Original Article

DOI: 10.7860/IJARS/2022/50751.2731

Anatomy Section

A Morphometric Study of Humerus to Determine Sexual Dimorphism in Indian Population

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ABSTRACT

Introduction: Recognising the gender from the skeleton or decomposed body is a difficult task. Morphometry of long bones is highly applicable in such cases. The morphological features of humerus show varying degrees of sexual dimorphism in various populations.

Aim: The study is focused on the morphometric analysis of humerus to evaluate the most reliable parameter for sexual dimorphism in Indian subcontinent.

Materials and Methods: This cross-sectional study was carried out from November 2016 to January 2020 on 82 dry completely ossified adult humeri of known sex (51 male and 31 female). The parameters included in this study were- Maximum Length of humerus (ML), Vertical Diameter of Head (VDH), Epicondylar Breadth (ECB), Maximum Mid-Shaft Diameter (Max. MSD) and Minimum Mid-Shaft Diameter (Min. MSD). The parameters were measured by electronic digital caliper and osteometric board. Descriptive and inferential statistical analysis was carried out to compute the demarking point and Discriminant Score (DS). Discriminant function analysis was performed using Wilk's lambda to determine that which variable provided the best discrimination between sexes.

Results: It was found that a higher demarking point indicates a male while the lower value indicates a female. In discriminant function analysis, the sectioning point greater than -0.42 was a male and less than -0.42 was a female. Wilk's lambda was least for VDH (0.349) followed by ECB (0.467) and ML (0.486), whereas Max. and Min. MSD (0.771, 0.700) showed greater values.

Conclusion: The VDH is the most reliable parameter in humerus for determination of sex followed by ECB and ML. Max. and Min. MSD have lesser contributions for sex determination. A combination of parameters is better than using a single parameter and this knowledge will be very helpful to forensic anthropologists.

Keywords: Discriminant function analysis, Epicondylar breadth, Forensic anthropology, Vertical diameter of head

INTRODUCTION

The determination of sex of an individual is important in forensic anthropology. It is a challenging task in cases of severely decomposed, commingled and dismembered bodies. Sex determination is the first step before evaluating other parameters of biological profile such as stature and age as these parameters are highly sex dependent [1]. Morphological and anthropometric methods are widely used to infer the sex from the available skeletal remains. Morphological methods need the whole skeleton for it to be accurate, whereas, in anthropometric methods sex determination is possible even when a single long bone is available. According to Krogman WM and Iscan MY, long bones alone showed an accuracy of 80% in sex determination [2].

Sex determination is better in post pubertal bone as the differences are not clear until after puberty [3]. More than length, the cross-sectional area of long bones is a better parameter as the growth of length stops after a certain age when epiphysis fuses, whereas cross-sectional area of long bone undergoes dynamic changes even after the long bone has stopped growing vertically. It is usually greater in males than females which indicates greater periosteal growth which depends on the amount of physical activity performed by them. But this does not serve as a reliable indicator always as females indulging in heavy activities can also have greater periosteal growth and cross-sectional area [3].

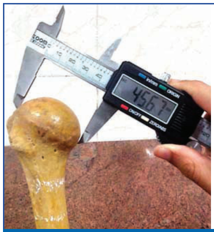
Many bones have been used for sex determination, mainly hip bone and skull which have higher accuracy rates. But when those bones are not available, long bones have proven to be reliable for sexual dimorphism. Measurements of any long bone depends upon the race and geographic region [4]. Among all the long bones, it has been proven that postcranial long bones like humerus show better accuracy than femur which is the most commonly used long bone for sex determination [5]. Many studies have been done on sexual dimorphism of humerus in various regions and populations to get base line parameters for that particular population [6-9]. The degree of sexual dimorphism is population specific. In an Indian study, the overall accuracy for sex determination of humerus by discriminant analysis was 90.34% [10]. As humerus is a reliable long bone to predict sex, the present study is focused on the morphometric analysis of humerus to evaluate the most reliable parameter for sexual dimorphism in Indian subcontinent.

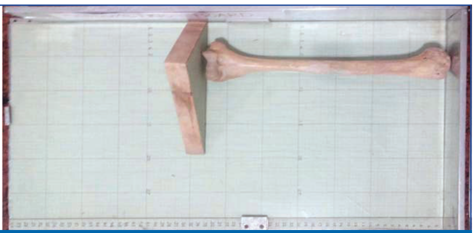
MATERIALS AND METHODS

The present cross-sectional study was conducted in Anatomy Department at Vydehi Institute of Medical Sciences and Research Centre, Bangalore, India, during November 2016 to January 2020 and the verbal permission from the concerned authority was taken prior to the study. This morphometric study carried out on 82 humeri (33 right and 49 left sided) of known sex in which 51 were male and 31 were female.

Inclusion and Exclusion criteria: The dry adult humeri which were completely ossified and properly processed were selected whereas damaged and distorted bones were excluded from the study.

All parameters except ML were measured by electronic digital caliper [Table/Fig-1] and ML was measured using the osteometric board [Table/Fig-2]. The following are the parameters included in this study and were measured in centimeters.





[Table/Fig-1]: Measuring VDH of humerus using electronic digital caliper.
[Table/Fig-2]: Showing the measurement of total length of humerus by osteometric board. (Images from left to right)

1. Maximum Length of humerus (ML): Direct distance from the most superior point on the head of the humerus to the most inferior point on the trochlea.
2. Vertical Diameter of Head (VDH): The direct distance between the most superior and inferior points of the articular surface of the head.
3. Epicondylar Breadth (ECB): The distance between the most laterally protruding point on the lateral epicondyle and the corresponding projection on medial epicondyle.
4. Maximum Mid-Shaft Diameter (Max MSD): The maximum diameter in the middle one-third of shaft of humerus.
5. Minimum Mid-Shaft Diameter (Min MSD): The least diameter in the middle one-third of shaft of humerus.

All the measurements were done in accordance with the standard osteometric techniques described by Ogedengbe O et al., and Basic Z et al., [6,11].

STATISTICAL ANALYSIS

Descriptive and inferential statistical analysis was carried out to compute the demarking point and DS. The demarking point for each variable was computed. The average of the mean for males and females represented the demarking point [12]. The DS higher than the demarking point indicates a male humerus and the female with a lesser DS than the demarking point. To assess the sexual dimorphism, the measurements were subjected to statistical analysis using student's t-test and p-value <0.05 was considered statistically significant. To assess the level of differences between sexes, the sexual dimorphism ratios were calculated [13].

Sexual dimorphism ratio=(male mean)/(female mean)×100

To determine that which variable provides the best discrimination between sexes, discriminant function analysis was performed using Wilk's lambda. Wilk's lambda is a test statistics in multivariate analysis of variance (MANOVA) [6]. After univariate analysis, multivariate discriminant function analysis was performed to establish whether there are differences between the means of groups of subjects on a combination of dependent variables. This analysis of variables developed an equation for sex determination of the humeri from the specific geographic region.

The statistical software Statistical Package for the Social Sciences (SPSS) 22.0 and R environment version 3.2.2 were used for the analysis.

RESULTS

For all the parameters the mean values for males are greater than that of the females and using student's t-test, it was found that this difference in the mean values is highly significant for all parameters [Table/Fig-3].

A higher demarking point indicates a male while the females have a lower value. The table also shows Wilks lambda for all the parameters which is the least for VDH followed by ECB and ML, whereas Max and Min MSD have greater values [Table/Fig-4]. Wilks lambda is given between the range of 0 to 1, where 0 means total discrimination and 1 means no discrimination and smaller Wilks lambda, close to 0 indicates greater discriminatory function of the variable towards the study whereas values close to 1 indicates a lesser discriminatory power. The efficacy of the dimorphism from each variable was tested and found that VDH contributes the best for determination of sex followed by ECB and ML. Maximum and Minimum MSD have lesser contributions for sex determination of humerus.

Variable	Males (n=51)	Females (n=31)	p-value
ML (cm)	32.08±1.33	29.19±1.46	<0.001
VDH (cm)	4.52±0.27	3.85±0.19	<0.001
ECB (cm)	5.97±0.25	5.36±0.33	<0.001
Max MSD (cm)	2.11±0.17	1.92±0.18	<0.001
Min MSD (cm)	1.63±0.12	1.43±0.18	<0.001

[Table/Fig-3]: Mean values of variables of dry humeri in males and females (student's t test).

Variables	Demarking point	Sexual dimorphism ratio	Wilks' lambda	F-ratio	p-value
ML (cm)	F <30.64 <M	109.90	0.486	84.625	<0.001
VDH (cm)	F <4.19 <M	117.40	0.349	149.521	<0.001
ECB (cm)	F <5.67 <M	111.38	0.467	91.209	<0.001
Max MSD (cm)	F <2.02 <M	109.89	0.771	23.799	<0.001
Min MSD (cm)	F <1.53 <M	113.99	0.700	34.314	<0.001

[Table/Fig-4]: Demarking points separating males from females, sexual dimorphism ratio, F-ratio and statistical significance in dry humeri.
Wilk's lambda is a test statistics in multivariate analysis of variance (MANOVA)

By the stepwise discriminant function analysis we formulated a linear equation to calculate the discriminant function or DS

DS=2.523×VDH+1.083×ECB+0.329×ML-0.713×Max.MSD+1.381 ×Min MSD -27.861

(-27.861 is a constant and other values are the regression coefficient of corresponding variables)

Classification Accuracy=97.6%, Wilks lambda=0.259, Chi-square= 104.726, p<0.001, Centroid=(1.303, -2.143: Male, Female)

Thus, to determine the sex of an individual, the DS can be obtained from specific function. Each humeral dimension is multiplied by its corresponding standardised regression coefficient and then added to the constant, if the score is greater than the sectioning point, then the individual is male, whereas lower score than the sectioning point indicates a female [14].

The sectioning point is the average of the male and female centroid. The stepwise discriminant function analysis showed that VDH is most accurate humeral dimension to predict the sex, giving a combined average accuracy value of 97.6% of three most reliable indicators i.e., VDH, ECB, ML. The centroid for male was around 1.303 and for females, it was -2.143. The sectioning point was -0.42. The DS less than the sectioning point indicates a female bone. For example, an individual with VDH (3.85), ECB (5.36), ML (29.19), Max. MSD (1.92), Min. MSD (1.43), the calculation will be:

Discriminant Function

DS=2.523×VDH+1.083×ECB+0.329×ML-0.713×Max.MSD+1.381 ×Min MSD -27.861=-4.4 (-27.861 is a constant).

As this value -4.4 is lesser than sectioning point -0.42, the individual is a female.

DISCUSSION

This study aimed to carry out sex determination of humerus using osteometric standards and to identify the most reliable parameter for sex determination. Among the five parameters we considered, it is identified that VDH is the most reliable parameter followed by epicondylar breadth and maximum length of humerus. It was found that mean values of all parameters were significantly high in males than the females and is in accordance with the previous studies [6,15]. The factors that contributed to the increased value could be due to the increased physical labour perfomed by males and the early maturity of females [16,17].

Present study showed that the best single parameter to detect the sex in humerus was VDH. Similar results were identified in different populations from Korea, Germany, South Africa, China and Cretan [4-6,18,19]. Among the South African whites, the Japanese and Thai populations, EB was found as the better parameter in humerus to predict the sex [14,18]. In present study, it is the second reliable parameter after VDH.

The South African whites showed the highest demarking point in ML (32.2 cm) and VDH (4.6 cm) than that of all other populations [14]. However, the present study showed similarities in the demarking points of ML and VDH with other populations [6,18,19]. The demarking point of ML (in cm) in this study is similar to that of Cretans (30.64 vs 30.74) [18] and with South African blacks it is (30.64 vs 30.75) [6]. The demarking point of VDH in the present study showed similarities with Chinese (4.19 vs 4.23), Japanese (4.19 vs 4.16) and Thai (4.19 vs 4.12) populations [18]. The demarking point of VDH is low in South African blacks [6] when compared to present study, while it was high in Cretans (4.4) [19] and South African whites (4.6) [14]. Ogedengbe O et al., suggested that the factors attributing to the varied demarking points may be due to the environmental factors contributing to the bone growth, nutrition, genetic variation and physical labour [6].

Another basis of the sexual dimorphism in long bones is that during adolescence the cortical bone formation is at a greater rate in males than the females. This increased subperiosteal growth results in an increase in the bone circumference in males [20]. Testosterone also plays a role in the increase in osteometric measurements [21]. Gray J and Wolfe L stated that sexual dimorphism based on stature is greater in population with extreme protein consumption [22].

Ogedengbe O et al., selected only VDH, ML, Transverse Diameter at the Lower-half of the Shaft (TDLS) and Mid-Shaft Circumference (MSC) in the relative order of discriminant function among the eleven parameters measured with standard osteometric techniques [6]. By the stepwise discriminant function analyses, they identified the unstandardised coefficients and sectioning points which led to formulate DS by which sex of an individual can be obtained. In present study, we have taken only five parameters for the study and with the same parameters, the stepwise discriminant function analyses, the standardised regression coefficients and sectioning points were identified to formulate the DS. In the present study, the sectioning point is -0.42, while it was -0.0675 in South African study by Ogedengbe O et al., [6]. In their study, the constant was -15.761 and in present study it is -27.861.

The discriminant function analysis is the well accepted method in osteometry and it shows the sexual dimorphism with high accuracy [19]. The measurements in the proximal epiphysis is more reliable than the distal epiphysis measurements in sexual dimorphism of humerus and among the proximal epiphyseal measurements VDH is the best sex discriminator [1,4,21]. Present study and many other previous studies substantiates that VDH is the most reliable parameter to determine the sex [4-6,18,19].

The combined accuracy of VDH, ECB and ML was 97.6% in the present study while it was 98.5% in a study with three variables of maximum diameter of head, minimum mid shaft diameter and ECB [23]. The combined accuracy was 87% in Korean population and it varied to 98.5% in other population [4,23]. This existence of variation suggests that there are definite variations in the pattern of humeral dimensions in different populations [7,24].

The sexual dimorphism is maximum in the proximal and distal dimensions of humerus [25]. A study from South India showed that ML is the best parameter to predict sex [15]. Another Indian study showed that, in male the average ML of humerus was 31.08 cm and 27.82 cm in females, whereas in present study it was 32.08 cm and 29.19 cm respectively [26]. The VDH was also high in our study. It was 4.52 cm in males and 3.85 cm in females while in their study it was 4.29 cm and 3.71 cm, respectively [26]. The degree and distribution of sexual dimorphism varies from one population to another of the same as well as different geographic region [15]. Because of that anthropologists widely accepted that the inter population difference necessitates the development of region based specific standards for sex determination. As the pattern of sexual dimorphism differs between populations, the accuracy of the result also varies in different ethnic group [15].

Limitation(s)

The smaller sample size and unequal number of male and female humeri were the limitation of this study.

CONCLUSION(S)

Even though the population differences affect the sexual dimorphism, many studies from various geographic regions showed that the VDH can be considered as a reliable parameter in predicting the sex which is a very useful tool to establish the biological profile in anthropological studies and medicolegal cases. It also imposed that the humerus can be used in sex determination but the accuracy is limited in the fragmentary state, as VDH, ECB and ML are the most required parameters for satisfactory accuracy. The combination of parameters is better than a single parameter for sex determination as it is more accurate than the individual parameters. The morphometric measurements of fragments are important for the orthopaedic surgeons in the treatment of proximal and distal fractures of humerus.

Acknowledgement

The authors would like to thank Dr K P Suresh, Scientist in Biostatistics, at National Institute of Veterinary Epidemiology and Disease Informatics (NIVEDI), Bangalore-560024 for reviewing the research methodology and statistical results of the study.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Jun 17, 2021
- Manual Googling: Aug 20, 2021
- iThenticate Software: Sep 11, 2021 (12%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Jun 12, 2021**
Date of Peer Review: **Jul 29, 2021**
Date of Acceptance: **Aug 26, 2021**
Date of Publishing: **Jan 01, 2022**