DETERMINATION OF SEX FROM FEMUR: DISCRIMINANT ANALYSIS

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ABSTRACT

The present study was conducted on 80 left femora (40 male and 40 female). Seven measurements of femur were taken. The mean values of all the seven measurements were significantly higher in males as compared to females ($P<0.001$) with univariate analysis. The most dimorphic single parameter on the basis of discriminant analysis was maximum diameter of head of femur with accuracy 72.5% in males and 85% in females. The second best variable according to stepwise discriminant analysis was maximum anteroposterior diameter of shaft with 67.5% accuracy in males and 80% accuracy in females. The combination of maximum diameter of head and maximum anteroposterior diameter of shaft provided better results with 82.5% accuracy in males and 92.5% accuracy in females.

Key Words- Femur, sex determination, discriminant analysis

INTRODUCTION

Determination of sex is relatively easy if the entire skeleton is available for examination. Even when skull and pelvis, the most reliable bones for sex determination are available not more than 98% of accuracy can be achieved in identifying the sex (Krogman and Iscan, 1986)[1].Often in medicolegal cases it is expected to determine sex from isolated long bones or their fragments from the crime site in order to establish a possible identity. Several studies have shown variability in osteometric dimensions between populations and it is well established that in determination of sex from various skeletal parts, standards specific to the population under study should be used. India is a vast country with a number of different populations but only a few studies pertaining to femur are available from this part of the world. Moreover, most of the studies for sex determination have not used the latest statistical techniques like multivariate analysis by which percentage of accuracy (sensitivity) in identification of sex increases. Therefore, in the present study, femur was studied for sex determination in the population of north-west region of India.

MATERIAL AND METHODS

The present study was conducted on 80 femora of left side (40 male and 40 female) collected in the department of Anatomy, Pt. B.D. Sharma PGIMS, Rohtak by maceration of unclaimed human bodies. The reason for choosing left side for femur is based on the reported observation that left lower limb is functionally dominant in majority of human beings (Dogra and Singh, 1971)[2]. All these bones belong to people from north-west region of India.

Seven measurements were taken. The measurements were made using osteometric board, vernier caliper (precision 0.01mm) and graph paper according to standard procedure recommended by Martin and Saller, (1961)[3]. Weight was measured using single pan balance sensitive to 0.1 gm.

The following measurements were taken:-

1. Maximun length- from the head to the medial condyle measured with an osteometric board.
2. Maximum head diameter measured with a vernier caliper.
3. Head circumference circumference taken on the border of the articular surface using graphpaper.
4. Maximum midshaft anteroposterior diameter- The anteroposterior diameter measured approximately at the midpoint of diaphysis at the highest elevation of linea aspera, using vernier caliper.
5. Midshaft circumference circumference taken at the midshaft with graph paper.
6. Distal epiphyseal breadth distance between the two most projecting points on the epicondyles, using vernier caliper.
7. Weight- measured using single pan balance sensitive to 0.1g.

The results were analysed using univariate and stepwise discriminant analysis for which

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Statistical package for social sciences (SPSS) was used. This analysis also calculated the canonical discriminant function coefficients, which included the raw coefficients, standard coefficients, structure coefficients & sectioning points.

The following discriminant function formula was used to calculate discriminant score (Z):-

Z= b0+b1x1+b2x2 ------

Where b0 is constant; b1, b2 ------ are raw coefficients and x1, x2 ---- are the measures of significant parameters

If Z is more than sectioning point the bone is classified as male.

If Z is less than sectioning point the bone is classified as female.

Sensitivity indicates the proportion of actual positives; it is same as percentage accuracy which was calculated by stepwise discriminant function analysis. Specificity indicates the proportion of negatives which are correctly classified. It was calculated for the significant parameters by the following formula-:

$$\text{Specificity} = \frac{\text{True negatives}}{\text{True negatives} + \text{false positives}}$$

RESULTS

The results of the present study are shown in tables I - IV

Table I shows that all the seven measurements were significantly higher in males as compared to females

Variables	*Males*		*Females*		*P value*
	Mean (mm)	*S.D.*	*Mean (mm)*	*S.D.*	
1. Maximum length	*439.57*	*30.14*	*410.60*	*21.90*	*<0.0001*
2. Max. diameter of head	*44.45*	*2.83*	*39.89*	*2.37*	*<0.0001*
3. Max. midshaft A.P. diameter	*27.82*	*3.09*	*25.25*	*2.10*	*<0.0001*
4. Midshaft circumference	*79.62*	*6.19*	*73.47*	*4.08*	*<0.0001*
5. Distal epiphyseal breadth	*76.27*	*4.21*	*69.26*	*5.50*	*<0.0001*
6. Head circumference	*136.63*	*8.08*	*122.82*	*7.19*	*<0.0001*
7. Weight (g)	*344.83*	*67.92*	*262.68*	*44.12*	*<0.0001*

Table I
Mean values of various variables of femur in males and females (univariate analysis)

Step	Variables entered	Wilks'Lambda	F-ratio	Degree of freedom
1.	Max. diameter of head	0.542	65.82	1.78
2.	Max. midshaft A.P. diameter	0.513	36.54	2.77

Table II Summary of stepwise discriminant function analysis

Variables	*Raw coefficients*	*Standard coefficients*	*Structure coefficients*	*Sectioning points*
1. Maximum length	*0.380*	*1.000*	*1.000*	-
Constant	*-16.134*			
2. Max.diameter of head	*3.829*	*1.000*	*1.000*	-
Constant	*-16.107*			
3. Midshaft circumference	*1.906*	*1.000*	*1.000*	-
Constant	*-14.590*			
4. Max. midshaft A.P diameter	*3.775*	*1.000*	*1.000*	-
Constant	*-10.019*			
5. Epicondylar width	*2.566*	*1.000*	*1.000*	-
Constant	*-18.676*			
6. Head circumference	*1.307*	*1.000*	*1.000*	-
Constant	*-16.931*			
7. Weight (g)	*0.017*	*1.000*	*1.000*	-
Constant	*-5.304*			
8. Max. diameter of head	*3.368*	*0.880*	*0.943*	*0.963*
Max. midshaft diameter	*1.281*	*0.339*	*0.503*	
Constant	*-17.833*			
9. Head circumference	*1.143*	*0.875*	*0.940*	*0.931*
Max. midshaft diameter	*1.256*	*0.333*	*0.519*	
Constant	*-18.145*			
10. Max. Length	*0.260*	*0.686*	*0.863*	*0.617*
Max. midshaft diameter	*2.021*	*0.535*	*0.762*	
Constant	*-16.434*			
11. Max. Length	*0.201*	*0.530*	*0.827*	*0.661*
Max. circumference	*1.213*	*0.636*	*0.883*	
Constant	*-17.833*			
12. Weight	*0.013*	*0.733*	*0.925*	*0.846*
Midshaft circumference	*0.812*	*0.426*	*0.756*	
Constant	*-10.102*			

Table III Canonical discriminant femur function coefficients

		Male		Female		Average
Functions	Total no. (N)	No. correctly identified	%	No. correctly identified	%	%
Maximum diameter of head	80	29/40	72.5	34/40	85	78.7
Maximum midshaft anteroposterior diameter	t80	27/40	67.5	32/40	80	73.7
Max.diameter of head and max.midshaft anteroposterior diameter	80	33/40	82.5	37/40	92.5	87.5

Table IV : Percentage of correct group membership

	Chinese[5]	Thai[6]	South African Whites[7]	American Blacks[8]	American Whites[8]	Germans[9]	Indians[4]	Present Study
Maximum diameter of head	83.1	91.3	85.9	90	90.9	[illegible].6	88.4	78.7
Epiphyseal breadth	94.9	93.3	90.5	86.6	89.2	81.4	86	-
Midshaft circumference	81.7	85.6	-	73.1	84.0	-	76.7	-

Table V: Comparison of discriminant analysis showing % accuracy in sex determination of femur

(P<0.001). Comparison of standard deviation suggests that males exhibit more variability than females in all measurements except distal epiphyseal breadth.

Table II shows the result of stepwise discriminant analysis. The maximum diameter of head and maximum midshaft anteroposterior diameter were selected in that order. F-ratio determines how much variation exists within and between the sexes and significance level of variance. Wilks' lambda calculates how useful a given variable is in stepwise analysis and order of variables to enter the function.

Table III shows the canonical discriminant function coefficients. Raw coefficients are used to calculate the discriminant scores for the functions. The sectioning point was also calculated. The standard coefficient column indicates the contribution of a variable to the discriminant score relative to other variables. In this study maximum diameter of head when used in combination had the maximum discriminating power (0.880). The structure coefficient gives an idea of what a variable contributes to function on its own. Here also the maximum diameter of head had the maximum structure coefficient (0.943) and therefore the highest contribution.

Table IV shows the percent of correct group membership (sensitivity). It is clear that the best parameter in both the sexes is maximum diameter of head. Second best is maximum midshaft anteroposterior diameter. However the accuracy increased in both the sexes when the above two variables were combined. The sensitivity of all the parameters was more for female bones.

The specificity with maximum diameter of head was 85% for male bones and 72.5% for female bones. With maximum midshaft anteroposterior diameter it was 80% for male bones and 67% for female bones. By the combination of these two variables specficity for male bones was 92.5%and for female bones it was 82.5%.

DISCUSSION

Sex determination from long bones or their fragments is often required to establish a possible identity. It is a common experience for the forensic expert to be confronted with poorly preserved or fragmentary bones. Due to the tubular structure of long bones they are often better preserved than other shorter bones. Thus data for long bone measurement will be more useful. In an Indian study from central India4 maximum diameter of head gave the best accuracy (90.4%) when applied singly. In the present study also the best accuracy was achieved by maximum diameter of head (78.7%) when applied singly. This is in contrast with Chinese5, Thai6 and South African Whites7 where the most dimorphic parameter was epiphyseal breadth. In American black and whites8 and Germans9 the best single parameter was also maximum diameter of head. However, the percentage accuracy was not the same in all populations as seen in table V.

A number of studies including present study have shown that combination of variables give better accuracy for sex determination.

The best results were obtained by a combination of distal epiphyseal breadth and midshaft circumference in Chinese[5] (accuracy 94.7%), distal epiphyseal breadth and maximum diameter of head in Thais[6] (accuracy 94.2%), epiphyseal breadth and maximum diameter of head in South African whites[7] (88.6%), head circumference and midshaft diameter in Germans[8] (91.7%), maximum head diameter and epicondylar width in another Indian study from central India4 (92.1%). In the present study (north-west India) the combination of maximum diameter of head and maximum midshaft anteroposterior diameter provided the best result with 87.5% accuracy emphasizing the importance of population specific data.

In the past several other methods like identification and demarking points have been used for sex determination from bones10. However, the results of these studies showed that very few bones could be identified with 100% accuracy, because of overlapping measurements in the two sexes. Due to different methodology for analysis, the results of these studies cannot be compared with those of present study.

In the present study the percentage accuracy (sensitivity) was less in males as compared to females but the specificity was higher in males. The method is more specific for male bones and more sensitive for female bones. This could be due to more variable lifestyle and differential labour expected in men as compared to women. This is further substantiated by the results of univariate analysis which shows more variability in all parameters in males as compared to females. However, the effect of environment and genetics on these parameters needs to be confirmed.

To conclude, the result of present study further confirms the views of earlier workers that population specific studies in this aspect are mandatory and beneficial for sex determination. The results of the present study will help in accurate diagnosis of sex from both complete and fragmentary femora from north-west India and thus constitute an important tool for forensic experts.

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