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Determination of Sex on Morphometric Study of Femur Bone in Nepalese Population

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Abstract

Determining the sex of human skeletal remains is vital for building a biological profile of an individual in medico-legal and bioarchaeological studies. The present study was conducted on 64 femur bone (32 male and 32 female). at National Medical College Birgunj, Nepal. Seven measurements of femur were collected. The descriptive statistics were done to find out the significant difference between the femur bone of male and female. The mean values of all the seven parameters were considerably greater in males as compared to females (P<0.001) with univariate analysis. The most dimorphic single metric on the basis of discriminant analysis was maximum length of femur with accuracy 87.1% in females and 61.3% in males. In vertical diameter of head of the femur with accuracy 93.5% in female and 83.9% in male. Epicondyle breadth and mid shaft diameter of femur exhibited 90.3% and 96.8% in female. Whereas Proximal breadth in male femur with accuracy 96.8% in female with accuracy 80.6%. Femur could be used for assessing the gender, in which breath is significantly responsible for large variation in comparison to length.

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1. INTRODUCTION

The femur is the long bone located in the upper leg of tetrapods. It is anatomically connected to the pelvis (hip) at its proximal end and to the knee at its distal end. The hip is connected to the body by a ball-and-socket joint, enabling a wide range of motion. [1] The distal end of the femur articulates with the proximal end of the lower leg, creating a synovial joint commonly referred to as the knee. This has two points of articulation: one with the patella (knee-cap) and another with the tibia. The femur is both the longest and most robust bone in the human body. [2,3]

The femur is classified as a long bone and consists of a diaphysis (shaft or body) and two epiphyses (extremities) that connect with neighbouring bones in the hip and knee.[3]. The anatomical knowledge of human sex from skeletal part is of particular importance in forensic osteology and it relies heavily on the up-to-date techniques in order to provide accurate information to medicolegal system. The initial stage in constructing an individual's profile and identity is the identification of their sex. the sex determination can be done at crime site from isolated bones or their fragments. Additionally, the process of determining height and age relies on the individual's gender. [4].

The diversity in pelvis morphology is due to the increased pelvic breadth in females, which is an adaptation for reproduction. This variance is impacted by both body size and musculature.

The majority of the time, long bones are retrieved in an undamaged state. The femur is considered to exhibit significant sexual dimorphism, particularly when compared to the skull and pelvis. [3,4,5].

It is widely acknowledged that the skeletal biology of one population is distinct from that of another. Therefore, the criteria for skeletal identification differ among various people, and the criteria established for one community cannot be applied to another one. Population-specific criteria have been established for several populations, including Indians, Chinese, Thai, Americans, Italians, Europeans, and South Africans. These standards have been developed by researchers such as Wu (1989), Trancho *et al.*, (1997), King *et al.*, (1998), Holliday & Falsetti (1999), Asala (2001), and Cavazzuti *et al.*, (2019) [6-11].

Unfortunately, the Nepali people does not have access to these standards. Hence, the purpose of this work was to create specialized formulas for the Nepali population to determine the sex of an individual based on measurements of the full femur portions. Additionally, a web application was developed to estimate sex by inputting combinations of femur measurements.

2. METHODOLOGY

The current study was conducted at the Anatomy Department of National Medical College in Birgunj, Nepal, from September 30th to January 20th, 2024. A total of 64 femur bones were used for this investigation. There were 32 femur bones from males and 32 femur bones from females. Prior to commencing the study, ethical approval (Ref: F-NMC/667/080-081) and authorization were acquired from the institutional Ethics Committee. The experiments were conducted in compliance with the ethical norms of the committee and aligned with the principles outlined in the Helsinki Declaration. The present investigation examined adult femur bones that were whole and well-formed, while excluding any bones that were shattered or injured.

Measurements

All measurements were conducted using a computerized Vernier calliper. The subsequent variables were quantified.

The maximum length of the femur is defined as the linear distance from the highest point on the head to the lowest point on the medial condyle.

Maximum Mid Shaft the antero-posterior diameter was determined by determining the distance from the middle of the maximal length.

The proximal breadth refers to the measurement taken from the innermost point of the skull to the outermost point of the greater trochanter.

The vertical diameter of the neck refers to the smallest diameter of the femoral neck when measured in a plane that is perpendicular to the midline of the head and neck.

The vertical diameter of the head refers to the direct measurement between the highest and lowest points on the skull.

The transverse diameter of the head is the direct measurement between the outermost points on the skull, perpendicular to the vertical diameter of the head.

Epicondylar Breadth refers to the greatest distance between the two most prominent spots on the lateral and medial epicondyles.

Statistical Analysis

The data were analysed using SPSS software, specifically version 20. A t-test was used to determine the mean disparities between genders. The measured data were subjected to both univariate and multivariate discrimination analysis. The discrimination formula (Y) was derived using Wilks lambda, Eigen value, and canonical correlation. If the discriminating function (D) exceeds the threshold value Y, it is classified as male. Conversely, if the D value is lower than Y, it is classified as female. In order to obtain more accurate probability findings, all of the data was inputted into a logistic regression analysis, with a cut-off value set at 0.5. If the value of logistic regression is larger than 0.5, it is classified as male. If the value is less than 0.5, it is classified as female.

3. RESULTS

The present study evaluated 48 femoral bones (male =32, Female=32) of known sex for gender dimorphism. The descriptive statistics of all parameters of both male and female were presented in Table 1.

The result showed that the mean values of all the measured variables of male femur bone were significantly higher ($p<0.001$) than female femur bone.

Table 1: Mean values of all the measured variables

Male			Female		T value	Level of Significance
Parameter	**Mean**	**SD**	**Mean**	**SD**		
Maximum length	44	4.17	39.85	2.27	4.86	<0.001
Proximal Breadth	7.37	0.66	6.20	0.46	8.04	<0.001
Vertical head diameter	4.60	0.39	3.93	0.31	7.35	<0.001
Transverse head diameter	3.68	0.52	3.30	0.55	2.01	<0.001
Epicondyle breadth	6.37	1.43	5.22	0.39	4.30	<0.001
Vertical Neck diameter	2.61	0.42	2.26	0.32	3.59	<0.001
Mid shaft Diameter	2.46	0.37	1.99	0.12	6.64	<0.001

Table 2: Stepwise univariate discrimination analysis for determination of sex

Dimensions	b0	bi	Canonical discriminant functions	Wilk's lambda	Eigen value	Canonical Correlation	F-Statistic	p
MAX LENG	-12.478	0.298	0.617	0.717	0.394	0.532	23.624	0.000
PROX BRE	-11.843	1.743	1.021	0.481	1.078	0.720	64.672	0.000
VERT D. HE	-11.910	2.790	0.934	0.526	0.902	0.689	54.122	0.000
TRA D. HEA	-6.439	1.843	0.357	0.884	0.132	0.341	7.902	0.007
EPI CON BR	-5.517	0.952	0.546	0.764	0.308	0.485	18.492	0.000
VERT D. NE	-6.431	2.638	0.456	0.823	0.215	0.421	12.920	0.001
MID SHA.D	-8.017	3.595	0.844	0.576	0.735	0.651	44.130	0.000

Table 2 represents the outcome of stepwise discriminant analysis. The maximum length, proximal breadth, vertical & transverse, epicondyle breadth, verticle neck diameter maximum midshaft anteroposterior diameter were chosen in that sequence. The F-ratio quantifies the amount of variation that exists between and between both sexes, as well as the significant degree of this variance. Wilks' lambda is a statistical measure that quantifies the usefulness of a certain variable in stepwise analysis and determines the order in which variables should be included in a function.

Table 3: Percentage of correct group membership for univariate discriminant function analyses

Dimensions	Male	Female	Overall
MAX LENG	61.3	87.1	74.2
PROX BRE	96.8	80.6	88.7
VERT D. HE	83.9	93.5	88.7
TRA D. HEA	67.7	67.7	67.7
EPI CON BR	77.4	90.3	83.9
VERT D. NE	67.7	58.1	62.9
MID SHA.D	64.5	96.8	80.6

Table 4: Multivariate discriminant function analysis for sex discrimination

Discriminant formula (Y)	Wilk's lambda	Eigen value	Canonical Correlation	Canonical discriminant functions	Percentage of correct membership		
					Male	Female	Overall
(0.108 × MAX LENG) + (0.703 × PROX BRE) + (2.443 × VERT D. HE) +(0.438 × TRA D. HEA) + (0.536 × EPI CON BR) - (0.545 × VERT D. NE) + (1.067 × MID SHA.D) - 25.412	0.194	4.142	0.898	2.002	100	100	100

Table 3 presents the proportion of correct group identification, also known as sensitivity. The proximal breadth diameter & vertical diameter of head, Epicondylar breadth, mid shaft diameter is the most ideal parameter in both males and females. The second most favourable choice is the maximum anterior-posterior diameter at the midpoint of the shaft. Nevertheless, the precision increased in both males and females when the aforementioned variables were merged. Female bones displayed heightened sensitivity across all criteria. Table shows that multivariate discrimination function for the sex determination. Discrimination formula has been derived. If the value of Y is greater than canonical discriminant value it is considered to be male and lesser in Y value then it is considered to be female.

Table 5: Variables in binary logistic regression model

Parameters	B	S. E	Wald	df	significance	Exp(B)	95% C.I for Exp(B)		% of correct
							Lower	Upper	
Maximum Length	-0.364	0.102	12.878	1	0.000	0.695	0.569	0.848	66.1
Constant	15.188	4.208	13.030	1	0.000	0.000			
Proximal Breadth	-4.426	1.143	15.007	1	0.000	0.012	0.001	0.112	88.7
Constant	29.943	7.811	14.697	1	0.000	0.000			
Vertical Head diameter	-5.463	1.401	15.198	1	0.000	0.04	0.000	0.66	88.7
Constant	23.247	5.951	15.259	1	0.000				
Transverse Head Diameter	-1.386	0551	6.333	1	0.012	0.250	0.085	0.736	67.7
Constant	4.843	1.944	6.204	1	0.013				

Epicondyle Breadth	-1.067	0.316	11.389	1	0.001	0.344	0.185	0.639	83.9
Constant	6.140	1.819	11.389	1	0.001				
Vertical Neck Diameter	-2.325	0.749	9.631	1	0.002	0.098	0.023	0.425	62.9
Constant	5.656	1.837	9.483	1	0.002				
Mid shaft Diameter	-9.343	2.750	17.546	1	0.001	0.000	0.000	0.019	80.1
Constant	19.969	5.725	12.167	1	0.000				

The cut off value in logistic regression model 0.5.

The sex can be determined by using following formula. If corresponding value greater than cut off value it is considered to be male and if the value if it is less than the cut off value, it is considered to be female.

For Sex:

1. Sex =Maximum length of femur bone× (-0.364) +15.188.
2. Sex =Proximal breadth of Femur × (-4.426) +29.943.
3. Sex=Vertical Head Diameter× (-5.463) +23.247
4. Sex=Transverse head diameter× (-1.386) +4.843.
5. Sex=Epicondyle breadth× (-1.067) +6.140
6. Sex= Vertical neck diameter× (-2.325) +5.656
7. Sex= Mid shaft Diameter× (-9.343) +19.969

Table 6: Comparison of percentage of accuracy between Discrimination function model and Logistic regression model

Parameters	Discrimination model (% of accuracy)	Logistic regression model (% of accuracy)
Maximum length	74.2	66.1
Proximal Breadth	88.7	88.7
Vertical Diameter of Head	88.7	88.7
Transverse diameter of Head	67.7	67.7
Epicondyle Breadth	83.9	83.9
Vertical Diameter of Neck	62.9	62.9
Mid shaft Diameter	80.6	80.1

4. DISCUSSION

Skeletal biology varies among human populations across different geographic locations. These variances mostly depend on their genetic composition, habitat, and the interactions between these two elements. Thus, in the field of forensic and physical anthropology, it is widely acknowledged that there is a need for further population-specific data to establish standards for human skeleton identification. When determining the sex of the human skeleton, the first priority is given to the physical characteristics of the pelvic girdle and cranium, followed by the long bones [12]. Due to technological advancements, molecular analysis has become more prominent than osteometric measurements. Prehistoric human skeletal remains from Nepal do not exhibit good preservation of deoxyribonucleic acid (DNA) due to the enduring environmental conditions. Hence, the current work aims to derive a formula specific to the Nepali population for estimating sex based on osteometric measures of the femur. The study revealed that the average values of various parameters of the male femur bone, including maximum length, proximal breadth, vertical and transverse diameter of the head, epicondyle breadth, vertical neck diameter, and midshaft diameter, were significantly larger than those of the female femur bone (p<0.001). The study revealed that the average values of various parameters of the male femur bone, including maximum length, proximal breadth, vertical and transverse diameter of the head, epicondyle breadth, vertical neck diameter, and midshaft diameter, were significantly larger than those of the female femur bone (p<0.001). Various studies revealed that length of the femur, proximal breadth, vertical and transverse diameter midshaft diameter were significantly higher than female [13-19]. Seven osteometric measurements were incorporated into a discrimination analysis model and a binary logistic regression model in order to determine which method provides a more accurate estimation of sex based on femur characteristics. The measurements included the maximum length of the femur, proximal breadth, vertical diameter of the head, transverse diameter of the head, epicondyle breadth, vertical diameter of the neck, and mid shaft diameter. The discrimination analysis model demonstrated similar accuracy with the binary logistic regression model (table 6) for the four osteometric measurements: maximum length, vertical diameter of head, epicondyle breadth, and mid shaft circumference. Male skeletons typically exhibit greater size and robustness compared to female skeletons. Long bones, being a component of the appendicular skeleton, also adhere to this principle. However, a complicating factor is that there is variation in sexual dimorphism, which refers to the differences in size and robustness, among different populations. For instance, American blacks and American whites exhibit a higher level of sexual dimorphism compared to Southeast Asian cultures, where it is less noticeable. Our analysis clearly shows that the maximum length, Vertical diameter, Epicondyle breadth and mid shaft diameter of the femur is the most dimorphic portion for the Nepali people. The study's findings indicate that the length of the femur in Nepali individuals is a reliable skeletal characteristic for diagnosing sex, achieving a classification accuracy of 87% (table 3,6). The findings of this study align with the results of previous studies conducted by Sikka et al. (2016), Gargi et al. (2010), Timonov et al. (2014), Singh et al. (2017), and Mahato et al. (2021) [20-24]. These studies determined the sex of femora and established baseline parameters for the North Indian and West Indian population.

An Indian study found that the greatest diameter of the skull yielded the highest level of accuracy, specifically 90.4%. [25] In this study, the maximum diameter of the head achieved the highest accuracy rate of 93.5%. In contrast to other studies undertaken in China, Thailand and among South African Whites where the most noticeable difference was observed in epiphyseal breadth, [26,27,28] our investigation found a different result. The greatest diameter of the skull was shown to be the most significant characteristic in both American black and whites and Germans [29,30]. Nevertheless, the level of accuracy varied across different populations. The current study demonstrated that the Mid shaft diameter of the femur bone in the Nepali population is the most effective factor for accurately determining sex, with an accuracy rate of 96.8%. This study aligns with previous research conducted by Dittrik j and Mayer et al. in 1986, which achieved an accuracy rate of 79.9%. Similarly, Liu Wu in 1989 achieved an accuracy rate of 79.4%. [31.32] Purokait R and Chandra et al. in 2002 reported accuracy rates of 82% for males and 90% for females [25]

5. CONCLUSION

This study suggests that femur measures can be a valuable method for determining the sex of human skeletal remains discovered in archaeological and forensic settings in Nepal. A linear discriminant analysis model is proposed as an alternative to the regression model for estimating the sex based on osteometric measurements of femur. Linear discriminant function analysis of four femoral parameters (anteroposterior mid-shaft diameter, epicondylar breadth, bi-trochanter length, and maximum shaft diameter) yields more accurate results in determining the sex of a fairly complete femur. The most effective method for determining the sex of an individual based on the femur is by measuring the anteroposterior mid-shaft diameter. This measurement is particularly useful when only the shaft of the femur is accessible.

6. FUNDING INFORMATION

There are no funds for this study.

7. CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

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