination of the sex of a dead person is a critical requirement in physical anthropology. Within past few years, the physical anthropologists have become increasingly involved in the problems of human identification[2]. The doctor, who is doing postmortem examination on highly decomposed body or on the skeletal remains of unknown person, plays an essential role in establishing

the identity of a dead person. While establishing the identification, age, sex, stature and race of the person are the primary criteria's (big fours) of identification. Among them, determination of sex is statistically most important criteria, as it immediately excludes approximately half of the population, where as the age, stature and race each provides the points within a wide range of variables.[3,4] Following the death, human body shows destructive effects ofpostmortem putrification and decomposition, but osseous skeleton is the only structure which resists this effect for longer time by maintaining its morphological features long after the soft tissues have been destroyed. Thus these persistent morphological features of the skeleton will help in establishing primary criterias of identification viz. age, sex, stature and race to a certain extent.[5] The Forensic anthropology involves building of an identification profile of a person from the skeletal remains. In many of such instances, Forensic personnel frequently consult the Anatomists to give their expertopinion for medicolegal purposes, regarding the personal identity with respect to sex, age, stature, race and also probable cause of death. Examination of such skeletal remains forms the basis of their opinion.[6, 7] Thus the accuracy of assessment of sex of a skeleton is directly proportional to the amount of bones available.[8] The femur is the most studied bone of all human long bones and clavicle is also considered to be an important long bone while dealing with sex difference in the skeletal material.[7] One of the most obvious sex differences in long bones is that the typical male bones are longer, heaviest and more massive than typical female bones. The male to female ratio for long bone length hovers around 100:90.[9] According to most of the authors; female clavicle is shorter, thinner,less curved and smoother. The clavicle is thicker and more curved in manual workers and in males the ridges for muscular attachment are better marked.[10,11] These traditional, non-metrical methods including size, weight and muscular markings are not always helpful, as these methods depends on experts' abilityand experience and shows subjective variations.[12] The sexing of the clavicle by metrical methods had been attempted in Western countries by various workers who found that the mid-clavicular circumference was a good criterion for sexing the clavicle.[13,14]

**Objectives**

The present study is aimed to determine whether sexing of unknown clavicles can be done by applying values of morphometric parameters and formulae generated by present study on clavicles of known sex and to find out the best parameters for sex determination.

**Review of Literature**

The scientific study of morphology of skeleton in parts and as well as in toto, with respect to sexing dates as long back as middle of 18$^{th}$ century. Whenever the skeletal remains are found under suspicious circumstances, the law enforcement agencies want to know whether the submitted bones are human or animal, usually it is for a matter of establishing a corpus delecti.[17] As soon as the fact is established that the available bones are human origin, the next question is 'whether the bones are of one or more than one individual ?' then specifically about the identification of sex, age and race. Any other information such as stature obviously depends upon the presence ofa fairly complete skeleton. In any case of course the amount of information that can be established from the skeletal remains depends to a large extent uponthe condition of the specimen. As for sex is concerned, the margin of error inany determination varies with the parts of skeleton available for examination.[17] According to Jit I, it is not difficult to determine the sex of an adult deceased when a complete or an almost complete skeleton is

available[8].Obvious sex differences in bones don't become apparent until after puberty, usually in the 15-18 years period, though specialized measurements on the pelvis can indicate the sex even in fetal material.[4, 5] The studies for determination of sex of skeletal remains by using various other bones like Indian femur (Purkait R, Chandra H)[1], pelvic girdles of Australian Aborigine (Devivongs V-1963)[18], mandible(Giles E-1964)[19], humerus (Singh S and Singh SP-1972)[20], ulna (Singh et al-1974)[21], hip bone (Singh and Butchi-1977)[22], fragmentary skeletal remains-femoral shaft circumference (Black III atlas vertebra (Paul GP.et al-1986)[23], sacrum of Agra region (Mishra SR, Singh PJ-2003)[24], etc., had been done in western world and in Indian scenario too. Devinvongs V(1963) studied the pelvic girdles of Australian aborigine for its sex differences and sex determination, where he observed that the ischiopubic index, acetabular diameter and length of the greater sciatic notch were useful parameters for sex determination.[18]. Terry RJ had studied American Negro clavicles based on mid-clavicular circumferences and roubustnes index.[13] Oliver G had worked on French clavicles using their length and mid-shaft circumference[14]. Both Terry and Oliver found that the mid-shaft circumference was a good criterion for sexing the clavicles.[13, 14] Jit I and Sahni D (1983) studied North Indian adult clavicles on the basis of length, weight and mid-shaft circumference. They found that by multivariate analysis on the basis of weight and mid-shaft circumference, 79% of male and 82% of female clavicles could be sexed correctly.[12] Singh D and Jit I (1996) stated that volume of clavicles as a single parameter is not of much value in ascertaining the sex of clavicle, but when combined with other parameters by multivariate analysis, the chances of precise sex determination will increase.[26] As per available literature, in Karnataka only two studies have been done on clavicle to determine the sex by using parameter like its length, weightand mid-shaft circumference (Padeyappanavar KV et al-2009 and Sayee R et al-1992).[7,] Kaur K (1997) who determined the gender differences adult clavicles by measuring their length, mid-shaft circumference and weight, opinioned that one measurement alone would not be satisfactory for sexing the clavicles. On applying multivariate discriminant analysis to these three measurements, they were succeeded in sexing 86.14% male and 96% female clavicles accurately.[25]

**Material and methods**

The total 155 dried clavicles of adult human bodies of known sexes (70 femaleand 85 male) were obtained from the department of Anatomy, at Indira Gandhi Institute of medical sciences, Patna. Also various medical college in Bihar. measuring various morphological data of adult human clavicle of known sex to generate literature on metrical data of the clavicle.

**Inclusion criteria**

Clavicles of adult human of both sex with complete ossification andfusion, without any deformity.

**Exclusion criteria**

The clavicles which were incomplete in ossification and fusion andthose showing deformities and degradation.

Bones showing any pathology like fracture, tumors, etc., Out of 85 male clavicles; 39 were of right side, 46 were of left side and out of70 female clavicles, 30 were of right side, 40 were of left side. Before measurementswere taken, clavicles were cleaned and dried. The metrical data after the measurementand observation of each clavicle were noted in the following manner.

**Length of clavicle:** The maximum length of each clavicle is measuredin millimeters (mm) from sternal end to acromial end with the help of Vernier caliper and graph paper.[7,] **Mid-shaft circumference of clavicle :** While measuring the length of clavicle, a mark was done with pencil at the middle of distance betweentwo ends of clavicle. At this midpoint, circumference was measured inmillimeters (mm) with the help of calibrated narrow strip of graph paperor a thread.[7,] The angles (inner angle and outer angle) of clavicles were measured in degrees with the help of compass or protractor. To measure the angles / curves of the clavicle, the method described by Parson FGwas followed.[27] A trailing of the counter of the bone was made from its superior aspect. Care being taken to ensure the same orientation in all the bones. The mid point of the sternal and acromial ends have been located and connected by a straight line. The mid axis of the tracing was laid in. After all measurements and observation, these data werestatistically analyzed by univariate discriminate functional analysis using single parameter and multivariate functional analysis using some parameters in combination. The demarking points are calculated using the formula mean $\pm$3SD. The findings thus generated are tabulated and compared with previous studies by different authors.

**Results**

In the present study, total of 155 dried and cleaned, adult human clavicles of known sexes have been studied by measuring their various morphometric parameters like length, mid-shaft circumference, weight, volume, length and breadth of rhomboid fossa and angles of curvature. Out ofthese 155 clavicles, 85 are of male sex (39 are of right side and 46 are of left side) and remaining 70 clavicles are of female sex (30 are of right side and 40 are of left side). The male clavicles range from hypomusculine to hypermuscularity while the female bones have a range of hypofeminity to hyperfeminity with a considerable overlapping portion between both sexes, which would thus cause difficulty or even impossibility in sex determination of clavicles. In univariate discriminate functional analysis using single parameter, range, mean, standard deviation (SD), p value, mean ±3SD were calculated applying statistical analysis. The values of range and mean of most of the parameter of male clavicles are higher compared to female clavicles. Even thenthere is considerable overlap of the value between male and female clavicles.The clavicle having the measurement of its parameter more than that of the upper limit of range of same parameter of female clavicles is identified as male clavicles. While the clavicle having measurement of parameter smaller than the lower limit of range of male clavicles is identified as of female. The sexing isalso attempted by using the 'demarking point' calculated for parameters like length, mid-shaft circumference, robustness index, weight and volume. By this method chance of mis-calculation of sex is very minimal. Application of multivariate analysis to metrical data reduces the overlap and hence more chances of correct sex differentiation in a multivariate discriminate functional analysis is also well documented. Thus it is planned to apply this statistical method of multivariate analysis to some of the parametersin combination. Right clavicle: The length of male right clavicles(No=39) varies from 123 to 167mm with a mean value of length being 142.1mm and SD of ±11.70 (~142.1±11.70mm), where as that of the female right clavicles(No=30) ranges from 115 to 150mm with mean length of 131.7mm and SD of 12.22 (~131.7±12.22mm). Thus right male clavicle is longer than female right clavicle by mean difference of 10.4 mm. The sex differentiation by comparing the length of male and female clavicles of right side is statistically highly significant ($p<0.001$) and probability of prediction of correct sex is 62% by male and 63.30% by female right clavicles. **Left clavicle:** The length of left male clavicles (No=46) ranges from 120 to 162mm with a mean of 143.8mm and SD of ±9.55 (~162 ±9.55mm).

While length of left female clavicles (No=40) ranges from 114.5 to 151mm with a mean of 132.7mm and SD of ±9.02 (~132.7±9.02mm). Thus, left male clavicle measures its mean length more than female clavicle by the mean difference of 11.1mm. This difference is statistically significant for sex differentiation of left side clavicles ($p<0.001$). The probability of prediction of sex by length ofleft clavicle is 76% in male and 67.50% in female clavicles. Out of 85 male clavicles, 82 (96.47%) clavicles bear rhomboid fossa and fossa is absent in only 3(03.53%) male clavicles. Whereas, out 70 female clavicles, only 53 (75.71%) of clavicles show presence of rhomboid fossa and absent in 17 (24.29%) of female clavicles. Thus incidence of rhomboid fossa is more common in male clavicles. When analyzed for sex differentiation by $X^2$test, presence or absence of RF is statistically highly significant in sex determination ($p<0.001$). Thus, 82.1% of right, 82.6% of left male and 80% of right and 87.75% of left female clavicles could be sexed correctly.

**Discussion**

The morphometric data of the clavicle of present study is compared with the similar studies in the past. However, all parameters used in this study werenot studied by all the workers, eg: metrical study of rhomboid fossa, volume of clavicle, angle of clavicle etc. which have been studied by only few workers. comparision of length of clavicles by different authors. In the present study, mean length of male clavicle is significantly higher than that of female clavicle. Thus, it is clear from table that, similar to studies of Padeyappanavar et al (2009)[7], Jit I and Sahni D[12], and Doengen RVthe present study observed statistically significant difference between length of male and female clavicles ($p<0.001$). Right clavicle: In the present study, in case of male, the mean length of clavicle (142.1mm) is comparable with the study of Doengen RV (139.57mm), Singh S and Gangrade KC (141.19mm) and Padeyappanavar KV et al (141.9mm). These values are higher in the studies of Jit I and Singh D (145.58mm), Jit Iand Sahni D (148.0mm), Terry RJ for USA whites (151.40 mm) and Singh S for USA Negroes (155.72 mm). In case of females, mean length of clavicle (131.1mm) is comparable with results of Jit and Sahni[12], Jitand Singh[15] studies, but much higher compared to Padeyappanavar KV[7], Sayee R[16] and Doengen RV study results, and less compared to American studies. Left clavicle: In the present study, mean length of male clavicle (143.8mm) is comparable with the studies of Doengen RV(139mm), Singh and Gangrade (144.18mm) and Padeyappanavar KV et al (143.5mm), but it is lowerthan the studies of Jit and Singh (147.59mm) and Jit I and Sahni D (149.8mm) Terry RJ for USA white (154.10mm) and Negroes (155.86mm) and Singh S for USA white (153.7mm) and Negroes (157.32mm).The mean length of left female clavicle in present study (132.7mm) is comparable with most of the studies except Jit I and Sahni D (134mm), TerryRJ for USA Negroes (141.8mm) and Singh S for USA Negroes (140.80mm) which are higher than the mean value of present study. This difference in the length of clavicle may be due to the fact that American Negroes and Whites and North Indians are taller and well built than South Indian population. Sexual difference: It is agreed by most of the previous workers that female clavicle has a smaller circumference than male and this difference is statistically highly significant and varies from 3.7 to 7.8mm. In the study by Terry RJ(1932)[13], the circumference of Negro female bone was about 5mm shorter than that of Negro male. Oliver G(1951)[14] found the difference to be 6.8mm in French bones. Jit and Singh S(1966)[15] found the difference to be 6mm - 7mm. In the present study, the difference is about 6.5 - 7mm. This shows that, mid-shaft circumference is an extremely useful data by which a fairly large number of clavicles can be sexed without any difficulty. The prediction of sex by mid-shaft circumference alone is 77%

in male, 83.30% in female right clavicles and 80% in male, 87.50% in female left clavicles. These results are similar to results of Jit and Singh S (1966)[15] and Padeyappanavar KV et al (2009)[7]. When this measurement is analysed by multivariate analysisalong with length, weight and volume will yield still better prediction of sex i.e., 87.2% in male right, 86.7% in female right and 82.6% in male left and 87.5% female left clavicles. In present study, side related differences are very less and sexual difference in mean medial angle of male is greater than female by 2.07° on right side and 1.74° on left side. This difference was found to be statisticallyinsignificant for sex differentiation. As medial angle is greater in males than females, medial two-thirds of female clavicles is more curved than maleclavicles. This observation is opposite to observations made by Parsons FG[27] and Kaur H et al[28]. The medial angle of North bihar male clavicle is almost the same as that of North West Indian and French clavicles but is smaller than that of American Negroes and English clavicles. While medial angle of North bihar female clavicle is 3 to 5° smaller (more curved) thannorth west Indian, French, English and USA Negro clavicles.[13, 14, 27] In the study by Kaur H et al (2002), sum of angles was greater on leftthan right. The right bone was therefore more curved than the left. The angleswere greater in females than males suggesting male bones are more curved than female bones and difference between mean sums of angles of male and femalewas 3.98° on right and 2.67° on left side. This difference was found to be statistically significant ($p<0.05$).[28] In the present study, sum of angles was greater on right side than left side, thus left clavicle is more curved than right and female bones are more curved than the male bones. These two findings in the present study are contrary to all the previous studies including study of Kaur H et al.[28] In the present study, the difference between the mean sum of angles of males and females was 7.25° on right side and 8.84° on left side. This sexual differencewas found to be statistically significant ($p<0.05$) similar to the findings of all previous authors.

## Conclusion

The results of present study on determination of sex of adult human clavicle by morphometric parameters showed some difference with respect to the same results of the studies done by various workers in the past, The length, mid-shaft circumference, weight and volume of the clavicle werebetter parameters which individually yield high probability of sex prediction. Amongthem weight was the best parameter to differentiate sex of right side clavicles and mid-shaft circumference for left sided clavicles.

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