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Research Article

SEX DETERMINATION FROM ADULT HUMAN ULNA BY STEPWISE DISCRIMINANT FUNCTION ANALYSIS

Bhaskar B.Reddy* and Doshi M.A

Department of Anatomy, Krishna Institute of Medical Sciences Deemed University, Karad.

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A B S T R A C T

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 Ulna bones can be done by applying values of morphometric parameters and formulae generated by present study on adult human Ulna bones 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 Ulna bones.

Results: Sex was correctly estimated by using stepwise discriminant function analysis, for the Ulna 95.6 % of males and 89% of females, with a total accuracy of 93.2 %.

Conclusions: Present study exhibited better classification accuracy for multiple variables than those of single variables. In the Ulna, the most discriminating variables in stepwise analysis are the Weight, Physiological length and Minimum olecranon breadth.

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. [2,3,4]

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 also probable cause of death. Examination of such skeletal remains forms the basis of their opinion.[5,6]

Expression of sexual dimorphism is another factor to consider when conducting osteometric studies. Three major trends were considered to influence sexual dimorphism namely, reproductive function as expressed in the morphology of the pelvis, genetic differences that influenced body size and proportions, and lastly differences in musculature between the sexes.[7] Researchers realized that despite sharing the same basic structure; sexual dimorphism, stature and other visible characteristics appeared to differ between population groups.
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.[8,9] 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 (Novotny V *et al*, 1993).[10] Very few studies are available in India on determination of sex from human skeleton, so present study made a sincere effort to enhance the accuracy of sex determination from

Corresponding author:* **Bhaskar B.Reddy
Department of Anatomy, Krishna Institute of Medical Sciences Deemed University, Karad

using various parameters of Ulna bones by applying stepwise Discriminant function analysis on population of Marathwada region of Maharashtra.

METHODS

The bones used in this study were obtained from Govt. Medical College, Aurangabad, Maharashtra. For the study, fully ossified dry bones, free of damage or deformity were used. Total of 280 bones were selected for the study out of which 180 were of males and 100 were of females. Weight of bones recorded with the help of scientific balance & weight, it is recorded in grams and all other measurements such as length and circumference were measured in millimeters. Present study was done on dry human bones, so ethical issues were not arised.

Ulna Measurements

1. Weight (W): weight of each dried ulna is recorded with the help of scientific balance and weight, it is recorded in grams.
2. Maximum length (L): it is measured from most superior point of the olecranon to the most inferior point of the styloid process, with the help of Osteometric board.
3. Physiological length (PL): distance between the most distal point on the surface of the coronoid process and the most distal point on the inferior surface of the distal end of ulna (styloid process is not included in this measurement) is measured with the help of Osteometric board.
4. Maximum olecranon breadth (MAX.OB): greatest breadth of the olecranon measured perpendicularly to the crest of the incisura trochlearis is measured with vernier calipers.
5. Minimum olecranon breadth (MIN.OB): smallest breadth of the olecranon measured perpendicularly to the crest of the incisura trochlearis is measured with vernier calipers.
6. Circumference of mid shaft (CMS): Circumference is measured with non elastic thread around mid shaft of ulna and thread length is measured on scale.
7. Width of distal end (DWD): width of distal end of ulna is measured with vernier calipers.
8. Circumference of head (CH): Circumference is measured with non elastic thread around head of the ulna and thread length is measured on scale.

RESULTS

An analysis of variance test (ANOVA) provided descriptive statistics 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 Weight (males: 44.96 gm, females: 29.15 gm.), Maximum length (males 267.30 mm, females: 239.04 mm.), Physiological length (males 232.26 mm, females: 207.33 mm.) and Circumference of mid shaft (males 43.72 mm, females: 38.67 mm.)

A statistically significant difference ($p < 0.001$) was found between males and females for the osteometric variables of ulna.

Stepwise discriminant analysis of Ulna

A Stepwise discriminant function was performed to determine the most significant variables contributing to the discrimination of gender.

Stepwise analysis was run on 8 measurements from the ulna. 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 8 variables were entered for the ulna (Function 1), selected variables included: Weight, Physiological length and Minimum olecranon breadth showed largest metric discrimination between the sexes.

Discriminant function score formula for Function 1 analysis of Ulna is

D= -15.737 + 0.072* W +0.032* PL + 0.312* MINOB

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

For the ulna, Function 1 analysis (Table 4) showed that 172 males out of 180 cases were correctly classified with 8 individuals misclassified as females, thus resulting in 95.6 % accuracy.

89 females out of 100 cases were correctly classified with 11 individuals misclassified as males, thus resulting in 89% accuracy.

Total 261 out of 280 cases were correctly classified with total accuracy of 93.2 %. Cross validation showed similar result of original analysis.

Table 1 Means, Standard deviations, Univariate F-ratio and demarking points for the Ulna

Variable Descriptions	Males (n =180)			Females (n = 100)					
	Mean	SD	SE	Mean	SD	SE	F- ratio	t -test	p value
				ULNA					
W	44.96	7.42	0.55	29.15	6.38	0.63	321.47	17.93	.000
L	267.30	14.06	1.04	239.04	13.51	1.35	266.80	16.33	.000
PL	232.26	12.45	0.92	207.33	12.06	1.20	263.42	16.23	.000
MAXOB	24.04	1.84	0.13	20.62	2.21	0.22	192.05	13.85	.000
MINOB	19.51	1.59	0.11	16.99	1.29	0.12	184.03	13.56	.000
CMS	43.72	2.81	0.20	38.67	2.51	0.25	223.47	14.94	.000
DWD	16.10	1.41	0.10	13.93	1.23	0.12	166.08	12.88	.000
CH	55.08	3.88	0.28	48.78	3.50	0.35	181.19	13.46	.000

Table 2 Variable wise calculation of discriminant functions of Ulna (Stepwise analysis)

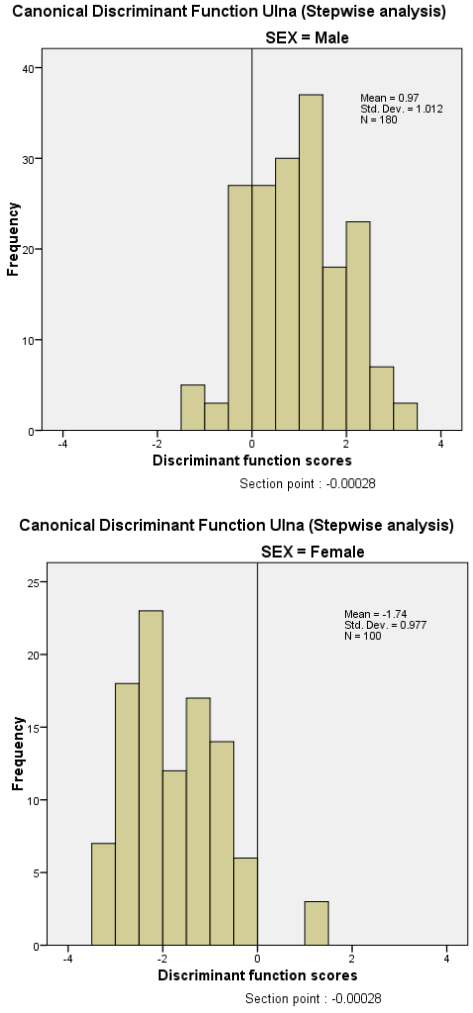
Function	Variable	unstandardized co efficient	standard coefficient	structured coefficient	Wilks Lambda	eigen value	canonical correlation
1 All variables	W	0.072	0.506	0.824	0.370	1.703	0.794
	PL	0.032	0.393	0.746			
	MINOB	0.312	0.466	0.623			

Table 3 Discriminant function equation for determining sex of Ulna (Stepwise analysis)

Function	Variable	Constant	Discriminant equation	Group centroid		Sectioning point
				Male	Female	
1All variables	W PL MINOB	-15.737	B= -15.737 + 0.072* W +0.032* PL + 0.312* MINOB	0.969	-1.745	-0.0002857

Table 4 Percentage of predicted group membership and cross validation for the Ulna (Stepwise analysis)

Function	Variable	% of bones Correctly classified					
		Male (n =180)		Female (n =100)		Total	
		original	Cross validated	original	Cross validated	original	Cross validated
1	W	172	172	89	89	261	261
All variables	PL MINOB	95.6	95.6	89	89	93.2	93.2



Graph 1 Discriminant scores of Ulna by sex using multivariate equation

D= -15.737 + 0.072* W +0.032* PL + 0.312* MINOB

DISCUSSION

Sex determination using human skeletal remains is one of the most important components in forensic identification and starting point of anthropologic researches. Sex determination is the most significant information which can be obtained from bones. In previous studies, morphologic methods were mostly used to determine sex. However, metric measurements were preferred due to their easy repeatability, high accuracy, and no requirement for special skills. Singh *et al.* (1974)[11] When assessing the ulna, measured a sample of 245 individuals and found that length, and midshaft circumferences were the most accurate variables to discriminate sex.

Introna F Jr *et al* (1993)[12] studied determination of skeletal sex using discriminant analysis of ulnar measurements. Twelve ulnar measurements take on a series of 80 skeletons (40 male, 40 female) of a known Southern Italian population. The highest percentage of correct sex classification (95%) was obtained by the association of the minimum circumference and the maximal length. Using other four discriminant functions sex is correctly identified in 93.75% of the sample.

Purkait R (2001)[13] studied measurements of ulna- a new method for determination of sex. Dry and adult ulnae (100 male and 60 female) of Madhya Pradesh, India were subjected to three measurements (Olecranon--coronoid angle, length, and width of inferior medial trochlear notch). The data were analyzed using discriminant function analysis. Direct analysis using single or multiple variables revealed the Olecranon-Coronoid angle as the best single parameter, yielding 85% accuracy. Measurements of the inferior medial trochlear notch have an additional advantage of being used in fragmentary bone where only the upper end is available. The calibrated discriminant functions correctly classified 90.6% of all males and females in an independent test sample.

Mall G *et al* (2001)[14] studied sex determination and estimation using maximum ulnar length, proximal ulnar, distal ulnar width, maximum radial length, radial head diameter and distal radial width. A discriminant analysis results shows percentage of 94.93% of cases were correctly classified when all measures of the radius were applied jointly, followed by humerus (93.15%) and ulna (90.58%).

Celbis O. and Agritmis H. (2006)[15] studied estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. Sample is composed of 80 males and 47 females with an average age of 36 and 30 years, respectively. Discriminant function statistics showed sex determination accuracy as high as 96%.

Barrier IL and L'Abbé EN (2008)[16] studied sex determination from the radius and ulna in a modern South African sample. Sixteen standard anthropometric measurements were taken from the radius and ulna and subjected to stepwise and direct discriminant function analysis. Distal breadth, minimum mid-shaft diameter and maximum head diameter were the best discriminators of sex for the radius, while minimum mid-shaft diameter and olecranon breadth were selected for the ulna.

Classification accuracy for the forearm ranged from 76 to 86%.

Srivastava R *et al* (2013)[17] studied sexual dimorphism in ulna: an osteometric study from India. Eight measurements were obtained on a sample of 106 ulnae (males--80, females--26) in the age range of 25-65 years. Results of stepwise and direct discriminant function analysis shows that the best discriminator of sex was the maximum length (84.9%) followed by radial notch width (84%). In stepwise analysis, these two variables were selected and provided an accuracy of 88.7% (M-87.5%, F-92.3%). The proximal end provided a classification rate of 81.1% (M-80%, F-84.6%) with selection of the notch length and olecranon width.

Present study shows, the most discriminating variables for ulna included in the stepwise analysis are the Weight, Physiological length and Minimum olecranon breadth with 95.6% accuracy in males, 89% accuracy in females and 93.2% overall accuracy.

CONCLUSIONS

In summary, the measurements of the ulna appear to be high discriminators of sex in present sample analyzed by stepwise discriminant function analysis. In the stepwise analysis, the most discriminating variables included the Weight, Physiological length and Minimum olecranon breadth.

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