

Determination of Sex by various Morphometric Traits of Clavicle in the population of Central India (Bhopal region)

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Abstract

Background: Identification is the determination of the individuality of a person based on certain physical characteristics. The clavicle is one of the bones which is less explored but has drawn considerable interest in this field, particularly concerning sexual dimorphism. **Aim & Objectives:** The present study evaluates the existence of sexual dimorphism based on various morphometric parameters of the clavicle in a dry sample and identifies the best predictor amongst these. **Materials & Methodology:** The study was conducted in the mortuary of the Department of Forensic Medicine, Gandhi Medical College, Bhopal on 100 random cases (50 males; 50 females) in which medico-legal post-mortem examination was done. After taking due consent, clavicle bone of deceased between 25 to 60 years age group were collected during the autopsy, dried and then examined for the study. Measurements were carried out and statistically compared to evaluate sexual dimorphism. The studied parameters include Maximum length of clavicle, Breadth of sternal end, Breadth and Length of acromial end, Area of acromial surface and Mid clavicular circumference. **Observations & Results:** Amongst all the parameters, Maximum length of clavicle and Mid clavicular circumference are the most reliable parameters for sexual dimorphism with 81% accuracy rate when considered together. If all the morphometric parameters are taken together then the sex can be determined with 87% accuracy. **Conclusion:** Sexual dimorphism exists in clavicle and all the measured parameters contribute to different sex individually and with 87% accuracy when taken together. The derived discriminant function equations can be used to correctly assign the bones to the proper sex.

Key Words: Clavicle, Identification, Sexual Dimorphism, Maximum length of clavicle, Length and Breadth of Acromial end, Area of Acromial end, Sternal end, Mid-clavicular circumference.

Introduction

While establishing the identity of an individual, the primary characteristics of identification are Sex, Age, and Stature^[1]. Amongst these, identification of sex is primary as age and stature are dependent on each other. To establish the sex effectively, often an expert has to extract as much information possible from fragmentary

and mutilated skeletal remains; then even a single bone like clavicle becomes important. The present study was designed to identify these morphological features (predictors) and examine the sexual dimorphism of adult clavicle in the population of Central India (Bhopal region), applying linear discriminant function analysis. As the skeletal remains that are usually brought for anthropological examination are in the dried and fragmented state, this study was conducted on dry clavicle.

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Aim & Objectives

The present study evaluates the existence of sexual dimorphism based on various morphometric parameters

of the clavicle in a dry sample and identifies the best predictor amongst these.

Materials and Methodology:

Study design:

This prospective study was conducted on 100 clavicles (50 males, 50 females) recovered from the medico legal autopsies conducted in the Mortuary of Department of Forensic Medicine and Toxicology, Gandhi Medical College, Bhopal. Prior approval of the Institutional Ethics Committee was taken. After obtaining written informed consent, random cases with known age and sex in between the age group of 25-60 years were taken for the study. Cases with any chronic illness, metabolic disorders, congenital anomalies, bony deformities or injury were excluded. After opening the thorax, clavicle was recovered using the routine standard autopsy technique. The gap was packed with cotton and body contour was restored. The clavicle was then cleaned to remove maximum soft tissues. It was then tagged with a numbered plastic disc. These bones along with their plastic discs bearing the number were buried in the ground and left for sufficient time (about 1 month), to allow complete separation of soft tissues from bone. It was then cleaned and dried at room temperature.

Anthropometric measurements:

Following measurements were taken in the dry state. All measurements were taken in millimeters.

a. Maximum length of the clavicle: The straight maximum distance between the sternal and acromial end measured by placing the clavicle in horizontal plane on the Osteometric board, taking precaution that sternal end and concavity of acromial half of clavicle are placed in the same line, the maximum length of clavicle is noted.

b. Maximum breadth of sternal end: It is the straight distance between highest and lowest point of sternal articular surface in coronal plane (superior to inferior). (Figure 1)



Fig.1: Measurement of Breadth of Sternal end

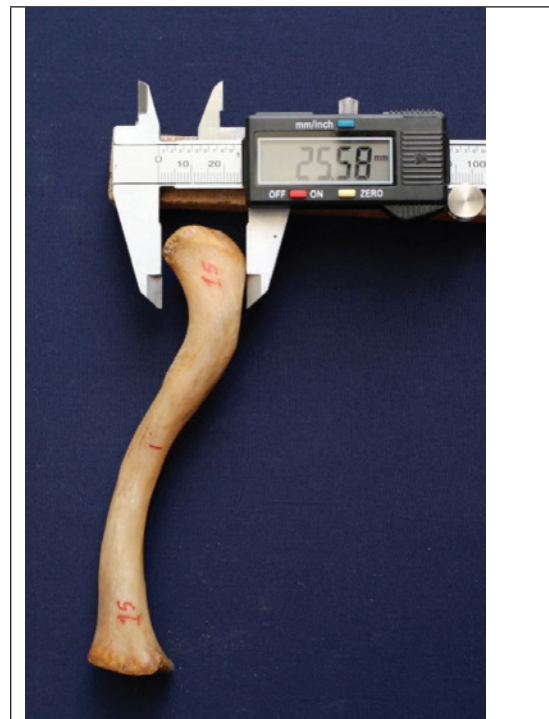


Fig.2: Measurement of Breadth of Acromial end

c. Maximum breadth of acromial end: It is the straight distance between the highest and lowest point of acromion articular surface in coronal plane (superior to inferior). (Figure 2)

d. Maximum length of acromial end: It is the straight distance between acromion facet to distal point of conoid tubercle in coronal plane (medial to lateral).

e. Acromial surface area: It is the product of the maximum length of acromial end and maximum breadth of acromial end taken up to 2 decimals.

f. Midclavicular circumference: It is measured at Midclavicular point, determined with the help of an

Osteometric board. The circumference was measured with the help of non-stretchable white colour twine thread. The twine thread was applied two rounds encircling the midclavicular point taking precaution that the thread is neither stretched nor overlaps on each other. After marking, the thread is removed from the bone and placed as a straight line and the distance between two farthest marks was measured in millimeters on the Osteometric board and was divided by two which gave the Midclavicular circumference. (Figure 3)



Fig.3: Measurement of Midclavicular circumference (MCC) with Thread.

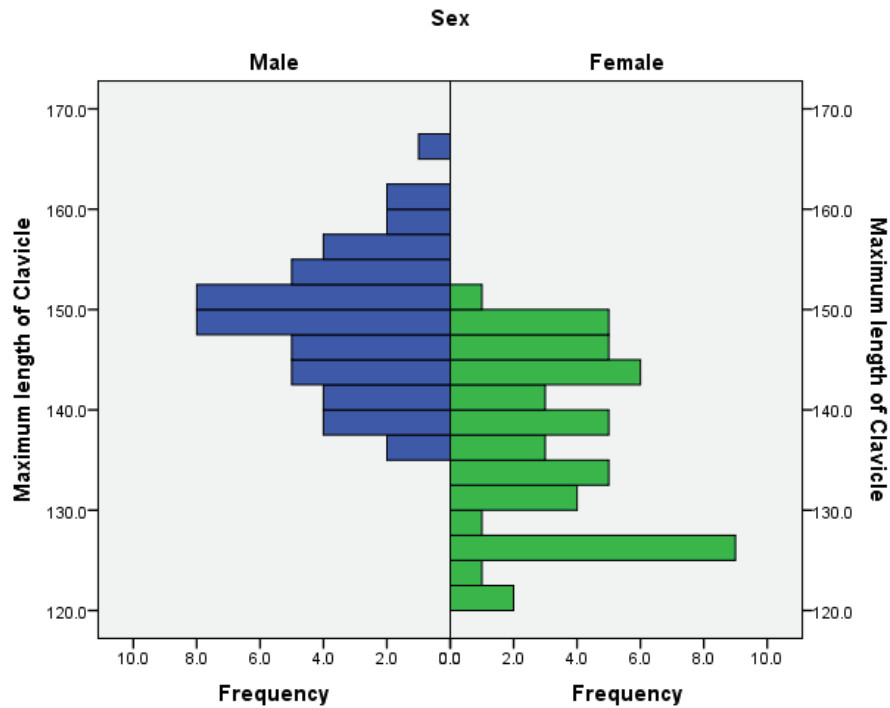
Statistical Analysis

Three readings were taken for each parameter and the average was recorded. The data was compiled and summarized as Mean and Standard Deviations using SPSS software. Discriminant function analysis and Student's t-test applied to examine the dimorphism and how the variables could correctly assign the bones to the proper sex; p value of less than 0.05 was considered significant.

Observations:

All the measured morphometric parameters showed the Range and Mean to be higher in males than females.

Overlapping of few values for both the sexes was also observed (Graph 1). For all the parameters, $p < 0.01$, which denotes that each variable has significant mean difference and can be used for the determination of sex. The 'Discriminant Function Coefficients' stipulated a discriminant function equation for each parameter whose cut score is 0. In cases where the DF score is above 0, the clavicle is that of a male and if less than '0', the clavicle is that of a female. (Table 1)



Graph 1: Histogram showing frequency-distribution of Maximum length of Clavicle

Table 1: Range, Mean with Standard deviation, Accuracy and Discriminant function equation.

Parameter	Range (in mm); Mean with Standard Deviation		Accuracy (in %)			Discriminant function equation
	Male	Female	Male	Female	Overall	
Maximum length of clavicle (MCL)	135.9 - 166.0 Mean = 148.72 S.D = 6.65	122.2 - 150.2 Mean = 136.88 S.D = 8.51	80	70	75	DF= 0.13MCL – 18.69
Maximum breadth of sternal end (BOSE)	20.80 - 32.70 Mean = 25.28 S.D = 2.06	15.60- 29.58 Mean = 22.83 S.D = 2.96	82	68	71	DF= 0.39BOSE – 9.43
Maximum breadth of acromial end (BOAE)	17.56 - 33.48 Mean= 24.71 S.D = 3.19	16.70 - 27.25 Mean = 22.83 S.D = 2.96	70	72	71	DF = 0.34BOAE – 7.85
Maximum length of acromial end (LOAE)	20.74 - 28.96 Mean= 23.61 S.D = 1.82	16.97 - 26.43 Mean = 20.56 S.D = 2.15	76	74	75	DF = 0.50LOAE – 11.06
Acromial surface area (AOAE)	364.19 - 882.70 Mean = 586.38 S.D = 105.35	290.25 - 720.22 Mean = 440.09 S.D = 91.55	70	74	72	DF = 0.01AOAE – 5.20
Midclavicular circumference (MCC)	32.40 - 45.46 Mean = 38.67 S.D = 3.3	28.18 - 38.62 Mean =33.04 S.D = 2.4	72	88	80	DF= 0.35MCC – 12.42

The 'Classification results' reveal that all the Mid-clavicular circumference predicts the sex with 80% accuracy followed by Maximum length of Clavicle and Length of acromial end with an accuracy of 75%.

When considered together, the 'Discriminant Function Coefficients' reveal that all the variables contribute more or less to the equation for determining sex, but **Maximum length of Clavicle and Mid-clavicular circumference** are the contributors to the maximum extent. When these two parameters are taken together, it was observed that 81% of original grouped cases [41 among 50 males (82%) and 40 females from 50 (80%)] were correctly classified by the **DF score = 0.04MCL + 0.3MCC - 15.636**.

When all the factors are considered together: When all the above-mentioned parameters are considered together, it is observed that 87% of original grouped cases [45 among 50 males (90%) and 42 females from 50 (84%)] were correctly classified by this **DFscore=0.03 MCL+0.22MCC+0.04BOSE+0.01AOAE-0.1BOAE-0.001LOAE -13.308**.

Discussion

Maximum length of clavicle is the most common parameter studied by various researchers followed by Mid clavicular circumference. Studies by Akhlaghi et al^[2] in 120 Iranian individuals showed an accuracy of 73-88% in determining sex by Maximum length of clavicle (MCL) and Midclavicular circumference (MCC). Sehrawat et al^[3] in 263 individuals of age group 17-94 year in Chandigarh zone (India) observed accuracy of 75.9% for males and 83.8% for females in sexual dimorphism by MCL (*Table 2*) and 79% in males and 86.8% in females by MCC. The inverse trend of increased accuracy for females by MCL is noted by Sehrawat et al as compared to the present study in which accuracy is more for males. when comparing the MCC, Sehrawat et al found it 79% & 86.8% accurate for sexual dimorphism in males and females respectively. An important resembling aspect seen is the higher accuracy of female clavicle in the study of Sehrawat et al and the present study, which strongly suggests that Midclavicular circumference is an important parameter

to correctly classify female clavicle as compared to male clavicle (*Table 3*). Compared to the present study, a higher accuracy of 85.6-94.8% was obtained by Frutos et al^[4] for both MCL and MCC in the Guatemalan population by studying 97 individuals and by Alcina et al^[5] in 77 individuals of the age group of 20-92 year of Spanish population with an accuracy rate of 90.9% for MCL and 88.3% for MCC. On the other hand, in the study conducted by Haque et al^[6] on 257 Nepalese individuals the accuracy was found as 13.33% in males and 4.44% in females for MCL. A study by Shobha et al^[7] in the Karnataka region (India) over 155 individuals shows an accuracy of 62% in males and 63.3% in females. Compared to the present study, the sample size is more in these studies but the accuracy is found to be less. In India, studies by Bindhu S. et al^[8] in Mangalore, Bagal et al^[9] in Maharashtra and Thulasi et al^[10] in Kerala have put forward the mean of maximum length of clavicle in males and females but does not comment on the accuracy with which the sex can be determined. In Durban, a study by Ishwar et al^[11] with a sample size of 100, only the mean of maximum length of clavicle is observed. Mean of Breadth of sternal end (BOSE) is found significantly higher in males as compared to females in studies done by Bindhu S. et al (Mangalore)^[8] and Sehrawat et al (Chandigarh)^[3] in India. Alcina et al (Madrid)^[5] and S. Ishwar et al (Durban)^[11] observed the same in their studies. The same applies to our study with accuracy for Males as 80% and for Females as 62%. The accuracy of a single variable has been mentioned by Sehrawat et al in Chandigarh region which is 75.9% for males and 66.2% for females, which is almost equivalent to our study. Breadth of acromial end (BOAE) has been studied by Anandi et al^[12] on 152 individuals of Maharashtra, India, Alcina et al on 77 individuals of Madrid, Spain and Ishwar et al on 100 individuals of Durban, Africa studied the mean but accuracy rate was not mentioned. The mean breadth of acromial end of Spanish population resembled with the present study. To the best of our knowledge the method to measure the Length of acromial end is not the same as adopted by other authors. Therefore, the area of acromial surface also varies and in both cases the accuracy of a single variable has not been mentioned by any authors. No study is available in the literature for comparison.

Table 2: Comparison of studies on Maximum length of Clavicle (MCL) associated with Sex

Studies by various experts	Sample size	Age group	Year of study	Male (mm)	Female (mm)	Region	Accuracy
Frutos et al [12]	97	-	2002	-	-	Guatemala	85.6 - 94.8%
Haque et al[13]	257	-	2011	143.21 ±11.13 >176.60mm – male <109.82mm – female		Nepal	M-13.33% F-4.44%
Akhlaghi et al [14]	120	-	2012	-	-	Iran	73.3-88.3%
Shobhaet al [15]	155	-	2014	142.1±11.70	131.7 ± 12.22	Karnataka (India)	M-62% F-63.30%
Ashish et al[16]	40	-	2014	138.71 ± 8.66		Telangana (India)	Not useful for sexing
Bindhu S. et al[19]	50	-	2015	144.3 ± 7.2	128.0 ± 10.1	Mangalore (India)	-
Alcina et al [20]	77	20-92 y	2015	155.12 ±10.1	132.38±7.96	Madrid (Spain)	90.9%
Bagal et al [21]	120	-	2016	138 mm	120 mm	Maharashtra (India)	-
Sehrawat et al [22]	263	17-94 y	2016	148.52±8.88	135.22±8.27	Chandigarh (India)	M-75.9% F- 83.8%
S. Ishwar et al [23]	100	-	2016	152.49±9.85	139.36 ± 6.76	Durban	-
Thulasi et al [24]	120	-	2017	134.57mm	120.53mm	Kerala (India)	-
Present study	100	25-60 year	2017	148.72 ± 6.65	136.88 ± 8.51	Bhopal (India)	M- 80% F-70%

Table 3: Comparison of studies on Midclavicular circumference (MCC) associated with Sex

Studies by various experts	Sample size	Age group	Year of study	Male (mm)	Female (mm)	Region	Accuracy
Frutos et al [12]	97	-	2002	-	-	Guatemala	85.6 - 94.8%
Akhlaghi et al [14]	120	-	2012	-	-	Iran	73.3-88.3%
Shivarama et al [17]	315	-	2015	43.0mm	30.0mm	Mangalore (Karnataka)	-
Alcina et al [20]	77	20-92 y	2015	38.0 ± 3.8	31.36 ± 2.3	Madrid (Spain)	88.3%
Bagal et al [21]	120	-	2016	39mm	31mm	Maharashtra (India)	-
Sehrawat et al[22]	263	17-94 y	2016	38.52 ± 3.28	32.66 ± 2.57	Chandigarh (India)	M- 79% F- 86.8%
S Ishwar et al[23]	100	-	2016	38.64mm	34.28mm	Durban (Africa)	-
Thulasi et al [24]	120	-	2017	35.50±3.37	26.82±2.40	Kerala (India)	-
Present study	100	25-60 y	2017	38.67±3.3	33.04±2.4	Bhopal (India)	M-72% F-88%

The overall observation suggests that even in a single country, variations are seen in the estimation of sex with the help of Clavicle. The causes for this can be Environmental, socioeconomic, geographical, heredity and growth patterns. The worldwide variation can also be seen in both extremes.

Conclusion

Based on the observations and results of the clavicle measurements, it can be concluded that the Mean of all the measured parameters is higher amongst males as compared to the females. Amongst all the parameters, Maximum length of clavicle and Mid clavicular

circumference are the most reliable parameters for sexual dimorphism with 81% accuracy rate when considered together. If all the morphometric parameters are taken together then the sexual dimorphism can be estimated with 87% accuracy in Bhopal (Central region).

Recommendations

The sample size can be increased in future studies with the usage of both side clavicles and increased individuals. Such studies in every region will help in compiling and studying the data and formulating one equation for the Indian population. The ethical issues related to the removal of a bone from a deceased person

is still a matter of concern for the relatives. This can be made justifiable with better communication & the importance of it in Research.

Conflict of Interest: The authors do not have any conflicts of interest.

Ethical Approval: The Institutional Ethics Committee for clinical studies (no.:7607-09). **Informed Consent:** Written informed consent was obtained from the next of the kin of the deceased. The procedure was described in local language to promote understanding.

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