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Sexual Dimorphism in Femur

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Abstract: *The determination of sex from skeletal remains is generally the first step in the establishment of a demographic profile of a deceased. Recognition of sex from skeleton is a challenging task in medico legal investigation. This study aims to detect the best set of variables for sex determination from different parameters of femur. The present study was conducted on 200 adult known femora (100 male and 100 female). Eight measurements were taken. The mean values of all parameters were significantly higher in males than females (P < 0.0001). In univariate analysis based on demarcating point - Maximum head diameter was found to the best discriminant parameter with accuracy of 65% in female femora and 29 % in male femora. However, overall accuracy was only 47 %. The multivariate analysis considerably improved the overall accuracy to 96 %. Moreover, with stepwise discriminant analysis the combination of Distal epiphyseal breadth, Maximum head diameter and Midshaft Transverse diameter provided the excellent results with 99 % males and 93 % females sexed correctly on the basis of sectioning point.*

Keywords*: Femur, discriminant analysis, sex dimorphism,*

I. Introduction

Determination of sex is relatively easy if the entire skeleton is available for examination. In medico legal cases it is expected to determine sex from isolated long bones or its fragments from crime scene in order to establish a possible identity. For the purpose of sex determination, the skull and pelvis are the highly reliable skeletal elements which can predict the sex accurately.[1,2,3] But long bones have specially been used because of the ease of defining measurements, better preservation and so on. Former studies like Pons [4], Sakaue K 2004 [5], Asala S 2004 [6] have shown that some combinations of diameters of the long bones have as strong a discriminatory power as do the pelvis or cranium.

India is a vast country with number of different populations but only a few studies pertaining to the femur are available from this part of the world. Moreover, most of the studies for sex determination have not used the latest statistical techniques such as multivariate analysis by which percentage of accuracy improves dramatically. Therefore, in the present study, femur was studied for sex determination of population of western Maharashtra region of India and subjected to multivariate discriminant analysis for setting the standards of sex determination in this population.

II. Methodology

The present study was conducted on 200 adult femora of left side (100 male and 100 female) collected in department of Anatomy from various medical colleges. The reason for choosing the left sided femur was based on reported observations that left lower limb is functionally dominant in majority of humans. [7]

Eight measurements were taken. Measurements were made using osteometric board, Vernier caliper, flexible measuring tape. Weight was measured using electronic weighing machine sensitive to 0.1 gm.

Following measurements were taken:

1. Weight – measured using electronic weighing machine.
2. Maximum length of femur – measured as the straight distance between the highest point of head and deepest point on the medial condyle using osteometric board.
3. Maximum Head diameter – measured with a Vernier caliper.
4. Head circumference – measured on the border of the articular surface by measuring tape.
5. Midshaft Anterioposterior diameter – measured with Vernier caliper approximately at the midpoint of diaphysis at the highest elevation of linea aspera.
6. Midshaft Transverse diameter - measured at the points right angle to AP diameter location with Vernier caliper.
7. Midshaft circumference – measured with flexible measuring tape at Midshaft.
8. Distal epiphyseal breadth – measured as a distance between two most projecting points on the epicondyles using vernier caliper.

Statistical Analysis : The data were analyzed using statistical software package SPSS 19.0 program. Univariate analysis was done by mean, standard deviation, t-test and demarcating point. P-value less than 0.05 considered as significant. In Multivariate analysis technique, discriminant function analysis and stepwise discriminant

analysis were performed to calculate canonical discriminant function coefficients, which included the raw coefficients, standard coefficients, structure coefficient and finally the sectioning points.
Following formula was used to calculate discriminant functional score (DFS).
DFS $= b_o + b_ix_i + b_2x_2 + \ldots\ldots\ldots\ldots + b_8x_8$
(Where b_0 is constant and $b_1, b_2 \ldots, b_8$ are raw coefficients and $x_1, x_2, \ldots x_8$ are variables of parameters)
If DFS is more than sectioning point the bone is classified as male and if it is less than sectioning point then classified as female.

III. Resutls

The results of the present study are shown as following tables ---

Table No. 1 shows that all the eight measurements were significantly higher in males as compared to females ($p<0.0001$). Comparison of standard deviation suggests that males exhibit more variability than females in most of the measurements.

Table No.1: Mean / Standard Deviation / P-Value

S. N.	Variables	Males		Females		P-Value
		Mean (mm)	S.D.	Mean (mm)	S.D.	
1	Weight	334.35	51.48	238.24	65.05	<0.0001
2	Maximum Length of Femur	441.36	24.04	394.60	23.89	<0.0001
3	Head Circumference	139.82	6.67	123.03	8.74	<0.0001
4	Maximum Head Diameter	44.37	2.12	38.44	2.47	<0.0001
5	Midshaft Circumference	83.96	4.43	74.78	4.01	<0.0001
6	Midshaft AP Diameter	27.07	2.14	23.89	1.88	<0.0001
7	Midshaft Transverse Diameter	26.12	1.84	23.25	1.73	<0.0001
8	Distal Epiphyseal Breadth	76.17	2.27	69.83	2.14	<0.0001

Table No.2 shows the univariate analysis with Overall % of femora sexed correctly based on Demarcating Point (D.P.).

Table No.2: Univariate Analysis with overall % of femora sexed correctly based on Demarcating Point(D.P.)

S. N.	Variables	Male Femora		Female Femora		Overall % Sexed Correctly
		D.P.	%Sexed correctly	D.P.	%Sexed correctly	
1	Weight	433.39	0%	179.92	25%	12.5%
2	Maximum Length of Femur	466.3	18%	369.23	2%	10%
3	Head Circumference	149.24	11%	115.98	17%	14%
4	Maximum Head Diameter	455.87	29%	38.02	65%	47%
5	Midshaft Circumference	86.78	26%	70.66	14%	20%
6	Midshaft AP Diameter	29.55	12%	20.66	0%	6%
7	Midshaft Transverse Diameter	28.43	9%	20.61	3%	6%
8	Distal Epiphyseal Breadth	76.26	40%	69.36	43%	41.%5

Table No.3 – shows tests of equality of group means. The Wilk's Lambda shows the percent contribution of each variable and determines the order of variables to enter in the function. F-ratio provides the strong statistical evidence of significant differences between mean of variables of male and female femora. More the value of F-ratio suggests that the variable is a better discriminator of sex.

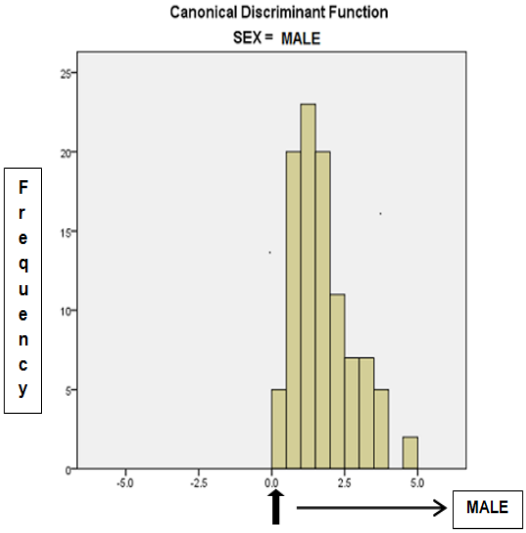
Table No. 3 : Tests of equality of group means table				
Sr. No	**Variables**	**Wilk's Lambda**	**F - Ratio**	**Df1**
1	Weight (gm)	0.5960	134.2309	1
2	Maximum Length of femur(mm)	0.5100	190.2488	1
3	Head Circumference (mm)	0.4594	232.9656	1
4	Maximum Head Diameter (mm)	0.3739	331.5706	1
5	Midshaft Circumference (mm)	0.4559	236.2778	1
6	Midshaft AP Diameter(mm)	0.6140	124.4719	1
7	Midshaft Transverse Diameter (mm)	0.6044	129.5789	1
8	Distal Epiphysis Breadth(mm)	0.3242	412.7030	1

Table No.4 depicts the standard coefficients, structure coefficients and raw coefficients for all the eight variables. The standard coefficient indicates how much a given variable contributes to the overall classification. Distal Epiphyseal Breadth (0.837) and Max. Head Diameter (0.524) added the most to the classification. The structure coefficient measures the correlation between the variable and the function. The raw coefficients were used to calculate the discriminant scores and the sectioning points. The sectioning point obtained for this function was - 0.41164.

Table No. 4: Canonical discriminant function coefficients of all the variables				
Sr. No	**Variables**	**Standard Coefficients**	**Structure Coefficients**	**Raw Coefficients**
1	Weight (gm)	-0.123	0.825	-0.002
2	Maximum Length of femur(mm)	0.081	0.739	0.003
3	Head Circumference (mm)	0.153	0624	0.02
4	Maximum Head Diameter (mm)	0.524	0.62	0.228
5	Midshaft Circumference (mm)	-0.06	0.56	-0.014
6	Midshaft AP Diameter(mm)	0.115	0.47	0.057
7	Midshaft Transverse Diameter (mm)	-0.377	0.462	-0.211
8	Distal Epiphysis Breadth(mm)	0.837	0.453	0.379
	Constant			**-35.519**

Using this sectioning point the classification of femora shows that 100 % male femora and 92 % female femora were sexed accurately. Overall /average accuracy of classification was 96 %. (Histograms and Table No.5)

Histograms showing distribution of Multivariate Discriminant Functional Scores and Sectioning Points of Male and Female Femora of Present study



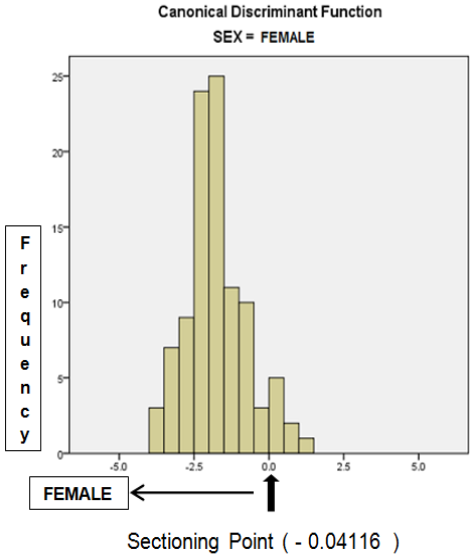


Table No. 5 : Sex wise distribution of cases by Multivariate Analysis

	Male		Female		Average	
Total No.(n)	No. Correctly Identified	%	No. Correctly Identified	%	No. Correctly Identified	%
200	100/100	100%	92/100	92%	192/200	96

While in the second part of multivariate analysis, stepwise discriminant analysis was applied. This test was used to find out the best set of predictors of discrimination and whether these set of variables enhance the accuracy of classification.

Table No. 6 shows that out of 8 variables only 3 were selected based on their Wilk's Lambda and F-ratio values and again their canonical discriminant function coefficients were calculated. These parameters were Distal Epiphyseal Breadth, Max. Head Dia. and Midshaft Transverse Diameter.

Table No.6: Canonical Discriminant coefficients of Three selected variables by Stepwise Analysis

Variables	Standard Coefficient	Structure Coefficient	Raw Coefficient
Distal Epiphysis Breadth	0.866	0.835	0.393
Maximum Head Diameter	0.609	0.748	0.264
Midshaft Transverse Diameter	-0.382	0.468	-0.214
		Constant	-34.317

The sectioning point obtained using these three variables together was 0.02033. It was observed that using this sectioning point the femora sexed accurately were 99 % for males and 93 % for female. The overall /average accuracy was 96 %. Thus the stepwise discriminant analysis improved the accuracy of classification especially in the female femora. (Table No.7)

Table No. 7 : Sex wise distribution of cases by Stepwise Analysis

	Male		Female		Average	
Total No.(n)	No. Correctly Identified	%	No. Correctly Identified	%	No. Correctly Identified	%
200	99/100	99%	93/100	93%	192/200	96

IV. Discussion

Sex determination from the 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 the past several other methods like identification and demarcating points have been used for the sex determination from the bones [8]. But, the results of these studied showed that very few bones could be identified with 100 accuracy. In our study also we could identify only about 47 % bone with demarcating point of maximum head diameter. This is because of significant overlapping of measurements in the two sexes.

However, a number of studies including present study have shown that combination of variables give better accuracy for sex determination. (Table no.8) The best results were obtained by a combination of Max. Femur Length +Trochanteric Lt. + Transverse Midshaft Dia.in Japanese [9] (accuracy 100%), distal epiphyseal breadth and Max. dia. of head in Thais[10] (accuracy 94.2%), epiphyseal breadth and Max. dia. of head in South African whites[11] (88.6%), Max. Head Dia. + AP thickness of Midshaft in Rohtak[12] , India (92.5%) , Max. Length + Max. Head Dia. + AP Dia. + Epicondylar Width from Bhopal[13],India (96.3%) , Weight + Max.Length + Midshaft AP Dia. from Bangalore[14],India (97.1) In the present study , the combination of Distal Epiphyseal Breadth, Maximum Head Diameter and Midshaft Transverse Diameter provided the best results with 96 % overall accuracy emphasizing the importance of population specific data.

The different combinations and their accuracies from geographically diverse populations are given in following Table No 8.

Table No.8:Comparison with other studies on Femur with different combinations of parameters for Sex Determination

Previous Studies	N	Number and % of femora sexed correctly				Parameters Used in Function
		Male		Female		
		No.	%	No.	%	
Ismail Ozer, 2006, Japanese [10]	151	75/75	100	75/75	100	Max.Femur Length +Trochanteric Length + Transverse Midshaft Dia.
Christopher King, 1998, Thai [11]	103	65/69	94.2	32/34	94.1	Max. Head Dia.+ Bicondylar Breadth
M Steyn, 1997, S African whites [12]	105	48/56	85.7	45/49	88.6	Femoral Head Dia. + Femoral Transverse Breadth + Femoral Distal Breadth
Gargi Soni, 2010,Rohtak, India [13]	80	33/40	82.5	37/40	92.5	Max.Head Dia. + AP thickness of Midshaft
Ruma Purkait,2002 Bhopal, India [14]	280	194/200	92	77/80	96.3	Max.Length + Max. Head Dia. + AP Dia. + Epicondylar Width
Leelavathy N,2000, Bangalore, India [15]	160	68/70	97.1	84/90	93.4	Weight + Max.Length + Midshaft AP Dia.
Present Study,2014 Western Maharashtra, India	200	99/100	99	93/100	93	Distal Epiphyseal Breadth +Head Dia. + Midshaft Transverse Dia.

Above table indicates that abroad as well as in different parts of India had different discriminant formula for different specific population groups.

In the present study , formula derived for Western Maharashtra region was distal epiphyseal breadth + Head Diameter + Midshaft Transverse Diameter which provided 96 % overall accuracy.

V. Conclusion

We conclude that the multivariate analysis is by far the best method for determination of femora with available resources. The data generated in this study would be useful and may be of interest as a reference for practical application in future anatomical, forensic (Medico–legal cases), anthropological and archeological studies.

It also concludes that there exist sex specific and population specific differences in the osteometric measurements of femur. The results of the present study further confirms the views of earlier workers that

population specific studies in this aspect are mandatory and beneficial for sex determination. Present study has given standards for the sex determination from femora which are specific to the western Maharashtra region and in future these standards can be used as reference for the sex determination from this region. Possible drawback of the present study is that the measurements were taken on dry bones and theses dimension may change during drying process.

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