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Sexing Ulna by Multivariate Analysis

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Abstract

Sex identification from skeletal remain has great medicolegal and anthropological significance.A number of studies are available in this regard. The studies being population specific and in general are of not universal help. Present study is an attempt to establish multivariate analysis of ulna for the determination of sex. Materials & Methods used as 193 adult human ulnae, 133 male and 60 female from the Bone Bank of Govt. Medical College Aurangabad, were used for the present study. Four different Parameters of ulnae were studied for making two groups and multivariate analysis of ulnae done for sex determination. SPSS (Sum of products and Sum of Squares) is used for applying multivariate linear discriminant analysis and a discriminant functional score is obtained. Any ulna falling on the male side of the sectioning point will be categorized as male ulna while that falling on female side of sectioning point will be categorized as female ulna. This enhances the accuracy of opinion.

Conclusion of study is Multivariate analysis of long bones including ulnae are of immense help in determination of sex of deceased person specially in cases where skeletal remains available are very less.

Keywords: Forensic anthropology; Sexual dimorphism; Multivariate analysis; SPSS; Sectioning point; Skeletal collection.

Introduction

Traditional non metrical methods for sex determination from various parts of skeleton depend on expert's ability and experience – factors which can seldom be evaluated objectively & accurately.

Recently a new approach to the old problem of sexing has developed which is concerned with presenting multivariate discriminant function technique based on various measurements of bones. Various studies based on multivariate discriminant analysis for sexing skull[1,2], teeth[3], mandible[4], scapula[2] , sacrum[5], pelvis[6], femur[7], tibia[8] and other bones of the body.

As a general rule definitive sexual traits in the skeleton do not manifest until after the full achievement of the secondary sexual traits that appear during puberty. The dividing line between immaturity and maturity is somewhere around 15-18 years. Prior to this age sexing the bones has been inconclusive. Hence the description of the sex differences is to be limited to the ages above 18 years.

The Ulna is a medial bone of the forearm and is parallel with the radius when the arm is supine. It articulates with the humerus at their proximal end and bones of wrist at their distal end. It has a large hook like articular surface on the proximal end and the somewhat angular shaft decreases in size to the rounded head and styloid process of the distal end.

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Various parameters of were studied for sexing ulna by multivariate analysis and compare the study with other studies carried out on ulnae.

Aims and Objectives

Aim of present study is to achieve the highest possible accuracy in establishing sex from ulna with the available resources.

The study is done with the following objectives:

1. To study the metrical data of adult male and female ulna.
2. To study the usefulness of various parameters and indices of ulna for sex determination.
3. To study the overlap in the observed values.
4. To derive a multivariate formula which will help us in establishing sex from ulna.
5. To compare the results of multivariate analysis with that of univariate analysis.

Materials & Methods

193 Adult human ulnae of known sex available in the Bone Bank of the Department of Anatomy, Government Medical College, Aurangabad are used for the present study.

Out of 193 ulnae, 60 are of females and 133 of males. All the ulnae are dry, free of damage or deformity and are fully ossified. The personal records of all the ulnae for age, sex & race are available with the Bone Bank.

The instruments which are used for the measurements of various parameters of ulna are as follows:

1. Scale.
2. Osteometer.
3. Sliding vernier Calliper.
4. Standardized flexible Steel tape.
5. Threads, marker pencils & pens.

Following measurements are taken for each ulna:

1. Total Length (L)

Total length from top of olecranon process to tip of styloid, measured parallel to the shaft, this is achieved by applying top of olecranon to osteometer wall and the sliding pointer is used to mark the tip of styloid.

2. Proximal ulnar width (PWD)

The maximum breadth of the upper end of ulna, it is measured by the vernier caliper.

3. Coronoid height (CH)

The maximum anterioposterior distance between the coronoid process and the posterior surface of the shaft taken perpendicular to the shaft axis.

4. Distal width (DWD)

The maximum breadth of the distal articular surface excluding the styloid process.

All measurements are recorded in mms.

A standard computer program, prepared according to "multivariate linear discriminant function" as proposed by armitage (1971) is used. The principle of "multivariate linear discriminant function" is that measured variables are taken as independent variables where as sex is a dependent variable. The measured variables are then analyzed by standard computer program and a discriminant functional score is obtained. This is done by the computer by summing the independent variables after weighing each of them by an appropriate co-efficient.

The formula is:

$Z = b_0 + b_1 x_1 + b_1 x_2 + \text{——} b_{18} X_{18}$

(Where Z is discriminant functional score & b_0 is constant

$b_1 b_2 + \text{——} b_{18}$ are coefficients and $x_1 x_2 -$

— — x_{18} are variables of parameters)

A few variables which are found statistically insignificant by routine statistical methods enhance the values of statistically significant variables in a multivariate analysis.

A mean functional score for males (Z_m) is obtained by subjecting mean values of all variables of males to discriminant function.

Similarly (Z_f) mean functional score for females is also obtained.

The arithmetic mean of the mean values of males and females when put in place of variables in the formula gives the sectioning point (Z_0)

Any ulna falling on the male side of the sectioning point Z_0 will be categorized as male ulna while that falling on female side of Z_0 will be categorized as female ulna. This enhances the accuracy of opinion.

Results

One hundred and ninety three ulnae of known sex available in Bone Bank of the Department of Anatomy, Government Medical College, Aurangabad, are studied and various dimensions are measured.

Multivariate linear discriminant analysis is applied to the data by selecting variable in groups and linear functions are obtained for each of them.

The differential functional score is designated as C for Group I variables, the values of C_m, C_f and C_o are calculated and subsequently for group II the differential functional score is designated as D, the values of D_m, D_f and D_o are calculated and then the respective ulnae are scored and categorized as male and female on the basis of their score.

All the ulnae are then analyzed by making use of differential functional scores of two groups of variables and the accuracy of sorting of each group of male, female and overall is calculated.

"Multivariate linear discriminant analysis" is applied to two sets of variables designated as group I, group II respectively, and their respective discriminant functional scores designated as C, & D respectively.

The variables of group I are

1. Total length.
2. Coronoid height.
3. Distal width.

The constant and co-efficient obtained are:

c_0=3.899, c_1=0.111 , c_2=0.632, c_3=0.012

The values of discriminant functional score calculated are designed as C, the respective values are:

C_m=54.99474, C_f=49.82462, C_0=52.40968

The discriminant functional score of each ulna is calculated on the basis of these variables and compared with C_0.

The variables of group II are:

1. Total length.
2. Proximal width.
3. Distal width.

The constant and co-efficients obtained are:

d_0=6.926, d_1=0.270, d_2=0.358, d_3-=0.080

The values of discriminant functional score calculated are designed as D, the respective values are:

Table 1: Percentage of ulnae accurately sexed by multivariate analysis

	Group I		Group II	
	Male	Female	Male	Female
Total No. of bones	133	60	133	60
No of bones identified	115	49	114	48
Percentage of accuracy	86.5%	81.7%	86%	80%
Overall no of bones identified out of 193	164		162	
Overall percentage of accuracy	84.97%		83.93%	

D_m=81.16122, D_f=74.27838, D_0=77.7198

The discriminant functional score of each ulna is calculated on the basis of these variables and compared with D_0.

Discussion

For multivariate linear discriminant analysis two groups of variables are made and separately analyzed.

Group I

Linear regression analysis of the same parameters which was done by Steel i.e. group I consisting of :

1. Total length.
2. Coronoid height.
3. Distal width is done.

Present study is compared with the study of Steel[9] (1972). Discriminant functional score less than the sectioning point classify as female and more than the sectioning poing classify as male by Steel.

Although the co-efficients and sectioning discriminant functional scores vary in the two studies. The difference in co-efficients obtained may be attributed to racial differences and number of bones studied. Steel[9] studied, 27 males and 33 females ulnae in England population. Whereas the present study is on population of Marathwada region of Maharashtra (India) and 133 males & 60 females ulnae are studied.

Table 2: Comparison of co-efficients of Steel and group I of present study

No of bones	Steel[9] M = 27 F = 33	Present study M = 133 F = 60
Constant	Zero	3.899
Total length	1	0.111
Coronoid height	0.9533	0.632
Distal width	0.4193	0.012
Dfs	634.50	52.40968

Where Dfs = Discriminant functional score

Table 3: Comparison of co-efficients and accuracies of Mall G. and present study group II

No of Bones Studied	Mall G[10] M = 64 F = 79	Present study M = 133 F = 60
Total length	0.552	0.270
Proximal width	0.337	0.358
Distal width	2.909	0.080
Sectioning point (dfs)	M $\geq$ 0.30 F $\leq$ 0.30	M > 77.7198 F < 77.7198
Accuracy	Overall = 90.58%	M= 86%, F = 80% Overall = 83.93%

Group II

Group II is made of the same parameters used by Mall G[10] (2001) i.e.

1. Total length.
2. Proximal ulnar width.
3. Distal width.

Present study is compared with the study of Mall G[10] (2001) the above table shows the details of two studies i.e. number of bones used, co-efficients obtained, sectioning discriminant functional scores, accuracies etc.

The earlier study is carried on German population, whereas the present study is on Indian race of Marathwada region.There is difference in the number of bones used and variation in the race of the present and the earlier study of Mall G.[10] This can explain the slight difference seen in the individual accuracies of male and female of the two studies.

Form the two groups it is observed that accuracies of both groups are nearer (approximately 85%-90%) and the simplest group is of group I which can be easy to use on large population.

Table 4: Accuracy found by multivariate analysis by previous workers and present study

Name of workers	Accuracy found		
	Male	Female	Overall
Introna F Jr.[12] (1993)	-	-	95%
Mall G. *et al*[10] (2001)	-	-	90.58%
Purkait R[11] (2001)	95%	83.3%	90.6%
Present study	86.25%	80.85%	83.55%

A comparison of the overall accuracies obtained by different workers in the determination of sex from ulna by multivariate analysis is shown in the following Table.

Summary and Conclusion

The multivariate analysis is applied to two groups of the parameters. The variable selected for group I are Total length, Coronoid height & Distal width and for group II are Total length, Proximal width & Distal width, all statistically significant. Sorting of ulnae can be increased by applying multivariate analysis. With group I variables, the individual male and female accuracy is 86.5% and 81.7% respectively. While with group II variables, the individual male and female accuracy is 86% and 80% respectively. Overall accuracy is being 84.97% in group I and 83.93 % in group II. Total number of ulnae sexed accurately by group I is 164 and group II is 162 out of 194.

It is obvious that results obtained in the present study are lesser as compared to other workers.

Difference in percentage of accuracies in different studies depend on number of bones used and racial variation

From the results of multivariate analysis we can conclude that:

1. Even if only ulna of the deceased is available, present study can determine the sex of the deceased person accurately by applying multivariate analysis in as many as 86% of cases.
2. Linear regression is far better than any of the independent variables used alone.
3. On comparing the results of group I, group II it is seen that, changing the combination of parameters does influence the percentage of ulna identified with total certainty.
4. Multivariate analysis is the best method for determination of sex of ulna with the available resources.
5. Sorting percentage can be increased by using more parameters for multivariate analysis.

On comparing the results of multivariate analysis with univariate analysis it can easily be seen that the accuracy obtained by multivariate analysis is much better than that of the univariate analysis.

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