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Original Research Article

Sex Estimation from the Shaft Fragment of Humerus Bone from Samples of Central Indian Skeletal Remains

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Abstract

Introduction: In medico-legal and disaster distress scenarios, the chances to get fragmentary body/bones are very common. Establishing the biological identity is quite challenging task for the authorities. Assessment of sex from fragmentary bones is one of the important task for medico legal investigators in during the disasters. Therefore, there is an urgent need to develop a population-specific discriminant function (DFA) which can be applied to the Fragmentary region of the bone. **Material & Methods:** A total of 402 (254 male and148 female) humerus bones were included in the study. The survival of the shaft region found higher compare to the upper and lower epiphysis due to various external factors. In present study only Shaft specific parameters i.e. Least Girth of Shaft, and Circumference at Deltoid Tuberosity were measured. One additional parameter developed i.e. Maximum diameter at deltoid tuberosity was measured and was tested for its efficacy. The statistical analysis done with SPSS version 16.0 and univariate statistics and discriminant function was calculated for all the parameters to reach the best estimation possible. **Results:** The univariate accuracy percentage to classify the male and female was found 90.1% for Circumference at deltoid tuberosity and 76.2% for least girth of the Shaft. In the non-conventional parameters, maximum diameter at deltoid tuberosity gives 84.4% per cent accuracy. In Stepwise discriminant function analysis, the measured combinations give an accuracy of 88.6 % for male and 94.0% for female whereas in the cross-validation they give 90.5%. **Conclusion:** The study shows that the parameters on fragmentary shaft of humerus may one of the best indicator for determining the sex of an unknown when no other bones are present.

1. Introduction

Identification of an unknown during mass disaster or any criminal activity is one of the main objectives of the medico-legal personnel's. The word "who he was" is the last service given by the concerning authority who deals with such cases. In a scenario where very limited physical resources available to establishing the identity of the unknown, the experts tried to establish his/her biological

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identity from the bone fragments are very challenging especially when it is through non-invasive techniques. In these situations, the assistance of the Forensic Anthropologist helps at an extent to reach out any conclusions. Forensic Pathologists may not able to identify demographic profile of an unknown human body when soft tissue has degenerated or in an advanced stage decomposition. Hence assistance of forensic anthropologists will be an excellent option in determining the time since death, a cause of death and manner of death.[1]

Normally visual/morphological or metrical approach or both are used in non-invasive techniques to determine the sex of the skeleton/remains. The visual method examines shape and size differences whereas in metric measurements of the bones are used. The obtained value then processed through the statistical analysis to check the efficacy of it. The osteometric measurements are found more reliable than visual examination because it gives more objective in assessing the sex from skeletal/remains. Sex determination from skeletal remains has been attempted by various workers in different parts of the world. Nearly all bones show some form of metric and morphologic sexual dimorphism.[2-4] Apart from the pelvis and skull Studies on the upper limb and long bone include humerus [5-10] radius[10-12] and on ulna[13-14] shows varies degree of sexual dimorphism. Studies showed[15] that discriminant analysis of the humerus bone gives strong average accuracy percentage as compared to the crania. The puberty and maturity falls earlier in female this will gives chance because of this deposition of the minerals at cortical bone found greater in men compared to females.[16-17] This deposition in bone helps in increasing the widths and circumference in males.[18]

Various post-mortem skeletal modifications have also happened with the bones and these modifications are caused by various environmental, animal and taphonomic changes. The authors also personally experienced that during the Forensic Anthropological studies at various medico-legal departments. They found that most of the submitted osteological remains for the expert opinions were in the fragmentary state rather than complete bones. In the case of humerus, it was also found that availability of shaft region was more compared to epiphysis regions of the humerus. The rate of deterioration and attack of the rodents on the softer parts (Head) are more prompt at proximal and distal epiphysis can be one of the main causes in long bones. Seeing these consequences this study was undertaken on the shaft region assuming that chance of availability of this portion are comparatively higher for humerus. With the mentioned objective present study was focused on the already available measurable parameters of the shaft and checking its efficacy in Sex determination. A non- conventional measurement was also devised during the study, checking its efficacy and its applicability was also incorporated in the aim of the present research. Apart from these, the study also produces a population-specific discriminant function formula which can be applied on the shaft region of humerus of an unknown belongs to Central Indian population.

2. Materials and methods:

Unlike western countries, known human bone collection are scanty in India. The reason may be because of religious belief, cultural practices and sentiments towards the dead. Which prevent to do anything on the dead or the skeletal bones/remains. In the cases where bodies/bones come for medico-legal opinion to the experts are given back to relatives once the procedure was done. The humerus bone sample belongs to collection of the department of anatomy (macerated ones whose sex was known) and skeletal collection submitted for an expert opinion at Forensic medicine department in the medical colleges in Madhya Pradesh. All the included sample belong to central Indian population. A total of 402 (254 male and148 female) humerus bones were included in the study. All the bones belong to adult age group. Only those which were complete and free from any orthopaedic and pathological disorder are included in the study.

The authors took nearly 20 parameters in the humerus but in the present paper only three parameters were analysed and reported which belongs to Shaft area. Among these three, two are conventional ones and one is non-conventional parameters. The details about the measurements are given below.

3. Measurements:

The undertaken parameters are measure by the standard osteometric techniques suggested by Martin & Saller[19] and Steyn and Iscan.[9] The diameter was taken with the sliding calliper (Dial calliper manufactured by Mitutoyo Corporation in Japan, accuracy 0.01 mm). The circumferences were measured by retractable plastic tape thrice and the mean value of that taken as the final reading.

Seeing the practical need and applicability of the parameters in determining the sex on an unknown fragmentary humerus bone one measurement was devised. The following parameters were measured on the humerus bones-

1. **Maximum diameter at deltoid tuberosity:** It measures the greatest diameter at the level of deltoid tuberosity without regard to the sagittal or transverse plane (Devised).
2. **Least Girth of Shaft:** It measures the least circumference of the shaft found at the lower half of deltoid tuberosity.[19]
3. **Circumference at deltoid tuberosity:** It measures the maximum circumference at the level of deltoid tuberosity.[9]

Only the right sides of the humerus bone included in the study considering that the majority of people are right-handed in this region. The data obtained were analysed by Statistical Package for Social Science (SPSS) version 16.0. Univariate statistics and discriminant function analysis (DFA) was calculated for the parameters to reach the best estimation possible. Wilks' lambda was calculated for DFA and classification percentages were calculated for single variable.

The practical approach on which the present study based that is to check discrimination formula for its validation for this population or not. For this purpose, the obtained formulae applied on the known sample of a set of 15 males and the same number of the female humerus for the efficacy testing.

4. Results:

Table 1 depicts the mean value and S.D. for the variables at the shaft of humerus. As expected the dimensions for male samples showed were statistically significantly larger than female. The same trend can also be seen for the standard deviation, which showed a greater variability in males. These values indicate the high sexual dimorphism in this population. **Table 2** provides results obtained by subjecting the data for DFA. The first two columns give the unstandardized coefficient and the constant of the discriminant function for calculating the discriminant score.

Table 1: Univariate statistical analysis of Humerus

S. No	Variable Name	Male		Female	
		Mean	SD	Mean	SD
1	Maximum Diameter at Deltoid Tuberosity	20.12	1.68	16.99	1.55
2	Circumference at Deltoid Tuberosity	62.91	3.9	53.86	3.3
3	Least circumference of the Shaft	57.09	4.38	50.67	4.16

The next column represents values of the Wilk's lambda, which indicates the percentage contribution of each variable to discriminating the sexes. As shown in table 2 that the accuracy percentage to classify the male and female is range between 76.2% (least girth of the Shaft) to 94.1% (Circumference at deltoid tuberosity). The non-conventional parameters maximum diameter at deltoid tuberosity gives 84.4% per cent accuracy which indicates that the shaft of humerus has the strong discriminant capacity. The table also displays the results of cross-validation analysis. A stepwise analysis runs for the Diaphysis parameters. By using the cut off value for Wilk's lambda with F= 3.84 to enter and F=2.71 to remove, stepwise Discriminant function procedure was performed.

Wilk's lambda determined the order in which the variable was selected to enter into the function. To determine the sex one has to multiply the variable with its raw (unstandardized) coefficient then to add constant. A stepwise procedure calculated for the parameters for sex estimation and presented in **table 3.** Only two parameters Circumference at deltoid tuberosity and Maximum diameter at deltoid tuberosity contributed significantly to the discriminant function. The standard coefficient, the structure coefficient, the unstandardized coefficient and the group centroids analysed are presented is presented in **table 4.**

Table 2: Details of discriminant analysis statistics of single variables of Humerus.

S. No	Parameters	Unstandardized coefficient	Constant	Wilks' Lambda	Correct Classification (%)			Cross validated Average %
					Male	Female	Average	
1	Maximum diameter at deltoid Tuberosity	0.610	-11.319	0.545	84.50	84.20	84.40	84.40
2	Circumference at deltoid tuberosity	0.274	-15.782	0.455	90.40	89.70	90.10	90.10
3	Least girth of the shaft	0.232	-12.50	0.662	78.50	71.90	76.20	76.20

Table 3. Stepwise discriminant function analysis of shaft variables of male and female of Central Indian population.

Step	Parameters entered	Wilks' lambda	Exact F ratio	Df
Function - diaphysis/Shaft				
1	Circumference at deltoid tuberosity	0.434	395.385	1,303
2	Maximum diameter at deltoid tuberosity	0.424	205.134	2,302

Table 4. Canonical discriminant function coefficient of humerus of male and female of Central Indian population – Only the variables in upper epiphysis included in the analysis.

Parameters	Standardised Coefficient	Structure Coefficient	Unstandardised	Centroids female	Centroids male
Function - diaphysis/Shaft					
Circumference at deltoid tuberosity	0.841	0.980	0.220		
Maximum diameter at deltoid tuberosity	0.242	0.724	0.146	1.236	-1.236
CONSTANT				-15.653	

Table 5: Percentage correct classification for the discrimination Functions of various combinations of the humerus of male and female of Central Indian population.

Functions	Identified Male (%)	Identified Female (%)	Average Accuracy	
			Original	Cross Validated
Function - (diaphysis/Shaft)	88.6	94.0	90.5	90.5

Table 6: Discrimination Functions Formula for the shaft of Central Indian population

D = 0.22 (Circumference at deltoid tuberosity) + 0.146 (Maximium diameter at deltoid tuberosity) -15.653

Table 7: Testing the Efficacy of the Parameters of humerus on known Test sample by using the Discrimination formula.

Types of Samples	Parameters	Sample size		Accuracy Percentage (%)		
		Male	Female	Male	Female	Average
Known Sample	Circumference at deltoid tuberosity + Maximum diameter at deltoid tuberosity	100	73	84.6	92.3	88.5
Test Sample	Circumference at deltoid tuberosity + Maximum diameter at deltoid tuberosity	15	15	82.8	90.4	86.6

Table 5 illustrates the average accuracy percentage when parameters entered for the analysis. The Discriminant score formula was depicted in **Table 6** for the Central Indian Population for the shaft region of humerus. Using the discriminant formula, the efficacy test was conducted on 15 unknown samples (**Table 7**). The result was quite appealing and proven its applicability on an unknown sample of Central Indian origin.

5. Discussion:

It was a valid discussion that standard developed on population cannot be applied on another, especially while dealing with the skeletal bones/remains. To assess the demographic characteristics including sex also needs population specific standard drawn from the same population samples and was supported by various skeletal biologists.[20-22] One cannot ignore the environmental

and other factors which differ from population to population and region to region. A number of researchers prove[23-24] that deficiency of protein plays a significant role in sexual dimorphism. Whereas many scholars[25-26] supports that extreme division of labour may enhance or reduce musculoskeletal development which effects sexual dimorphism internally and externally.

The aim of present research was to study which variables in the shaft of humerus bone give the best metric diagnosis of sex in the central Indian population. The study using discriminant function analysis showed that parameters in the shaft humerus bone exhibited good discriminating power specially Circumference at deltoid tuberosity (90.1%). Applying stepwise discriminant analysis on shaft sections of the humerus in studied population exhibit strongest (90.5%) discriminating power.

The mid-shaft section consisting of parameters minimum and maximum mid-shaft diameters analysed by Kranioti and Michalodimitrakis[27] achieved 83.3% accuracy. In the present study, the same section consisting of the circumference and maximum diameter at deltoid tuberosity produced 90.5% accuracy. Though the purpose of making sections of the humerus was to use it on fragmentary pieces, Kranioti and Michalodimitrakis[27] used mid shaft parameters which interestingly cannot be determined in the absence of upper and lower epiphysis. The accuracy of 89.3% in the shaft and 86.9% in shaft among the Cretans[27] are found to be lower than the present study. Saffont et al.,[18] suggested in his study on femur bone that circumference measurements are good indicators in determining the sex. The reason is these shaft area bears the functional demands as well as musculature affect. The finding of the present study also supports the theory for the humerus bone.

6. Conclusions:

Except for a few sporadic studies, there is a lack of comprehensive study on skeletal remains in India. Those which are available are either derived from old aged bone or developed from unknown origin and sex. This study provides standard discriminant function formulae from the recent population of central India and can be used for sexual dimorphism of the fragmentary humerus. Reflection of the high classification accuracy in shaft region showed that this region is also having an importance in sexual dimorphism. The findings of the present study showed that the shaft of humerus can be used for determining the sex in medico-legal context when all or no other bones is present.

The simple nonconventional measurements give a path for the future researchers to find out other sites on the bone from sex can be diagnosed. All of us know that in the practical scenario it not possible to get complete skeletal remains through which and identity can be established. Therefore, there is an urgent need to follow the parameters which has a practical applicability in real scenario and develop a population specific standard so that we can help medico-legal personal whenever they confront with human bones/remains. The developed central Indian population specific standard for sex estimation in a modern Central Indian population may be beneficial to experts dealing with unknown remains of individuals in murder cases and mass disasters belong to this region.

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Ethical Clearance: Yes

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