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Original Research Article

Determination of sex of adult human clavicle by discriminant function analysis in Marathwada region of Maharashtra

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ABSTRACT

Background: Determination of biological sex is one of the most important determinations to be made from human remains and is an essential first step in the development of the biological profile in forensics, anthropology and bioarchaeology. The aim of this study was to determine whether sexing of unknown adult human clavicles can be done by applying values of morphometric parameters and formulae generated by present study on adult human clavicles of known sex and to find out the best parameters for sex determination.
Methods: Various metric measurements were recorded using osteo metric board, measuring tape, non-elastic thread, sliding calipers and vernier calipers on adult human clavicles.
Results: Sex was correctly estimated by using stepwise discriminant function analysis, for the clavicle 93.3 % of males and 94.4% of females, with a total accuracy of 93.7 %. Direct discriminant function analysis, correct estimated sex for the clavicle was 93.9 % in males and 93.3% in females with a total accuracy of 93.7 %.
Conclusions: Present study exhibited better classification accuracy for multiple variables than those of single variables. In the clavicle, the most discriminating variables in stepwise analysis are the mid clavicular circumference, posterior curved length, medial 2/3 and lateral 1/3 junction circumference and Weight. In direct analysis, the single most useful variable was the mid clavicular circumference.

Keywords: Mid clavicular circumference, Medial 2/3 and lateral 1/3 junction circumference, Posterior curved length

INTRODUCTION

Sex determination of the human skeleton has been studied in forensic and physical anthropology.[1] Since the beginning of the field of physical anthropology, osteologists and anatomists have studied human remains in order to provide new and more accurate ways of building the biological profile.

While DNA analysis has proven successful in identifying unknown victims and perpetrators of crime, it is of little value when there are no family members to positively identify or claim the deceased.[2-4] In India, forensic pathologists frequently encounter situations in which standard avenues for identification, e.g., fingerprints, DNA and ante mortem dental records, are of little or no value. In these situations, Forensic personnel frequently consult the anatomists to give their expert opinion for medico legal purposes, regarding the personal identity with respect to sex, age, stature, race and probable cause of death. Examination of such skeletal remains forms the basis of their opinion.[5,6]

In the present scenario, forensic anthropologists are involved in discovering new methods of identification from skeletal remains, cadavers as well as living beings. The reason to work on new populations is that the earlier acquired standards of age and sex determination have lost

their values due to secular changes in the modern populations.[7,8] Therefore, there is always a need to apply and test the methods to newer populations for making population standards for achieving precision and accuracy.

Therefore, it was suggested that osteometric studies should be considered "population specific", which implies that sexual dimorphism varies between populations to such an extent that osteometric standards developed from one group cannot be reliably used on another population.[9]Very few studies are available in India on determination of sex from human clavicle, so present study made a sincere effort to enhance the accuracy of sex determination from adult human using various parameters by applying discriminant function analysis on population of Marathwada region of Maharashtra.

METHODS

The bones used in this study was obtained from government medical college, Aurangabad, Maharashtra, India. For the study, fully ossified dry bones, free of damage or deformity were used. Total of 254 bones were selected for the study out of which 164 were of males and 90 were of females. Present study was done on dry human bones, so ethical issues were not arisen.

Clavicle measurements

- Weight (W): weight of each dried clavicle is recorded with the help of scientific balance and weight, it is recorded in grams
- Linear length (L): maximum distance between the most extreme ends of clavicle is measured with the help of Osteometric board
- Anterior curved length (ACL): anterior curved length is measured with non-elastic thread along anterior curvature of clavicle. Then thread length is measured on scale
- Posterior curved length (PCL): posterior curved length is measured with non-elastic thread along posterior curvature of clavicle. Then thread length is measured on scale
- Mid clavicular circumference (MC): midpoint of shaft is measured with Osteometric board while measuring its length and marked. Circumference is measured with non-elastic thread and thread length is measured on scale
- Medial 2/3rd and lateral 1/3rd junction circumference (JC): it is measured at medial 2/3rd and lateral 1/3rd junction of clavicle with non-elastic thread and thread length is measured on scale
- Mid clavicular antero posterior diameter (APD): it is measured with vernier calipers at the level of mid shaft.

RESULTS

An analysis of variance test (ANOVA) provided descriptive statistics for the clavicle, including the means, standard deviations and F-ratios of all the variables in both sex groups (Table 1).

The greatest differences in mean values appeared to be in mid clavicular circumference (males: 34.87 mm, females: 28.67 mm.), linear length (males 141.30 mm, females: 125.71 mm.), posterior curved length (males: 151.65 mm, females: 134.36 mm) and medial 2/3 and lateral 1/3 junction circumference (males: 40.50 mm, females: 34.93 mm) (Table 1).

Table 1: Means, standard deviations, univariate F-ratio and demarking points for the clavicle.

Variable descriptions	Males (n =164)			Females (n = 90)					
	Mean	SD	SE	Mean	SD	SE	F- ratio	t -test	p value
Clavicle									
W	16.57	3.45	0.26	10.78	2.23	0.23	205.79	14.34	0.000
L	141.30	8.34	0.65	125.71	6.11	0.64	242.44	15.57	0.000
ACL	137.15	8.98	0.70	122.27	6.43	0.67	192.56	13.87	0.000
PCL	151.65	9.78	0.76	134.36	7.14	0.75	217.16	14.73	0.000
MC	34.87	2.96	0.23	28.67	2.28	0.24	297.35	17.24	0.000
JA	40.50	2.99	0.23	34.93	2.67	0.28	216.29	14.70	0.000
APD	11.71	1.26	0.09	9.67	0.86	0.09	187.14	13.68	0.000

A statistically significant difference ($p < 0.001$) was found between males and females for the osteometric variables of clavicle. As can be seen in Table 1, the univariate F-ratio scores were the highest in the mid clavicular circumference, linear length, posterior curved length and medial 2/3 and lateral 1/3 junction circumference, and lowest in anterior curved length and mid clavicular antero posterior diameter. From the descriptive statistics, it is possible to suggest that the metric variables with the highest F-ratios mentioned

above, could be useful in distinguishing between the sexes; similarly, variables with low univariate F-ratios may not be as useful in distinguishing between these groups. Stepwise discriminant analysis of clavicle (Table 2, 3 and 4).

Table 2: Variable wise calculation of discriminant functions of clavicle.

Function	Variable	Unstandardized co efficient	Standard coefficient	Structured coefficient	Wilks lambda	Eigen value	Canonical correlation
1 All variables	MC	0.171	0.469	0.821	0.364	1.751	0.798
	PCL	0.050	0.447	0.702			
	JA	0.071	0.204	0.700			
	W	0.075	0.232	0.683			

Table 3: Discriminant function equation for determining sex of clavicle.

Function	Variable	Constant	Discriminant equation	Group centroid		Sectioning point
				Male	Female	
1	MC, PCL, JA, W	-16.689	D = -16.689 + 0.171* MC + 0.050* PCL + 0.071*JA + 0.075* W	0.976	-1.779	-0.00018

Table 4: Percentage of predicted group membership and cross validation for the clavicle.

Function	Variable	% of bones correctly classified					
		Male (n =164)		Female (n =90)		Total (n=254)	
		Original	Cross validated	Original	Cross validated	Original	Cross validated
1	MC, PCL, JA, W	153	153	85	85	238	238
		93.3	93.3	94.4	94.4	93.7	93.7

A Stepwise discriminant function was performed to determine the most significant variables contributing to the discrimination of gender. Stepwise analysis was run on seven measurements from the clavicle.

The stepwise discriminant function procedure was performed using Wilk's Lambda with F = 3.84 to enter and F = 2.71 to remove. When all seven variables were entered for the clavicle (Function 1), selected variables included: mid clavicular circumference, posterior curved length, medial 2/3 and lateral 1/3 junction circumference and weight showed largest metric discrimination between the sexes.

A direct analysis was then carried out on these above-mentioned variables, as they appeared to be the most constructive in statistically discriminating between the sexes (Table 5, 6 and 7, direct functions).

Discriminant function score formula for Function 1 analysis of clavicle is

D = -16.689 + 0.171* MC + 0.050* PCL + 0.071*JA + 0.075* W

The classification accuracy of the clavicle for the discriminant function formulae are presented in Table 4.

For the clavicle, function 1 analysis (Table 4) showed that 153 males out of 165 cases were correctly classified with 11 individuals misclassified as females, thus resulting in 93.3% accuracy.

85 females out of 90 cases were correctly classified with 5 individuals misclassified as males, thus resulting in 94.4% accuracy. Total 238 out of 254 cases were correctly classified with total accuracy of 93.7 %. Cross validation showed similar result with original analysis.

Direct discriminant analysis of clavicle (Function 1 to 7, Table 5, 6 and 7) (each variable separately).

A direct analysis was carried out on all individual variables separately to identify the most constructive variable in statistically discriminating between the sexes. The results of the direct analysis and discriminant function score formula for each variable appear in Tables 5, 6 and 7 as Function 1 to 7.

By direct discriminant analysis, mid clavicular circumference is the best discriminant variable among all variables with 90.2% for males and 87.8% for females, with a total accuracy of 89.4%

A direct discriminant analysis was applied to evaluate the diagnostic ability of individual variables that were previously selected as best discriminators of sex during the stepwise analysis. The results of the direct analyses appear in Table 6,7 and 8 as function 5, function 4, Function 6 and Function 1 and refer to analysis of the mid clavicular circumference, posterior curved length, medial 2/3 and lateral 1/3 junction circumference and weight respectively. Direct discriminant analysis of clavicle (Function 8, Table 5, 6 and 7) (all variables entered together).

Table 5: Variable wise calculation of discriminant functions of clavicle.

Function	Variable	Unstandardized co efficient	Standard coefficient	Structured coefficient	Wilks lambda	F ratio	Eigen value	Canonical correlation
1	W	0.325	1	1	0.550	205.79	0.817	0.670
2	L	0.131	1	1	0.510	242.44	0.962	0.700
3	ACL	0.122	1	1	0.567	192.56	0.764	0.658
4	PCL	0.112	1	1	0.537	217.16	0.862	0.680
5	MC	0.365	1	1	0.459	297.35	1.180	0.736
6	JA	0.346	1	1	0.538	216.29	0.858	0.680
7	APD	0.878	1	1	0.574	187.14	0.743	0.653
8 All Variables	W	0.070	0.214	0.672	0.356	-	1.806	0.802
	L	0.073	0.558	0.730				
	ACL	-0.048	-0.389	0.650				
	PCL	0.032	0.284	0.691				
	MC	0.182	0.500	0.808				
	JA	0.072	0.208	0.689				
	APD	-0.057	-0.065	0.641				

Table 6: Discriminant function equation for determining sex of clavicle.

Function	Variable	Constant	Discriminant equation	Group centroid		Sectioning point
				Male	Female	
1	W	-4.718	D= -4.718 + 0.325*W	0.667	-1.215	0.00015
2	L	-17.785	D = -17.785 +0.131*L	0.724	-1.319	0.000102
3	ACL	-16.140	D= -16.140 +0.122*ACL	0.645	-1.175	0.000118
4	PCL	-16.275	D = -16.275 +0.112*PCL	0.685	-1.248	0.000078
5	MC	-11.923	D = -11.923 +0.365*MC	0.802	-1.461	0.00015
6	JA	-13.339	D = -13.339 +0.346*JA	0.684	-1.246	0.000142
7	APD	-9.649	D = -9.649 +0.878*APD	0.636	-1.159	-0.000024
8	All variables	-17.382	D = -17.382 + 0.070*W + 0.073*L - 0.048*ACL +0.032*PCL+ 0.182*MC + 0.072*JA - 0.057*APD	0.992	-1.807	0.000228

A direct discriminant analysis was applied to evaluate the diagnostic ability of all variables entered together in direct discriminant analysis (Function 8, Table 5, 6 and 7). Discriminant function score formula for Function 8 analysis of clavicle is,

D = -17.382 + 0.070*W + 0.073*L -0.048*ACL +0.032*PCL+ 0.182*MC + 0.072*JA - 0.057*APD.

The classification accuracy of the clavicle for the discriminant function formulae are presented in Table 7.

For the clavicle, Function 8 analysis showed that 154 males out of 165 cases were correctly classified with 11 individuals misclassified as females, thus resulting in 93.9 % accuracy.

84 females out of 90 cases were correctly classified with 6 individuals misclassified as males, thus resulting in 93.3 % accuracy.

Total 238 out of 254 cases were correctly classified with total accuracy of 93.7 %. Cross validation showed that

only two extra cases were misclassified, therefore not greatly affecting the overall percentage.

Table 7: Percentage of predicted group membership and cross validation for the clavicle.

Function	Variable	% of bones correctly classified					
		Male (n =164)		Female (n =90)		Total (n=254)	
		Original	Cross validated	Original	Cross validated	Original	Cross validated
1	W	144	144	67	67	211	211
		87.8%	74.4	87.8%	74.4	83.1	83.1
2	L	144	144	77	77	221	221
		87.8	87.8	85.6	85.6	87.0	87.0
3	ACL	136	136	76	74	212	210
		82.9	82.9	84.4	82.2	83.5	82.7
4	PCL	145	145	75	75	220	220
		88.4	88.4	83.3	83.3	86.6	86.6
5	MC	148	148	79	79	227	227
		90.2	90.2	87.8	87.8	89.4	89.4
6	JA	146	146	65	65	211	211
		89.0	89.0	72.2	72.2	83.1	83.1
7	APD	144	144	66	66	210	210
		87.8	87.8	73.3	73.3	82.7	82.7
8	All variables	154	154	84	82	238	236
		93.9	93.9	93.3	91.1	93.7	92.9

Table 8: Comparison of clavicle value for sex determination between previous studies and present study.

Study	Country	Year	Method	Overall accuracy	Accuracy in males	Accuracy in females
Jit and Singh[10]	India	1966	Measurement of length and circumference of clavicle	-	8%	14%
McCormick et al[11]	North America	1991	Measurement of length and circumference of clavicle	93%	94%	84%
Jit and Singh[12]	India	1996	Measurement of volume, weight, length and circumference of clavicle	-	80.54%	86.69%
Murphy et al[13]	New Zealand	2002	Measurement of length and width of the two ends of clavicle	-	97.7%	-
Frutos[14]	Guatemala	2002	Measurement of length and circumference of clavicle	85.6 - 94.8%	87- 96.8%	82.8- 94.6%
Mitra Akhlaghi et al[15]	Iran	2009 - 2010	Measurement of length and circumference of clavicle	73.3 - 88.3%	-	-
Present study	India	2014	*MC, PCL, JA, W	93.7	93.3	94.4
			**W, L, ACL, PCL, MC, JA, APD	93.7	93.9	93.3

*Most discriminating variables, ** All variables; W=weight, L=length, ACL=anterior curved length, PCL=posterior curved length, MC=mid clavicular circumference, JA=medial 2/3 and lateral 1/3 junction circumference, APD=mid clavicular antero posterior diameter.

DISCUSSION

Sex determination using human skeletal remains is one of the most important components in forensic identification and starting point of anthropologic researches. In this research, we investigated clavicle bone.

Measurements of clavicle bones indicated that men often have greater bone dimensions than women. Present study also shows males have greater bone dimensions. Table 8 illustrates clavicle dimensions and clavicle accuracy in both sex in present study and previous reports.

Sex determination accuracy in current study was more than Jit and Singh study due to racial differences and used method.[10] Overall accuracy was 93.7 % in this study which is like McCormick et al, Murphy et al and Luise Frutos studies.[11,13,14]

However, overall accuracy was much higher in current study when compared to Mitra Akhlaghi et al study.[15] This is attributed to the racial differences, and environmental factors affecting the growth or sampling method of the studied population.

In a study done by Haque MK et al shows that mid-clavicular circumference is the most reliable single indicator of sex similar to our findings.[16]

Present study shows, the most discriminating variables included in the stepwise analysis are the Mid clavicular circumference, posterior curved length, medial 2/3 and lateral 1/3 junction circumference and weight with 93.3% accuracy in males, 94.4% accuracy in females and 93.7% overall accuracy.

In, direct analysis, the single most useful variable was the mid clavicular circumference with 90.2% accuracy in males, 87.8% accuracy in females and 89.4% overall accuracy.

CONCLUSION

In summary, the measurements of the clavicle appear to be good discriminators of sex in present sample analysed by stepwise and direct discriminant function analysis.

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