_____

An observational study to determine the sex of a femur

Saroj Kumar Ranjan[1],Pinki Kumari[2],Aman Kumar[3],Sanjeev Kumar[4*],Sanjay Kumar[5],Mukesh Prasad[6]

[1]*Senior Resident,Department of FMT, IGIMS, Patna, Bihar,India*
[2]*Assistant Professor, Department of FMT,NetajiSubash Medical College & Hospital, Bihta, Patna, Bihar,India*
[3]*Professor& Head,Department of FMT, IGIMS, Patna, Bihar,India*
[4]*Associate Professor, Department of FMT, IGIMS, Patna, Bihar,India*
[5]*Assistant Professor, Department of Anatomy, IGIMS, Patna, Bihar,India*
[6]*Assistant Professor, Department of FMT,IGIMS, Patna, Bihar,India*

Abstract
Background: Bones are an important tool for establishing the biological profile of an individual. In the absence of skull and pelvis, long bones can play a major role in determining the sex. Femur is the longest and strongest bone of the body and resists environmental effects and hence becomes important in medico-legal investigations.**Aim:** To determine the sex of 180 femora and to set up baseline parameters for the North Indian population with the help of demarcating and limiting values.**Materials and Methods :**Seven parameters were studied in 180 femora to determine their sex. Mean and standard deviation were calculated. They were analysed using student 't' test, Hotelling T^2 square test for multivariate analysis and discriminant function analysis. Also, demarcating and limiting values were calculated for each parameter.**Result:** The difference between males and females for all parameters was highly significant. Males showed higher values as compared to females. By multivariate analysis also, p value was less than 0.001. We could correctly classify 90% bones using discriminant function analysis.**Conclusion:** Femur exhibits significant sexual dimorphism. Different populations require their own standards of sex determination. The accuracy of classification increases with increase in number of parameters.
Keywords: Femur, Anthropometry, Forensic Medicine, Sex Determination, Discriminant Function Analysis.

Introduction

The femur is the longest and strongest bone of the body. Its length is associated with striding gait, its strength with weight and muscular forces.[1] It is widely studied to determine the stature and locomotion pattern, for sex identification in skeletal remains as it shows significant variation between individuals.[2] Owing to its robustness and strength, it is most likely to resist environmental effects and animal activities.[3]Bones are an important tool in establishing the biological profile of an individual. The first step in creating a profile and establishing the identity of an individual is determination of sex, as subsequent methods of age and stature determination are highly sex dependent.[3] Skull and pelvis are considered to be the most sexually dimorphic, but in their absence sex has to be determined from available bones.[4] Long bones are frequently recovered intact. Of these, femur is considered most sexually dimorphic. The reasons for this can be manifold; namely, the differences in morphology of pelvis due to greater pelvic breadth in females influenced by the reproductive function.[1], genetic differences that influence body size and proportions and lastly differences in musculature. [5,6] Female femora are usually shorter and exhibit greater obliquity. It is seen that the typical male bones are 'large, long, rough and massive' than the typical female long bones. The study on sexual dimorphism is based on the principle that the axial skeleton weight of the male is relatively and absolutely heavier than that of the female and the

initial impact of this weight is borne by the femur in transmission of the body weight.[1,7] Hence, in the present times of increasing violence, accidents and mass disasters when encountering human skeletal remains has become common; femur can play an important role in determining sex.The process of sex determination in unknown skeletal materials has to be accurate. It usually depends on the available fragmented or isolated remains; ageing and non-availability of standards.[4] Though there have been previous studies on sexual dimorphism in femur, it has been found that magnitude of sex related differences depends on the particular regional population. It is dependent on race, dietary habits, lifestyle, cultural practices, etc.[6,8] India is a land of diversity with different geographical and climatic zones. Hence, there is wide variation in anthropometric dimensions between different populations. Therefore, each population needs its own set of baseline parameters and anthropometric determinants. The present study was therefore planned to determine the sex of femur and also to establish demarcating and limiting values for femora belonging to North India. Another objective was to conduct a discriminant function analysis of sexual dimorphism based on femur and set up standards for North Indian population.

Materials and Methods
This prospective study was conducted at Department of FMT, Indira Gandhi Institute of Medical Sciences, Patna. The study was approved by institutional research and ethical committee. The Study was conducted over a period from June 2019 to February 2021. The present study was conducted on 180 femora of unknown sex. The bones were already present in the Department and had been collected from dissected cadavers. All intact, well-formed and adult femora

*Correspondence
Dr.Sanjeev Kumar
Associate Professor, Department of FMT, IGIMS, Patna, Bihar,India
E-mail: drsanjeevsix@yahoo.co.in

_____

were included in the study. Pathological, deformed, damaged or broken bones were excluded from the study.A total of seven parameters were studied. Measurements were taken using an osteometric board and vernier callipers.

Following Parameters were Measured for each Bone[3]

- **Maximum Length of Femur (MLF):** The straight distance between the highest point on the head and the lowest point on the medial condyle.

- **Maximum Mid Shaft Antero Posterior Diameter:** The antero-posterior distance measured at the midpoint of the maximum length.

- **Proximal Breadth (PB):** The distance between the most medial point on the head to the most lateral point on the greater trochanter.

- **Vertical Diameter of Neck:** The minimum diameter of femoral neck in a plane perpendicular to the head–neck midline.

- **Vertical Diameter of Head (VDH):** The straight distance between the highest and the lowest point on the head.

- **Transverse Diameter of Head (TDH):** The straight distance between the most laterally projected points on the head perpendicular to the VDH.

- **Epicondylar Breadth (ECB):** The maximum distance between the two most projecting points on the lateral and medial epicondyles.

The measurements were recorded, tabulated and analysed statistically. Mean and Standard Deviation (S.D.) for each parameter were worked out.To assess the efficacy of statistical tests in determining sex and to predict the proportion of individuals which can be identified correctly either male or female, a limiting value was worked out, either side of which represented a particular sex. To determine this, demarcating and limiting values were calculated assuming normal distribution. Calculated range is mean±3 S.D., covering 99% population. For instance, in males mean–3 S.D. be denoted as 'a', mean+3 S.D. denoted as 'b'; then a to b is calculated range for males. Similarly, mean–3 S.D. be denoted by 'x' and mean+3 S.D. be denoted as 'y'; then x to y is calculated range for females. The demarcating point for females is 'a' below which all will be females and 'y' is demarcating point for males above which all will be males. Based on the above values, limiting value was worked out. A limiting value is the value above which majority bones were male and below which most bones were female.

Statistical tests used were student's 't' test, Hotelling T^2 test for multivariate analysis and discriminant function analysis with SPSS. Discriminant function analysis is used to develop an index to have

maximum discrimination among two groups where variation is maximum among groups and minimum within groups. We developed a discriminant function on 120 bones (2/3 of the total 180) taken randomly and then based on this, predicted the sex of the rest of 60 (Which were not a part of the model) bones to test the efficacy and validity of the function developed.

Results

The current study was conducted to determine the sex of 180 femora. The metric parameters are summarised in Table 1.As is evident from Table 1, there were 115 male bones and 65 female bones. The mean values for all parameters are greater in males as compared to females. Using student's 't' test, p <0.001 for all parameters showing that the difference is highly significant for all parameters. The standard deviation is also higher in males for all the above parameters denoting that males show greater variability as compared to females.The demarcating and limiting values are summarised in Table 2. It is an extension of sex determining values for metric traits. Limiting value of maximum length of femur could correctly classify 80.6% males and 87.8% females. With proximal breadth, 94.3% males and 70% females could be correctly categorised. Considering the vertical diameter of head, 94% males as well as females could be correctly classified; 83.5% males and 93% could be categorised using the limiting value of transverse diameter of head. Using the mid shaft diameter and vertical diameter of neck, 95% females could be correctly categorised, though only 70% males could be identified; 94% males and 86.2% males were correctly identified using epicondylar breadth. It is clear from above that more females could be correctly identified with the use of limiting values.As the probability value for different parameters varies indicating different level of significance, Hotelling T2test was applied to understand how these parameters behave collectively in determining sex. The calculated variance at $F_{7\ 172}$ by Hotelling T^2 test for multivariate analysis is 40.90, which is highly significant with a p value of <0.001. This demonstrates that all parameters when taken together exhibit effective sexual dimorphism.For the model (n_1=120) bones using discriminant function analysis, 108 bones could be correctly classified, i.e. a correct classification of 90%. When this model was tested on the rest of the 60 bones, 57 bones could be correctly classified, i.e. with an accuracy of 94%.On using different combinations of various parameters, we found that maximum accuracy was achieved with epicondylar breadth and vertical diameter of head taken together. Using the two together, an accuracy of 84% was achieved. On considering all seven parameters together, this increased to 90%, hence more the number of parameters we consider more will be the probability of correct classification.

Table 1: Descriptive Analysis of Metric Parameters in Males and Females

Parameter	Male (n=115)		Female (n=65)		p
	Mean (cm)	S.D.	Mean (cm)	S.D.	
Maximal Length	47.04	2.38	42.72	3.13	<0.001
Proximal Breadth	9.08	0.54	8.07	0.51	<0.001
Vertical Diameter of Head	4.38	0.26	3.83	0.28	<0.001
Transverse Diameter of Head	4.40	0.25	3.84	0.29	<0.001
Epicondylar Breadth	7.76	0.46	6.89	0.40	<0.001
Vertical Diameter of Neck	3.13	0.21	2.64	0.28	<0.001
Mid Shaft Diameter	2.85	0.25	2.44	0.25	<0.001

Table 2: Demarcating Points and Limiting Values for Metric Parameters

Parameter	Males (n=115)	Females (n=65)	Limiting Value(cm)
	DemarcatingPoint 'y' (cm)	Demarcating Point 'a' (cm)	
Maximal Length	52.1	39.9	46.0
Proximal Breadth	8.6	7.5	8.0
Vertical Diameter of Head	4.7	3.6	4.1
Transverse Diameter of Head	4.7	3.7	4.2
Epicondylar Breadth	8.1	6.4	7.2
Vertical Diameter of Neck	4.5	2.5	3.5
Mid Shaft Diameter	3.7	2.1	2.9

_____

Discussion

The present study was conducted using multiple parameters to ascertain the sex of femur in the North Indian population. Though, there have been previous studies by several workers in different populations; according to Krogman and Iscan, standards of morphological and morphometric attributes in the skeleton may differ with the population samples involved and this is true with reference to dimensions and indices (Average and range) and as a general rule, standards should be used with reference to the group from which they are drawn and upon which they are based. [9,10] Kate working on different femora from different regions of India found that the values showed a regional variation and also a downward gradient from North to South.[11,12]Reliability of sexual dimorphism depends on magnitude of sexual dimorphism exhibited in a population, availability of skeletal elements, anatomical areas of the bone preserved and degree of preservation. The variables most suited for identifying sex vary in different populations demonstrating the population specific nature of sexual dimorphism. Hence, the need for establishing baseline parameters for the North Indian population.

These parameters are not only useful in medico-legal practice, but are of use to anatomists, orthopaedicians also. Length of femur is an important and reliable skeletal element for sex determination. [13] Mean maximum length was 47.04 cm in males and 42.72 in females. It was higher in males as compared to females, which is similar to previous works.[3,7,10,13-15] The mean values were lower in studies on Japanese and Thai populations.[16,17], which supports the inference that these parameters differ with the population under consideration. This difference in mean length may possibly be a result of factors affecting bone morphology like genetic constitution, diet, nutrition status, environment and physical activity.[10]The mean proximal breadth was 9.08 cm and 8.07 cm in males and females respectively. The difference between the two is highly significant. In a study on South Indian population, the mean values were lower and the $p<0.04$ which is less than the present study $(p<0.001)$.[2]The mean for vertical diameter of head and transverse diameter of head was 4.38 cm and 4.40 cm respectively in males and 3.83 cm and 3.84 cm respectively in females. The values are higher when compared to a study on the South Indian population, but are similar to studies on North Indian population.[2,3,15,18] Wu concluded that the maximum diameter of head is the best single variable for determination of sex.[19] The knowledge of various dimensions of head in both sexes will not only help the anatomists and forensic experts in sexing the femora, but will also be of immense importance in prosthesis of femoral head which may be used by the orthopaedic surgeons in femoral head replacement surgery.[12]The mean epicondylar breadth was higher in males as compared to females (7.76 cm and 6.89 cm respectively). This is in agreement with previous studies.[2,3,7,16] Mid shaft diameter is also higher in males, which is similar to previous workers.[3,15]Some of the powerful methods of sex determination from skeletal element are based upon the application of statistical analysis to osteological material. Discriminant function analysis is one of the sophisticated mathematical approaches.[17] The most common application of discriminant function analysis is to include many measures in the study, in order to determine the ones that discriminate between groups. The prediction accuracies vary from 70.5% to 83.6% in the North Indian population.[3] This is higher in our study with a value of 90%.The present study also uses multivariate analysis, which shows that all parameters taken together also show significant dimorphism.The discriminant function analysis using the combination of vertical diameter of head and epicondylar breadth shows a classification accuracy of 84%. This is lower than the result (92.1%) observed by Purkait and Chandra.[7] The classification accuracy increased to 90% when all seven parameters were considered together. This is similar to previous studies where prediction accuracy increases with increase in number of parameters.[7]Previous researchers have concluded that sexual dimorphism is exhibited more in width measurements than length. This may be due to the differential cortical remodelling that has its maximum impact on breadth. While length of a bone stops to grow at an earlier age due to epiphyseal fusion, width wise growth continues potentially unlimited. The cortical remodelling that continues throughout the life of an individual bearing the effect of physical activities related to occupation, nutrition, etc. may result in subsequent dimorphism.[3]

Conclusion

The results of the present study clearly reaffirm the marked sexual dimorphism exhibited by femur. The current study clearly demonstrates that all statistical techniques are individually as well as collectively effective in sex determination. Special attention was paid to develop standards for ends of femur, so that sex can be determined even if fragmentary remains are available. The classification accuracy increases with increase in number of parameters. In addition, the demarcating values and limiting values found out in this study can help set up baseline parameters for sex determination in the North Indian population.

References

1. Standring S, Borley NR, Coliins P et al. Gray's anatomy the anatomical basis of clinical practice. In: Girdle P, Region G, Thigh. 40th ed. Spain, Elsevier Churchill Livingstone. Ch 80, 2008, 1360-5.
2. Hema N, Bhagya B, Sucharitha S et al. Metric assessment of femur using discriminant function analysis in south Indian population. Int J Anat Res. 2013;1(2):29-32.
3. Rashmi S, Vineeta S, Rajesh KR et al. A study of sexual dimorphism in the femur among north Indians. J Forensic Sci. 2011;57(1):19-23.
4. Krogman WM, Thomas CC. Springfield. The human skeleton in forensic medicine. AJO-DO. 1963;49(6):474.
5. Black TK. A new method for assessing the sex of fragmentary skeletal remains: femoral shaft circumference. Am J Phys Anthrop. 1978;48:227-32.
6. Igbigbi PS. Sex determination from femoral head diameters in black malawains. East Afr Med J. 2000;77(3):147-51.
7. Purkait R, Chandra H. Sexual dimorphism in femora: an Indian study. Forensic SciCommun. 2002;4(3):1-6.
8. Pavel T, Antoaneta F, Dobrinka R et al. A study of sexual dimorphism in the femur among contemporary Bulgarian population. Euras J Anthropol. 2014; 5(1):46-53.
9. Krogman WM, Iscan MY. Human skeleton in forensic medicine. 2nd ed. Thomas CC, Springfield 1986.
10. Pandya AM, Singel TC, Akbari VJ et al. Sexual dimorphism of maximum femoral length. Nat J Med Res. 2011;1(2):67-70.
11. Kate BR. A study of the regional variation of the Indian femur-the diameter of the head-its medicolegal and surgical application. J AnatSoc India. 1964;13(1):80-4.
12. Laeeque MD,Diwan.Determination of sex of femur by combination of parameters.Int J Basic Med Sci. 2013;3(6):173-7.
13. Bhosale RS, Zambare BR. Sex determination from femur using length of femur in Maharashtra. IOSR Journal of Dental and Medical Sciences. 2013;3(4):1-3.
14. DiBennardo R, Taylor JV. Classification and misclassification in sexing the black femur by discriminant function analysis. Am J Phys Anthrop. 1982;58(2):145-51.
15. Gargi S, Usha D, Sudha C. Determination of sex from femur: discriminant analysis. J AnatSoc India. 2010; 59(2):216-21.
16. King CA, Iscan MY, Loth SR. Metric and comparative analysis of sexual dimorphism in the Thai femur. J For Sci. 1998;43(5):954-8.
17. Ismail O, Katayama K. Sex determination using the femur in an ancient Japanese population. Coll Antropol. 2008; 32(1):67-72.
18. Wu L. Sex determination of Chinese femur by discriminant function. J For Sci. 1989;34(5):1222-7.
19. Urvik CK, Tulsibhai CS, Pratik NT et al. Sex determination from vertical diameter of femoral head in Gujarati population. Int J Adv Res.2014;2(6):859-63.

Conflict of Interest: Nil
Source of support:Nil

_____