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Sex determination from the proximal and distal part of the humerus in a Bulgarian contemporary population.

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ABSTRACT

Determination of sex from the skeleton is vital to medicolegal investigations. There is no longerany question that populations differ in size and proportions and these differences affect the metricassessment of sex. The purpose of this research is toestablish metric standards for sex determination from the humerus of Bulgarian contemporary population. On the other hand, when fragmentary and incomplete bones are all that are available to the forensic anthropologist for use in sex determination,non-metric and metric sex discriminating parameters that have been derived from complete bones may be of little use. In suchcircumstances, sex discriminating metric methods that are of specific application to fragmentary bones will be more useful. Circumference of the head, vertical diameter of the head, transverse diameter of the head and epicondylar breadth have been measured in 135 adult humeri of known sex (47 females and 88 males) and subjected to discriminant function analysis.Discriminant function equations were derived for individual and combined variables from theupper and lower ends of the humerus.The most effective single dimension is circumference of the head (90,1%). Multivariate discriminant function analysis including three variables of the proximal part of humerus (circumference of head, vertical diameter of head and transverse diameter of head) achieves an average accuracy from 90,4%.The upper end is more successful in sex identification than the lower end of humerus (90,4% vs 85,6%) because this area is subjected to greater biomechanicalfunction and stress.

Keywords: Humerus, Sex estimation, Discriminant function analysis, Forensic anthropology

Introduction

The estimation of sex is important in the forensic analysis of human skeletal remains. The identification is the cardinal parameter in skeletal analysis since the determination of age at death as well as race and stature to an extent depends on the sex of the deceased. When visual assessment of the pelvis and cranium, considered to be the most accurate method for sex estimation is not possible[1,2], due to the fragmented state of these bones and severe decomposition of the body, metric estimation is a useful approach if only for the high rates of accuracy[3,4,5,6]. Diverse studies have shown variability in osteometricdimensions between populations. Regional variations in the standard statistical values for determination of sex are an established fact.Numerous factors such as genetics/inheritance, environmental, racial,socio-cultural factorsetc areresponsible for these variations[7]. This study aims to demonstrate the accuracy of sex determination through use of the circumference of the head, vertical diameter of the head, transverse diameter of the head and epicondylar breadth of humerusamong the contemporary Bulgarian population.One of the advantages of the measurements on the proximal and distal end of humerus is that they can be used on fragmented bone where the shaft is missing. The study has applied value in the field of forensic anthropology.

Materials and methods

A total of 135 complete humeri from 47 females and 88 males were studied. The bones were collected from the Department of General and Clinical Pathology and Forensic Medicine, Medical University-Plovdiv and the Department of General and Clinical Pathology and Forensic Medicine, Medical University-Varna, Bulgaria. The bones included in this study fulfill the following criteria: show no anomalies, deformations or abrasions; have sustained no fractures previously; have reached skeletal maturity. They belong to Bulgarians born after 1910; the average age of the known male bones is 56,8 ± 13,44 years, and of the female ones 64.3 ± 13,97 years (Mean±SD). A total of four humeral dimensions (to the nearest millimeter) were taken using sliding caliper and steel tape. Measurements include *circumference of the head, vertical diameter of the head, transverse diameter of the head and epicondylar breadth* and were taken according standard procedure[8,9].(Fig.1)

Statistical package for social sciences (SPSS 17.0) was used. Wedefined the protocol as follows: for each pair, the humeral parameters were measured on both left and right humeri in order to assessif a statistical significant difference between the two sides could berecorded. The Paired simple t-test was used to compare the rightand the left sides. In order to minimize measurement error, wecompleted five measurements for each variable of each side. Then we excluded the least measurement and the greatest measurement. Finally, we computed the meanof the three other values and used it to characterize a bone. Basic descriptive statistics were computed. For each side,the values of the bones were tested for normality of the distribution by the Kolmogorov-Smirnov test. TheIndependentSamplestestfor equality of means of male and female independent samples was performed for all measured variables. All measurements that were obtainedfor all variables were also subjected to discriminant functionanalysis using univariate and multivariatemethods.

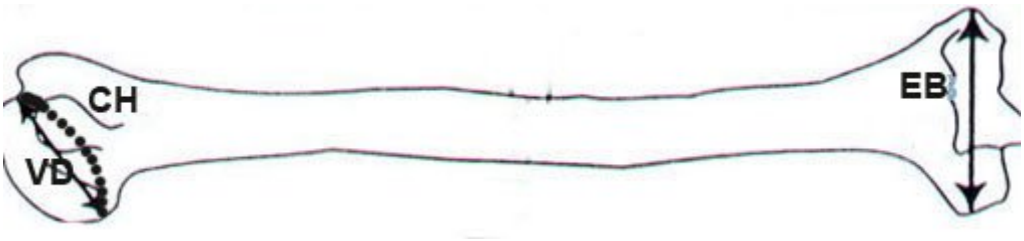

Fig.1 EB - epic.breadth of humerus, CH - circumference of the head and VD - vert. diameter of the head.

Results

The Kolmogorov-Smirnov test could not reject the hypothesisof normality of the distribution of the mean values computed ($P > 0,05$). No statistical difference wasfound between the right and left side for the mean values computed for both genders ($P > 0,05$), thus, allowingthe bones of both sides to be grouped together. However,only one bone, either the left or right, has been included inthe analysis (database – 135 humeri). All measurements are exhibiting highly significant sex differences (**Table 1**).As a result, these landmarks may successfully be used as sex discriminants.

Table 1. Summary statistics of variables

	M (88) F(47)				
	$\overline{x}$*SD*$\overline{x}$	***SD t P***			
1. circumference of the head	148,5	8,61	128,6	7,77	12,764 <0,001
2. vert. diameter of the head	47,9	3,02	41,2	2,90	12,075 <0,001
3. transv. diameter of the head	43,9	2,87	38,01	2,58	11,408 <0,001
4. epic. breadth of humerus	64,5	4,76	55,1	4,24	10,976 <0,001

Univariate analysis

Table 2 shows the fourmeasured variables and their corresponding unstandardized coefficients,constants and male and female group centroids. Themean value of each variable, its unstandardized coefficientand constant are used to formulate the corresponding discriminantfunction score equations, into which independentmeasured variables from unknown humerus may be substitutedfor sex identification.The percentage of identification of sex of theselected humerus sample is highest for the circumference of the head(90,1%).It gave the highest percentag of sex identification of the upper end of the bone. Theepicondylar breadth gave 85.6% of sex identification of the lower end of the humerus.

№ UnstandardizedDiscriminantMale and femaleSectioningPercentage					
Variable coefficientfunction constantgroup centroids point identified					
1	0,120	- 16,934	M=0,819	F=-1,561	-0,371 **90,1%**
2	0,334	- 15,228	M=0,775	F=-1,479	-0,352 88,8%
3	0,359	- 15,025	M=0,730	F=-1,393	-0,332 80%
4	0,217	- 13,300	M=0,780	F=-1,350	-0,285 85,6%

Table 2. Univariate discriminant function coeficients and sectioning points

Multivariate analysis

Tree variables of the upper end of humerus were selected by the multivariate procedure. The discriminant statistics and the classification percentage of the function can be seen in **Table 3 and Table 4**. The combined accuracy was 90,4 %. Adiscriminant score is obtained by multiplying each variableby itsunstandardized(raw) coefficient and adding them together along withthe constant. If the score is greater than the sectioning point,the individual will be classified as male, a value below thatpoint will be female.

Raw Standart Structure Sectioning			
coefficientcoefficientcoefficient point			
circumference of the head	0,087	0,706	0,989- 0,396
vert. diameter of the head	0,043	0,125	0,931
transv. diameter of the head	0,078	0,212	0,876
constant	-17,487		

Table 3. Multivariate Discriminant Function coefficients and sectioning points

Percent correctly classified		
MaleFemaleTotal		
92,1 %	87 %	**90,4 %**

Table 4. Percentage of correct sex classification for the discriminant function equation

Discussion

Diverse studies have shown that the humerus is a usefulbone for metric estimation of sex[3,6,7,10,11,12,13]as well as for nonmetric estimation of sex[14,15]. These studies have also shownthe differences in humeral dimensions between populations.Numerous factors such as genetics/inheritance, environmental, racial,socio-cultural factorsetc areresponsible for these differences.This is evidence of the need for creation of the population-specific standards.Cross-validation tests confirmed thatformulae developed from one population are less discriminating when applied toanother[16].

All four measurements of the Bulgarian humerus show the presence of sexual dimorphism.The most effective single dimension as determined by direct discriminant analysis is circumference of the head(90,1%). Multivariate discriminant function analysis including three variables of the proximal part of humerus (circumference of the head, vertical diameter of the head and transverse diameter of the head) achievesan average accuracy from 90,4 %.The upper end is, overall, more successful in sex identification than the lower end of the humerus (90,4 % vs 85,6 %). We conclude that proximal measurements are likely to be more accurate because this area is subjected to greater biomechanicalfunction and stress. Another possible explanation for this phenomenon is the fact that the motions of elbow joint are more restricted than the motions of shoulder joint. Morphology of the elbow joint has shownsexually dimorphic traits because of more distinct valgus angulationin women in comparison with men[17]. The lateral deviation ofthe human forearm from the axis of the

humerus is distinctivebetween men and women, being about 10–15 degreein men and 20–25 degreein women[18]. The soft tissue anatomy of the ulnar collateral ligament(which originates on the medial epicondyle and inserts on themedial aspect of the coronoid process of the ulna) as well as thehard tissue anatomy of the trochlear spool changes this carryingangle during elbow flexion. Hard tissue morphology relating to theulnar collateral ligament and the trochlear spool should thereforeexhibit differences between men and women which have been presentedhere. The medial epicondyle is obviously the origin of ligamentsthat preserve the carrying angle; the olecranon fossa shape isthe receptacle for the olecranon process superiorly and is connectedto the coronoid process inferiorly; and trochlear extension is anexpansion of the trochlear spool and the articulation between thetrochlea and the coronoid process. All of these anatomical soft tissuecharacteristics correlate to hard tissue characteristics and shouldbe sexually dimorphic[14]. The Bulgarian population is less sexually dimorphic in these anatomical landmarks,it may be explained by approximately same lifestyle of the men and women, osteoporosis, and general bodybuild, nowadays.

On the other hand, these dimensions are a useful tool when bones are fragmented or forensic data must be collected quickly.

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What's New in This paper

1.

What is already known on this topic?

The estimation of sex is important in the forensic analysis of human skeletal remains. Diverse studies have shown that the humerus is a useful bone for metric estimation of sex as well as for nonmetric estimation of sex. These studies have also shown the differences in humeral dimensions between populations. Numerous factors such as genetics/inheritance, environmental, racial, socio-cultural factors etc are responsible for these differences. This is evidence of the need for creation of the population-specific standards. 2.

What this study adds?

This study aims to demonstrate the accuracy of sex determination through use of the circumference of the head, vertical diameter of the head, transverse diameter of the head and epicondylar breadth of humerus among the contemporary Bulgarian population. One of the advantages of the measurements on the proximal and distal end of humerus is that they can be used on fragmented bone where the shaft is missing. All four measurements of the Bulgarian humerus show the presence of sexual dimorphism. The most effective single dimension as determined by direct discriminant analysis is circumference of the head (90,1 %). Multivariate discriminant function analysis including three variables of the proximal part of humerus (circumference of the head, vertical diameter of the head and transverse diameter of the head) achieves an average accuracy from 90,4 %. The upper end is, overall, more successful in sex identification than the lower end of the humerus (90,4 % vs 85,6 %). We conclude that proximal measurements are likely to be more accurate because this area is subjected to greater biomechanical function and stress. 3.

Suggestions for further development

When fragmentary and incomplete bones are all that are available to the forensic anthropologist for use in sex determination, non-metric and metric sex discriminating parameters that have been derived from complete bones may be of little use. In such circumstances, sex discriminating metric methods that are of specific application to fragmentary bones will be more useful.