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Sex determination from the femur in a Bulgarian modern population

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ABSTRACT

Assessment of sex from femoral dimensions has been tried before in several populations. Studies conducted so far have demonstrated that populations differ from one another in size and proportion. The discriminant formulae developed for determining sex for one population group cannot be applied on another. This study establishes standards for determining sex from complete femurs in a modern Bulgarian population. The sample is composed of 140 femora (82 male and 58 female) from elderly individuals born after 1920. Sixteen measurements were taken. No statistical difference was found between the right and left side ($p > 0.05$). The mean values of all measurements were significantly higher in males as compared to females ($p < 0.001$). The most dimorphic single parameter on the basis of univariate discriminant analysis was linear dimension - maximum length of femur (and bicondylar length) with 90,1 % accuracy rate for sexing individuals. The combination of maximum length, midshaft circumference and bicondylar breadth according to stepwise discriminant analysis provided the best result with 95,7 % accuracy. These findings indicate that linear dimensions such as length are more discriminating than breadth and

circumference measurements in long bones, unlike the previous studies. Probably, this is due to the influence of specific genetic factors.

Keywords: Forensic anthropology, Discriminant function analysis, Femur, Sexual dimorphism

Introduction

One of the main goals of forensic anthropology is sex determination, either from skeletal remains, decomposed or mutilated bodies, or cremains [1]. Data concerning the sexing potential of the femur are available in the literature and it is well known that these data vary a great deal according to the population sample from which they were taken[2,3,4,5,6,7]. These studies all contribute to demonstrate that there is considerable intra- and inter-population variability in femoral dimensions[8] and no single standardized formula can be used within all population groups for sexing individuals[2].

This is due to the influence of specific genetics, the environment and socio-cultural factors.

From the above, it is deduced that it is necessary to develop equations from skeletal parts often using Bulgarian population of known sex and age. The aim of this study is to conduct a discriminant analysis of sexual dimorphism in the modern Bulgarian femur and to establish standards for this population that will facilitate future forensic identifications. The Bulgarian data are then compared with data similarly from Thai, North American, African, East Asian and Croatian samples and than tested using functions derived from them to determine if populations specific sexing formulas are necessary.

Materials and Methods

A total of 35 pairs of adult femora (24 males, 11 females) and 105 single femora (58 male, 47 female) of modern Bulgarian population were measured. These bones were collected in 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 age and sex of all the specimens were documented. All of the individuals examined in this collection were born after 1920. We excluded bones with femoral prosthesis, cortical bone deterioration, extreme osteophytic activity and diffuse osteoarthritis.

Sixteen measurements were taken [Figure 1]. The measurements were made using digital osteometric board [Figure 2], vernier caliper (precision 0,01 mm) and graph paper according to standard procedure recommended by Martin and Saller[9] and Brauer[10] and Alekseev[11]: *maximum length (**M 1**), bicondylar length (**M 2**), „physiological" length from greater trochanter (**A**), sagittal midshaft diameter (**M 6a**), transverse midshaft diameter (**M 7a**), midshaft circumference (**M 8**), vertical diameter of the head (**M 18**), transverse diameter of the head (**M 19**), maximum head diameter, head circumference (**M 20**), sagittal subtrochanteric diameter (**M 10**), transverse subtrochanteric diameter (**M 9**), supero-inferior neck diameter (**M 15**), distal epiphyseal breadth (**M 21**), maximum sagittal diameter of the lateral condyle (**M 23**) and maximum sagittal diameter of the medial condyle (**M 24**).*

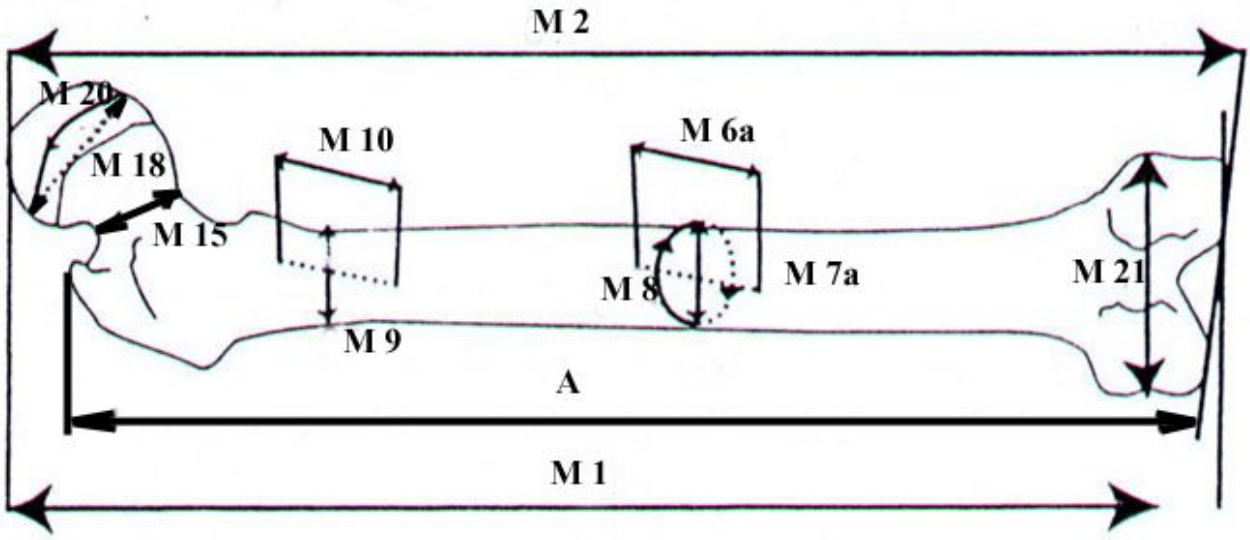

Figure 1 - Femoral parameters: maximum length (M 1), bicondylar length (M 2), „physiological" length from greater trochanter (A), sagittal midshaft diameter (M 6a), transverse midshaft diameter (M 7a), midshaft circumference (M 8), vertical diameter of the head (M 18), maximum head diameter, head circumference (M 20), sagittal subtrochanteric diameter (M 10), transverse subtrochanteric diameter (M 9), supero-inferior neck diameter (M 15) and distal epiphyseal breadth (M 21).



Figure 2 - Digital osteometric board. It provides measurement of the following linear dimensions: maximum length (M 1), bicondylar length (M 2) and „physiological" length from greater trochanter (A).

Statistical package for social sciences (SPSS 17.0) was used. We defined the protocol as follows: for each pair, the femoral parameters were measured on both left and right femora in order to assess if a statistical significant difference between the two sides could be recorded. *The Paired simple t-test* was used to compare the right and the left sides. In order to minimize measurement error, we

completed five measurements for each variable of each side. Then we excluded the least measurement and the greatest measurement. Finally, we computed the mean of the three other values and used it to characterize a bone. For each side, the values of the bones were tested for normality of the distribution by the *Kolmogorov-Smirnov test*. The *Independent Samples test* for equality of means of male and female independent samples was performed for all measured variables. All measurements that were obtained for all variables were also subjected to discriminant function analysis using *univariate, multivariate and stepwise methods.*

To assess population differences, cross-population tests were then carried out on the Bulgarian sample using the most accurate formulas derived from each of the groups – Thais[12], Croatia[13], Chinese[14], American blacks and whites[4] and South African whites[15].

Results

The characteristics of the sex repartition and the age mean value of the population are detailed in **Table 1.**

Table 1 Sex repartition and age mean value (N – number of cases, SD - standard deviation, M - male, F - female)

Sex N % Age mean Range SD
M 82 59 50,55 19 – 83 16,91
F 58 41 55,88 31 – 82 16,89

The Kolmogorov-Smirnov test could not reject the hypothesis of normality of the distribution of the mean values computed ($P > 0,05$). No statistical difference was found between the right and left side for the mean values computed for both genders ($P > 0,05$), thus, allowing the bones of both sides to be grouped together. However, only one bone, either the left or right, has been included in the analysis (database – 140 femora). All measurements are exhibiting highly significant sex differences **(Table 2).**

Table 2 Summary statistics of variables

Variables	***M (82)***		***F(58)***			
	$\bar{x}$	***SD***	$\bar{x}$	***SD***	***t***	***P***
1.maximum length	461,77	19,91	411,74	23,24	13,656	<**0,001**
2. bicondylar length	460,15	19	410,42	23,21	13,571	<**0,001**
3."physiological" length from greater trochanter	438,34	19,79	393,10	19,56	13,381	<**0,001**
4.saggital midshaft diameter	30,23	2,75	26,06	2,30	9,424	<**0,001**
5.transverse midshaft diameter	27,67	2,21	24,89	1,78	8,216	<**0,001**
6.midshaft circumference	93,41	5,52	83,00	4,57	11,763	<**0,001**
7.vertical diameter of the head	47,53	2,45	42,00	3,00	11,936	<**0,001**
8.transverse diameter of the head	48,10	2,48	42,70	2,93	11,762	<**0,001**
9.maximum head diameter	48,33	2,53	42,89	2,84	13,656	<**0,001**
10.head circumference	156,24	7,87	138,12	9,23	12,483	<**0,001**
11.saggital subtrochanteric diameter	27,22	1,98	24,07	2,08	9,068	<**0,001**
12.transverse subtrochanteric diameter	30,48	4,42	27,11	1,99	5,431	<**0,001**
13.supero-inferior neck diameter	34,12	2,51	28,98	3,36	9,849	<**0,001**
14.distal epiphyseal breadth	84,92	4,27	74,62	3,76	14,744	<**0,001**
15.maximum saggital						

diameter	65,46	3,21	58,86	3,42	11,656	<**0,001**
of the lateral condyle						
16. maximum saggital						
diameter	64,90	3,37	58,01	3,84	11,223	<**0,001**
of the medial condyle						

Univariate analysis

Table 3 shows the sixteen measured variables and their corresponding unstandardized coefficients, constants and male and female group centroids. The mean value of each variable, its unstandardized coefficient and constant are used to formulate the corresponding discriminant function score equations, into which independent measured variables from unknown femurs may be substituted for sex identification. The percentage of identification of sex of the selected femur sample is highest for the maximum length and bicondylar length of the femur (**90,1%**). The vertical diameter of the head gave the highest percentage (**86.4%)** of sex identification of the upper end of the femur. The distal epiphyseal breadth gave the highest percentage (**88.6%**) of sex identification of the lower end of the femur.

№ Unstandardized Discriminant Male and female Sectioning Percentage						
Variable coefficient function constant group centroids point identified						
1	0,047	-	20,654	M=0,971	F=-1,372	-0,200 **90,1%**
2	0,047	-	20,580	M=0,965	F=-1,364	-0,199 **90,1%**
3	0,051	-	21,296	M=0,951	F=-1,345	-0,197 87,9%
4	0,388	-	11,058	M=0,670	F=-0,947	-0,138 80,7%
5	0,489	-	12,960	M=0,563	F=-0,796	-0,116 73,6%
6	0,118	-	17,574	M=0,887	F=-1,254	-0,185 85,7%
7	0,371	-	16,768	M=0,848	F=-1,199	-0,175 **86,4%**
8	0,374	-	17,137	M=0,836	F=-1,182	-0,173 85,7%
9	0,375	-	17,281	M=0,845	F=-1,195	-0,175 85,0%
10	0,118	-	17,574	M=0,887	F=-1,254	-0,183 85,7%
11	0,494	-	12,797	M=0,887	F=-1,254	-0,133 72,1%
12	0,276	-	8,027	M=0,645	F=-0,911	-0,08 79,3%
13	0,345	-	11,050	M=0,735	F=-1,040	-0,152 85,0%
14	0,246	-	19,812	M=1,048	F=-1,482	-0,217 **88,6%**
15	0,303	-	19,003	M=0,828	F=-1,171	-0,171 80,0%
16	0,280	-	17,344	M=0,798	F=-1,128	-0,165 80,7%

Table 3 Univariate discriminant function coeficients and sectioning points***Stepwise analysis***

The result of this analysis is shown in **Table 4.** The maximum length, distal epiphyseal breadth and midshaft circumference were the three variable selected out of the sixteen entered into the analysis for the femur.

Table 4 Multivariate (Stepwise) Discriminant Function coefficients and sectioning points

Function variable	***Unstandardized coefficient***	***Standardized coefficient***	***Wilk's lambda***	***Structure coefficient***	***Constant centroids***	***Group Sectioning point***	***Pecentage classified***
distal epiphyseal breadth	0,136	0,552	0,378	0,865	-24,243	M=1,211 F=-1,712	-0,2505 **95,7 %**
Maximum length	0,019	0,397	0,348	0,802			
midshaft circumference	0,057	0,295	0,337	0,690			

Cross-population tests

The best results are from South African white and American black derived formulas (81% in males and 93,1% in females; 92,6% in males and 87,9% in females). **(Table 5).**

Table 5 Cross-test of sex determination accuracy using discriminant function formulas derived from four geographically diverse populations.

Cross-validation Total and Comparative N Group	***Male Female % %***	***Dimensions in Function***
Present study 140 95,1% **96,6%**		distal epiphyseal breadth + maximum length + midshaft circumference
Thai formula 140 **100% 41,3%** *on Bulgarian*		distal epiphyseal breadth + maximum head diameter
Thais original 104 94,2% 94,1% *Study*		
Chinese formula 140 **100% 58,6%** *on Bulgarian*		distal epiphyseal breadth + midshaft circumference
Chinese original 76 94,6% 94,9% *Study*		
S Afr white formula 140 **81% 93,1%** *On Bulgarian*		maximum head diameter + distal epiphyseal breadth + transverse midshaft diameter
S Afr white original 105 85,7% 91,8% *Study*		
Am white formula 140 **0% 100%** *on Bulgarian*		maximum head diameter + distal epiphyseal breadth + maximum length + midshaft circumference
Am white original 101 91,1 % 92,6 % *Study*		

Amer black formula 140 **92,6%** **87,9%** *on Bulgarian*	maximum head diameter + distal epiphyseal breadth + maximum length + midshaft circumference + sagittal midshaft diameter
Amer black original 103 92% 93,4% *Study*	
Croatian formula 140 **73%** **89,6%** *on Bulgarian*	maximum head diameter + distal epiphyseal breadth
Croatian original 195 92.3% 96.7% *Study*	

Discussion

All sixteen measurements of the Bulgarian femur show the presence of sexual dimorphism. The most dimorphic single variables on the basis of univariate discriminant analysis were linear dimensions - maximum length and bicondylar length of femur with **90,1 %** accuracy rate for sexing individuals. This result is contrary to the finding of Ruff et al.[16], according to which the contemporary long bone is less pronouced variability in diaphysis than its epiphysis, because of the influence of specific socio-cultural factors. This fact may be explained by approximately same lifestyle of the men and women, nowadays.

At the lower end of the femur, distal breadth is the most successful in sex identification - **88,6%.** This supports previous studies that showed that distal breadth was the important sex discriminator in some studies[2,12,14,15]. In the upper end, vertical diameter of the head is the most successful in sex determination (86,4%). The lower end is, overall, more successful in sex identification then the upper end of the femora.

The result of our study confirm that Bulgarian femur is a good sex predictor, with classification accuracy reaching to **95,7%.** Stepwise discriminant function analysis selected three variables, maximum length, midshaft circumference and bicondylar breadth, to achieve this sex determination.

The bad results of cross-population tests are evidences of the need for creation of the population-specific standards.

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