Sex determination by discriminant function analysis of femoral heads of a North Indian population

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Abstract

Context: Intangible variation in skeletal remains is an area of interest for many forensic anthropologist and that is useful in instituting the individual identity. For the determination of sex from human remains, use of discriminant function analysis is progressively increasing.

Aims: Development of discriminant function for the determination of sex from femoral heads of North Indian Population

Settings and Design: Study was done in the Department of Anatomy and it was a prospective study.

Materials and Methods: Present study was conducted on 60 wet cadaveric specimens from north India (41 males and 19 females) and the femur which appeared normal as per inclusion criteria were considered. Two diameters of femur were measured.

Statistical Analysis Used: The Trial version of SPSS (Statistical Package for Social Sciences) was used for conducting the statistical analysis and significance level was set at $P<0.05$

Results: By means of stepwise discriminant function analysis, two variables were chosen as key discriminant between sexes. The discriminant rate for the group of 2 variables resulted in accurate sex determination in 85% in case of vertical diameter of head of femur and 81.7% in case of transverse diameter of femur.

Conclusion: The outcome of the study manifests that femoral head can be used for establishing the sex from remains and the result of current study are analogous with other related studies.

Keywords: Vertical diameter of femur, Transverse diameter of femur, Discriminant function analysis

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Introduction

An extensive knowledge of the physical properties of bone enables the forensic anthropologist to furnish information on subtle variations in the human skeleton that useful in establishing individual identity[1].

In addition to establishing individual identity, forensic anthropologists are now consulted for trauma analysis, facial reconstruction, photographic superimposition, determination of time interval since death, and crime-scene recovery[2].

After adolescence, when the secondary sex characters have made their appearance it is possible to recognize the sex of a skeleton and on the experience of the observer. The parts that provide the best indication are the pelvis (particularly the ischium-pubis complex), the skull and the joint ends of some of the long bones(the ball joints are best)[3].

The most popular statistical model in sex determination is the discriminant function analysis, which encouraged many anthropologists and others to assess their anthropometric data accordingly[4]. Discriminant function analysis is increasingly used to determine the sex from skeleton. It is trustworthy method, reduces the examiner's idiosyncratic opinion and more reliable. But the outcome attained from discriminant function analysis for the establishment of sex are restricted to specific population and, therefore, the outcome cannot be applicable to other geographical area because of population disparity[5].

Aims and Objectives

The present study was instigated with following aims and objective:

1. Development of discriminant function for the determination of sex from femoral heads of a North Indian Population

Material and Methods

After approval from institutional ethical committee, this study was carried out in the Department of Anatomy, Government Medical College, Patiala. 60 cadaveric femurs of both sides were dissected and the femur which appeared normal as per inclusion criteria were considered.

Inclusion criteria

The following criteria was included in the study:

1. Femoral head with smooth articular cartilage having homogenous appearance up to the margin, with no sign of marginal ossification.

Instrument

Vernier calipers was used for all measurements taking into account the error if any, in the instruments. The Vernier calipers which had a resolution of 0.02 millimeters, was used for the measurement.

Procedure of Measurement

Various parameters of head of femur were measured on the wet specimens.

1. **Vertical diameter of femoral head**: It was measured between the most superior and most inferior point on the femoral head that is right angles to the long axis of the neck of femur.
2. **Transverse diameter of head of femur**: It was measured at right angles to the vertical diameter of femoral head. It is a horizontal distance between most anterior point to the most posterior point on the head of femur.

The data so obtained was compiled and was subjected to statistical computations.

3. **Discriminant Function Analysis**: Discriminant analysis is beneficial for condition where one wants to figure out a foretelling model of group membership based on studied traits of each case. The procedure generates a discriminant function (or, for more than two groups, a set of discriminant functions) based on straight grouping of the predictor variables that deliver the best discrimination between the groups. The functions are generated from a sample of cases for which group membership is known, the functions can then be applied to new cases with measurements for the predictor variables but unknown group membership (SPSS – in the Philippines [Online]).

Note: The grouping variable can have more than two values. The codes for the grouping variables must be integers; however, it is needed to specify their minimum and maximum values. Cases with values outside of these bounds are excluded from the analysis.

Discriminant analysis has two stages: 1) If the discriminant model is significant as a whole then F test (Wilks' Lambda) is used 2) if significance shown by the F test, then the individual independent variables are evaluated to see which vary significantly in mean by group and these are used to classify the dependent variable. Stepwise discriminant function analysis allows to list those variable which in combination, best discriminate between the sexes within each species.

Observations

In the present study 60 Hip Joints of North Indian subjects were dissected and grossly inspected. The femora which appeared normal as per inclusion criteria were considered, out of which 41 belong to the Males and 19 to the Females.

Table 1: Showing Mean, Standard Deviation, Minimum and Maximum of Different Parameters (n=60)

Measurement Parameters	Mean	Standard Deviation	Min	Max
Vertical Diameter of Head of Femur (mm)	44.90	3.59	38.57	53.05
Transverse Diameter of Head of Femur (mm)	44.61	3.45	38.58	52.98

Table 2: Showing Mean, Standard Deviation, Minimum, Maximum t value and 'p' Value of Different Parameters in males and females (Male=41, Female =19)

Measurement Parameters	Sex	Mean	Standard Deviation	Min	Max	t value (58)* (student t test-extended)**	'p' Value (Significant level)
Vertical Diameter of Head of Femur (mm)	M	46.44	2.98	40.53	53.05	6.302	$p < 0.001$
	F	41.57	2.30	38.57	48.87		
Transverse Diameter of Head of Femur (mm)	M	46.02	2.94	40.56	52.98	5.799	$p < 0.001$
	F	41.57	2.32	38.58	48.96		

*Value in parenthesis shows degree of freedom

** Norman and Streiner[6] (1998)

Statistical Analysis of Vertical Diameter of Head of Femur by Discriminant Analysis

Statistical analysis of vertical diameter of head of femur by discriminant analysis as an independent variable.

Table 3: Classification Function Coefficients

Measurement	Sex	
	Male	Female
Vertical Diameter of Head of Femur	5.983	5.356
Constant	-139.327	-112.469

Fisher's linear discriminant functions

Discriminant Function Equation

The following discriminant function equation was obtained subsequent to determination of classification function coefficients of the vertical diameter of head of femur.

For Males: Score=X_1 x 5.983 – 139.327

For Females: Score=X_1 x 5.356 –112.469

X_1 =Vertical Diameter of Head of Femur

Table 4

		Sex	Predicted Group Membership		Total
			Male	Female	
Original	Count	Male	35	6	41
		Female	3	16	19
	%	Male	85.4	14.6	100
		Female	15.8	84.2	100

Vertical diameter of head of femur correctly sexed 84.5% of the males and 84.2% of the females with overall classification rate of 85 %.

Statistical Analysis of Transverse Diameter of Head of Femur by Discriminant Analysis

Statistical analysis of transverse diameter of head of femur by discriminant analysis as an independent variable.

Table 5: Classification Function Coefficients

Measurement	Sex	
	Male	Female
Transverse Diameter of Head of Femur	6.005	5.423
Constant	-138.565	-113.874

Fisher's linear discriminant functions

Discriminant Function Equation

The following discriminant function equation was obtained subsequent to determination of classification function coefficients of the transverse diameter of head of femur

For Males: Score=X_1 x 6.005– 138.565

For Females: Score=X_1 x 5.423– 113.874

X_1 = Transverse Diameter of Head of Femur

Table 6

		Sex	Predicted Group Membership		Total
			Male	Female	
Original	Count	Male	37	4	41
		Female	4	15	19
	%	Male	90.2	9.8	100
		Female	21.1	78.9	100

Transverse diameter of head of femur correctly sexed 90.2% of the males and 78.9% of the females with overall classification rate of 86.7% but on cross validation it is reduced to 81.7%.

Table 7: Function at Group Centroids

Sex	Function
Male	-1.197
Female	.555

Table 8: Vertical Diameter of Head of Femur (Performance of Binary Classification Test in %)

	Measurement	95% Confidence Interval	
		Lower Limit	Upper Limit
Sensitivity	92.10	77.51	97.93
Specificity	72.7	49.56	88.38
Positive predictive values	85.4	70.13	93.90
Negative predictive values	84.2	59.50	95.83

Table 9: Transverse Diameter of Head of Femur (Performance of Binary Classification Test in %)

	Measurement	95% Confidence Interval	
		Lower Limit	Upper Limit
Sensitivity	90.2	75.94	96.82
Specificity	78.9	53.90	93.02
Positive predictive values	90.2	75.94	96.83
Negative predictive values	78.9	53.90	93.03

Discussion

Age, sex and racial affinity are the three most crucial determinations that must be taken care of when dealing with skeletal remains. It would be nearly impossible to identify an individual without this information. Sex is usually one of the easiest determinations made from skeletal material and one of the most reliable if the essential parts of the skeleton are present and in good condition[6].

Forensic identification often involves fragmentary remains[7]. Fragmented, scattered, incomplete or burned remains limit the success obtained in sex determination[8]. The sex can be successfully determined from fragmentary remains if appropriate bones are selected. The bones that are chosen for sex determination should be resistant to damage and sexually dimorphic. To the best of our knowledge not much literature is available on these parameters of North Indians femora.

Precision in categorization of sex and race has been improved several time with use of osteometry and statistical analysis. The most widely used statistical technique has been multivariate discriminant analysis of sex determination for skeletal measurements. Discriminant function analysis is a concrete statistical technique for sex determination[9]. The discriminant function analysis generates a discriminant function based on linear combinations of the predictor variables that provide the best discrimination between the groups.

The following metric measurements, vertical diameter of head of femur, transverse diameter of head of femur were taken. The metric data so obtained was statistically analyzed by Discriminant function analysis. The discriminant rate for the group of 2 variables resulted in accurate sex determination in 85% in case of vertical diameter of head of femur and 81.7% in case of transverse diameter of femur.

From amongst the two variables, vertical diameter of head of femur, were found to be the most reliable and hence best discriminators for the sex. The reliability was ascertained by stepwise discriminant function analysis applied to these 2 variables, at each step, the variable that minimizes the overall Wilk's lambda was entered.

This is in consonance with the study of Mall et al[10] which shows 86.8% discrimination for vertical diameter of the head of femur while Mario Slaus et al found 94.4% accuracy in his study on croatia femora[11].

In northwest region, Gargi soni et al[12] in their study found maximum diameter of femur shows sexual dimorphism 85% in male and 72.5% female while in central India, Ruma purkit[13] found accuracy of 91% for male and 91.3% in dimorphism on same parameters.

Hema nedugala[14] et al had done discriminant analysis on south Indian femora and found that the vertical diameter of head, antero-posterior diameter of lateral condyle, epicondylar breadth, proximal breadth had shown statistically significant for dimorphism ($p<0.05$). Discriminant analysis shows accurateness of 62.7% and 65.3% for the stepwise discriminant analysis after considering the all parameter together.

Limitation

The sample size of current study is small because of paucity of the cadavers. Results cannot be generalized but provides baseline data for future studies.

Conclusion

The result present study confirms that femoral head can be used for sex determination. Study also helps in development of population specific data which can used as a baseline data for further studies.

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