Original Research Article

SEX DETERMINATION FROM ADULT HUMAN FEMUR BY DIRECT DISCRIMINANT FUNCTION ANALYSIS

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ABSTRACT

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

Results: Sex was correctly estimated by using direct discriminant function analysis for the femur 97.8% of males and 96 % of females with a total accuracy of 97.1 %.

Conclusions: Present study exhibited better classification accuracy for multiple variables than those of single variables. In the femur, the most discriminating variable in direct analysis is circumference of mid shaft.

Keywords: Sex determination, Circumference of mid shaft, Direct discriminant analysis, Femur.

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]

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.[7, 8] 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.[9]

Very few studies are available in India on determination of sex from human femur, so present study made a sincere effort to enhance the accuracy of sex determination from adult human femur bones using various parameters by applying direct discriminant function analysis on population of Marathwada region of Maharashtra.

METHODS

The bones used in this study was 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. All the measurements were measured in millimeters Present study was done on dry human bones, so ethical issues were not arised.

1. Maximum length (FML) : it is measured from most superior point on the head of the femur to the most inferior point on distal medial condyle with the help of Osteometric board.
2. Proximal breadth (FPB) : maximum width from the head of the femur to the greater trochanter is measured with the help of Osteometric board.
3. Vertical diameter of head (VHD) : the maximum diameter of the femoral head taken in the vertical plane that passes through the axis of the neck with the help of vernier calipers.
4. Horizontal diameter of head (HHD) : the maximum diameter of the femoral head taken in the horizontal plane perpendicular to vertical diameter of head with the help of vernier calipers.
5. Circumference of mid shaft (FMC) : Circumference is measured with non elastic thread around mid shaft of femur and thread length is measured on scale.
6. Epicondylar breadth (FEB) : the maximum distance from the most lateral point on the lateral condyle to the most medial point on the medial condyle taken parallel to the infracondylar angle with vernier calipers.

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 Vertical diameter of head (males: 44.03mm, females: 37.15 mm.), Horizontal diameter of head (males 43.83 mm, females: 37.10 mm.), Proximal breadth (males 88.95 mm, females: 76.24 mm.) and Circumference of mid shaft (males: 84.31 mm, females: 72.90 mm.)

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

A direct analysis was carried out on all individual variables of femur separately to identify the most constructive variable in statistically discriminating between the sexes. The results of the direct analyses and discriminant function score formula for each variable appear in Tables 2, 3 and 4 as Function 1 to 6.

By direct analysis, Circumference of mid shaft is the best discriminant variable among all variables with 97.8 % for males and 92 % for females with a total accuracy of 95.7 %.

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

Variable Descriptions	Males (n =180)			Females (n = 100)					
	Mean	SD	SE	Mean	SD	SE	F- ratio	t -test	p value
FEMUR									
FML	440.37	18.46	1.37	398.03	17.70	1.77	348.11	18.65	.000
FPB	88.95	4.21	0.31	76.24	4.18	0.41	587.17	24.23	.000
VHD	44.03	1.96	0.14	37.15	1.76	0.17	851.97	29.18	.000
HHD	43.83	2.00	0.14	37.10	2.03	0.20	721.20	26.85	.000
FMC	84.31	4.12	0.30	72.90	3.43	0.34	552.77	23.51	.000
FEB	77.06	4.09	0.30	66.15	3.36	0.33	516.28	22.72	.000

Table 2: Variable wise calculation of discriminant functions of Femur (Direct analysis)

Function	Variable	unstandardized co efficient	standard coefficient	structured coefficient	Wilks Lambda	F ratio	eigen value	canonical correlation
1	FML	0.055	1	1	0.444	348.11	1.252	0.746
2	FPB	0.238	1	1	0.321	587.17	2.112	0.824
3	VHD	0.528	1	1	0.246	851.97	3.065	0.868
4	HHD	0.497	1	1	0.278	721.20	2.594	0.850
5	FMC	0.257	1	1	0.335	552.77	1.988	0.816
6	FEB	0.260	1	1	0.350	516.28	1.857	0.806
7 **All Variables**	FML	0.000	0.008	0.583	0.214	-	3.683	0.887
	FPB	-0.029	-0.121	0.757				
	VHD	0.559	1.058	0.912				
	HHD	-0.202	-0.406	0.839				
	FMC	0.109	0.426	0.735				
	FEB	0.055	0.212	0.710				

Table 3: Discriminant function equation for determining sex of Femur (Direct analysis)

Function	Variable	Constant	Discriminant equation	Group centroid		Sectioning point
				Male	Female	
1	FML	-23.371	B = -23.371 + 0.055*FML	0.831	-1.496	-0.000071
2	FPB	-20.071	B = -20.071 + 0.238*FPB	1.079	-1.943	-0.000285
3	VHD	-21.972	B = -21.972 + 0.528*VHD	1.300	-2.340	0
4	HHD	-20.593	B = -20.593 + 0.497*HHD	1.196	-2.153	-0.000071
5	FMC	-20.609	B = -20.609 + 0.257*FMC	1.047	-1.885	-0.000142
6	FEB	-19.003	B = -19.003 + 0.260*FEB	1.012	-1.822	-0.000142
7	All variables	-25.426	B = -25.426 + 0.000* FML - 0.029* FPB + 0.559* VHD - 0.202* HHD + 0.109* FMC + 0.055* FEB	1.425	-2.566	-0.000357

Table 4: Percentage of predicted group membership and cross validation for the Femur (Direct analysis)

Function	Variable	% of bones Correctly classified					
		Male (n =180)		Female (n =100)		Total (n=280)	
		original	Cross validated	original	Cross validated	original	Cross validated
1	FML	166	166	83	83	249	249
		92.2	92.2	83	83	88.9	88.9
2	FPB	172	172	88	88	260	260
		95.6	95.6	88	88	92.9	92.9
3	VHD	170	170	94	94	264	264
		94.4	94.4	94	94	94.3	94.3
4	HHD	170	170	92	92	262	262
		94.4	94.4	92	92	93.6	93.6
5	FMC	176	176	92	92	268	268
		97.8	97.8	92	92	95.7	95.7
6	FEB	174	174	92	92	266	266
		96.7	96.7	92	92	95	95
7	All variables	176	176	96	96	272	272
		97.8	97.8	96	96	97.1	97.1

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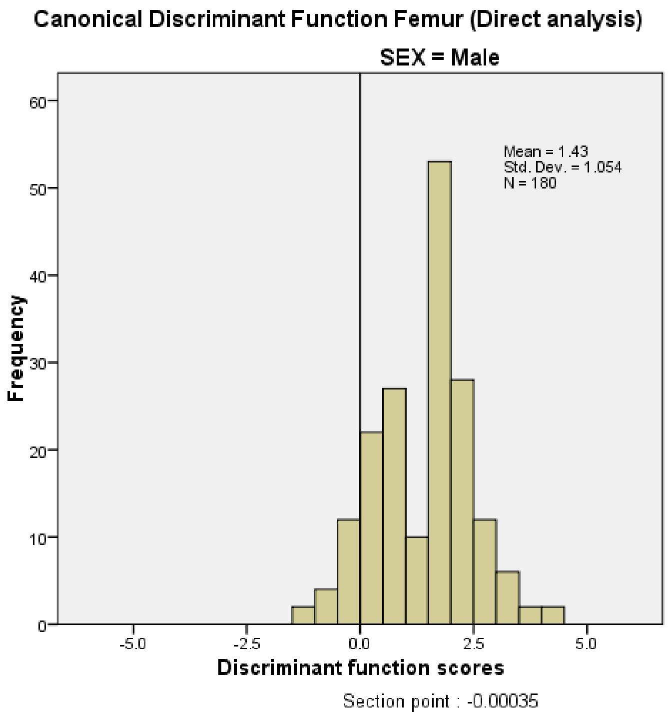

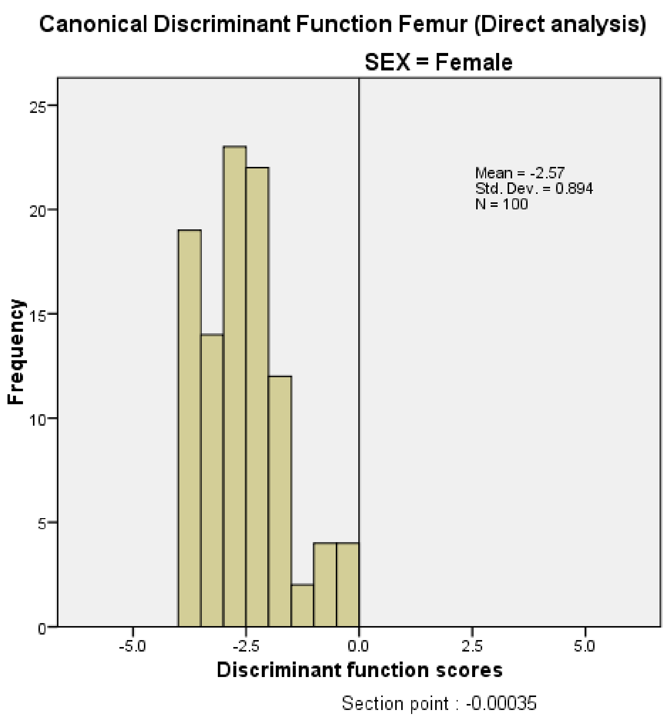

Graph 1. Discriminant scores of Femur by sex using multivariate equation

D = -25.426 + 0.000* FML -0.029* FPB + 0.559* VHD -0.202* HHD + 0.109* FMC + 0.055* FEB

Direct discriminant analysis (Function 7, Tables 2, 3 & 4)

(all variables entered together)

A direct discriminant analysis was applied to evaluate the diagnostic ability of all variables entered together in direct discriminant analysis.

Discriminant function score formula for Function 7 analysis of Femur is

D= -25.426 + 0.000* FML -0.029* FPB + 0.559* VHD -0.202* HHD + 0.109* FMC + 0.055* FEB

The classification accuracy of the Femur for the discriminant function are presented in Table 4. For the femur , Function 7 analysis showed that 176 males out of 180 cases were correctly classified with 4 individuals misclassified as females, thus resulting in 97.8 % accuracy.

96 females out of 100 cases were correctly classified with 4 individuals misclassified as males, thus resulting in 96 % accuracy.

Total 272 out of 280 cases were correctly classified with total accuracy of 97.1 %.

Cross validation showed similar results of original analysis.

CONCLUSIONS

The adaptation of the female pelvis to childbirth and the resulting larger distance between the hip joints compared to the male pelvis produces several dimorphic features which may potentially be useful for sex determination. These include a reduced oblique length, which is the length of the femur measured on an osteometric board when both femoral condyles are aligned with the end of the board.

Various components of femora have been studied to determine sex and have been found to show considerable accuracy, ranking third behind the pelvis and cranium. The accuracy for sex allocation is enhanced by the availability of multiple femoral variables which can be measured**.**

Steyn and Iscan[10] studied white South Africans of known sex, Safont et al[11] used Late Roman material from Spain with the sex estimated from pelvic and cranial criteria, Dittrich and Suchey[12] investigated pre-historic remains from Central California with the sex derived from the pubis, Dibennardo and Taylor[13] studied European–American individuals from New York of documented sex and Black[14] researched a poorly preserved burial site in Ohio where the sex of a portion of the specimens was also estimated from the pelvis from which parameters to assess the femurs of the remainder were derived.

Purkait[15] developed another method for determining sex from the proximal femur by taking measurements related to areas of muscle attachment. He found that a combination of two or three of the measurements gave only marginally better results.

In summary, the measurements of the femur appear to be high discriminators of sex in present sample analyzed by direct discriminant function analysis. In, direct analysis, Circumference of mid shaft was the single most useful variable.

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Conflict of interest: None

Ethical approval: Study involved only dry human skeletal material, so ethical approval is not required.

REFERENCES

1. Krogman W.M. – "The Human Skeleton In Forensic Medicine", in “Sexing skeletal remains”, second printing. Charles C.Thomas Publisher, Springfield, Illinois. USA, (1973), 112-152.
2. Goes AC, Silva DA, Domingues CS, Sobrinho JM, Carvalho EF. Identification of a criminal by DNA typing in a rape case in Rio de Janeiro, Brazil. Sao Paulo Med J. 2002; 120(3):77-79.
3. Iscan MY, Solla H.E., McCabe B.Q. Victim ofa dictatorial regime: identification of Mr. Roberto Gomensoro Josman. Forensic Sci Int. 2005; 151(2-3):213-220.
4. Oz C, Levi JA, Novoselski Y, Volkov N, Motro U. Forensic identification of a rapist using unusual evidence. J Forensic Sci. 1999; 44(4):860-862.
5. Krishan K. Anthropometry in Forensic Medicine and Forensic Science: Forensic Anthropometry; Internet J Forensic Science. 2007, Vol. 2(1).
6. Padeyappanavar KV., Kazi AM., Bhusareddy PS., Kulkarni UK. Sexual dimorphism in adult human clavicles of North interior Karnataka. J Karnataka Medico-legal Soc, 2009 June; 18(1):3-13.
7. Ulijaszek SJ, Masci-Taylor CJN (1994 p 213). Anthropometry: The individual and the population, Cambridge studies in biological anthropology. Cambridge UK: Cambridge University Press.
8. Eveleth, P B and Tanner, J M (1976 p287) World-wide Variation in Human Growth, Cambridge: Cambridge University Press.
9. Novotny V, İşcan MY, Loth SR. Morphological and osteometric assessment of age, sex and race from the skull. In: İşcan MY, Helmer RP, editors. Forensic Analysis of the Skull. Wiley-Liss, Inc; 1993.p. 71-88.
10. Steyn M, Işcan MY. Sex determination from the femur and tibia in South African whites. Forensic Sci Int. 1997 Nov 10;90(1-2):111-9.
11. Safont, S., Malgosa, A. and Subira, M.E. 2000. Sex Assessment on the Basis of long Bone Circumference. American Journal of Physical Anthropology. 113:317–28.
12. Dittrick J, Suchey JM. Sex determination of prehistoric central California skeletal remains using discriminant analysis of the femur and humerus. Am J Phys Anthropol. 1986 May;70(1):3-9.
13. DiBennardo, R. and Taylor, J.V. 1979. Sex Assessment of the Femur: A Test of a New Method. American Journal of Physical Anthropology. 50:635–8.
14. Black, T. K. 1978. A New Method for Assessing the Sex of Fragmentary Skeletal Remains: Femoral Shaft Circumference. American Journal of Physical Anthropology. 48:227–32.
15. Purkait R, Chandra M. Sexual dimorphism in femora: An Indian study . Forensic Sci Commun 2002; 4:1-7.