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Original scientific paper

Sex Estimation from the Upper End of Bulgarian Femur Using 3D Hand-Held Laser Scanner

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A B S T R A C T

The present study aimed to establish standards for determining sex from the upper end of the femur in a modern Bulgarian population focused on an innovative approach to the numerical assessment of gluteal tuberosity through 3D visualization and its use as a sex predictor. The sample is composed of 156 femora. Seven measurements were taken: vertical head diameter, transverse head diameter, maximum head diameter, head circumference, sagittal subtrochanteric diameter, transverse subtrochanteric diameter and supero-inferior neck diameter. The surface of gluteal tuberosity was captured in a 3D image, using a hand-held laser scanner. A 3D shape comprising two tetrahedrons with a common base was constructed. The volume of the rough area of muscle insertion was approximately equal to the sum of the area of volumes of these two tetrahedrons (volume). Several points were placed on the surface of the area of roughness on the 3D image. Based on these points a two-dimensional shape was created which was a function of the three-dimensional one. Thus, volume, area of the newly-formed shape, its greatest elevation and the three angles between the constructed planes were used as sex predictors. The mean values of all metric and 3D measurements showed significant differences between genders p<0.001, volume p=0.02. According to stepwise discriminant analysis the combination of head circumference, sagittal subtrochanteric diameter, transverse subtrochanteric diameter and supero-inferior neck diameter provided 88.5% accuracy. Using the same analysis the combination of volume, elevation and angle b1 provided the best result with 93.0% accuracy.

Key words: *forensic anthropology, discriminant function analysis, femur, sexual dimorphism, laser scanner*

Introduction

Gender and age are important parameters for forensic identification, either of human skeletal remains, decomposed or mutilated bodies, or cremains[1,2]. Thanks to DNA analysis it is easy to achieve sex estimation, but this is still an expensive and time-consuming process. The estimation of sex by an osteometric method is a quick procedure applied in cases of mass disasters, burned skeletal remains, mass burials, etc. Unfortunately in such accidents, the forensic anthropologist is confronted with fragmentary, mixed or scattered skeletons and some of the fragments may be missing. This makes sex estimation very difficult. Therefore it is necessary to obtain sex – discriminating standards for fragments, which have the following features: 1. fairly high sex dimorphism of their metric and non-metric characteristics; 2. fairly high resistance to external and mechanical factors; and 3. their frequent use as a sex discriminant from skeletal remains.

In general, the upper end of the femur possesses such features. Firstly, the significant sexual dimorphism of this part is based on several facts:

a. the relative axial skeleton weight of males is more than that of females[3] and the first brunt of this body weight is borne by the upper end of the femur[4];

b. another factor involving the upper part of the femur is the modification of the female pelvis with respect to its specialized function of reproduction. Thus, the stress and strain experienced by the femur is different in males and females[4,5];

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c. influence of the difference between male and female gait. Females have significantly greater hip flexion and less knee extension before initial contact, greater knee flexion moment in pre-swing, and greater peak mechanical joint power absorption at the knee in pre-swing. These biomechanical differences may be important for the development of the insertions of muscles[6,7]; *d.* a higher incidence of congenital hip dislocation and osteoarthritis in females[7];

e. the anthroposcopic landmarks (such as gluteal tuberosity, etc.) differ considerably in men and women in their sizes and impressions[4,8].

Secondly, the femur is a paired bone, which is the largest and the strongest part of the human skeleton. Besides, the upper end is protected by adjacent tissues and bones of the pelvis. On the grounds of these features the upper end of the femur can almost always be found at the crime scene in cases of decapitated, dismembered or cremated bodies of victims of murder.

The aim of our study was to create metric standards for sex estimation of the proximal femur in a Bulgarian contemporary population by osteometric analysis. A second goal was to focus on an innovative approach to the numerical assessment of the gluteal tuberosity through 3D visualization and its use as a sex predictor like Purkait's sex indicator at the upper end of femur[4], which is also a quantitative assessment of muscle traction and directly related to the general functional ability of the person to stress and strain.

Materials and Methods

A total of 156 femora representing 156 different individuals (95 male, 61 female) of a modern Bulgarian population were measured. In order to test the bilateral variation in 2D and 3D measurements, 35 sets of femora were subjected to paired t-test. If the difference was found to be insignificant at the 0.05 level, this would allow bones from either side to be used in the study. As this was the case, only one bone, either the left or right, from each individual was chosen randomly and included in the analysis. 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 age and sex of all the specimens were documented. All of the individuals examined in this collection were born after 1920. Bones with femoral prosthesis, cortical bone deterioration, extreme osteophytic activity and diffuse osteoarthritis were excluded.

Firstly, seven measurements were taken. A vernier caliper (precision 0.01mm) and graph paper were used according to the standard procedure recommended by Martin and Saller[9] and Brauer[10], to determine vertical head diameter (M 18), transverse head diameter (M 19), maximum head diameter, head circumference (M 20), sagittal subtrochanteric diameter (M 10), transverse subtrochanteric diameter (M 9) and supero-inferior neck diameter (M 15).

Secondly, the gluteal tuberosity was scanned using a Hand-Held Laser Scanner (FastSCAN)[11,12]. It was the object of analysis due to the following features and fact: 1. Males are relatively stronger and use their muscles more heavily than females[13,14]. 2. The heaviest muscle in the human body, gluteus maximus, which provides hip extension[15], is inserted in it. 3. The tuberosity is the thickened area of a bone where a tendon attaches. It is thickened because bone growth has responded to the increased stress at the area of attachment (any stress on a bone causes the stressed area to thicken and grow stronger)[16]. 4. Gluteus maximus stabilizes the hip joint, which in turn shows great sexual dimorphism of the shape and size of the muscle markers[3]. 5. The activity and function of gluteus maximus are continuous and daily. Gluteus maximus has many different functions such as providing sacroiliac joint stability, strength for lifting and control of gait and it is hypothesised that it provides stability to the sacroiliac joint by creating a selfbracing mechanism[17]. Gluteus maximus has also been shown to be an important muscle during lifting activities[17]. Wilson et al.[17] have shown that emphasis should be placed on contraction during the early phase of the lift to provide pelvic stability thus enabling a safe and effective movement to occur. Gluteus maximus also makes a large contribution to gait and ineffective functioning can compromise many aspects of the gait cycle[17].

Based on these characteristics, the authors hypothesized that this anthroposcopic landmark differs considerably in men and women in its size and impression and could be used successfully as a sex predictor.

As a first step of the scanning analysis the surface of the gluteal tuberosity was captured as a 3D image. Afterwards, the following points (markers) were placed on the surface of the 3D image in physiological position of the femur as follows: the uppermost point of the margin between the roughened area and – femoral surface margin (point a); the lowest point of the roughened area – femoral surface margin or on the margin where it meets the lateral lip of the linea aspera (point d); the most medial point of the area of roughness – femoral surface margin (point b); the most lateral point on the roughened area – femoral surface margin (point f); and the most elevated point which was empirically selected on the roughened area itself (point 2). Each of these points was defined by certain x, y and z values. The result was a 3D shape comprising two tetrahedrons (abf2 and dbf2) with a common base (bf2). Therefore, the volume of the roughness was approximately equal to the sum of the volumes of these two tetrahedrons and it represented the first 3D variable: $V=V_{abf2}+V_{dbf2}$[12]. The measurement unit is in mm^3. This method of calculation of volumes of descriptive characteristics by creation of geometrical figures similar in size and shape to the studied objects and their use as sex discriminants has been applied, for example, in morphological assessment of the lips and the external nose in facial reconstruction[16,17] (Figure 1 and 2).

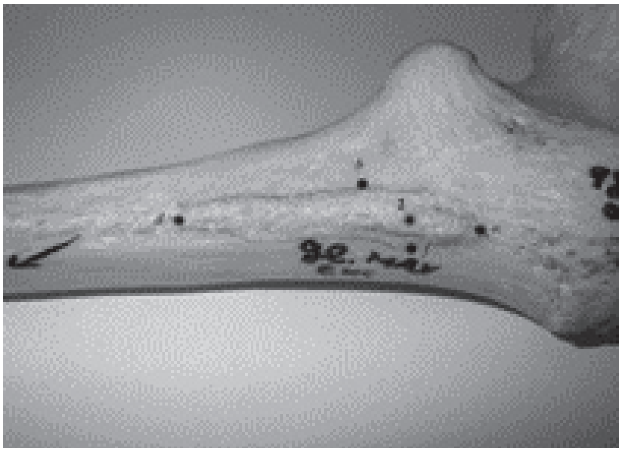


Fig.1. Locations of the points – a, f, d, b and 2.

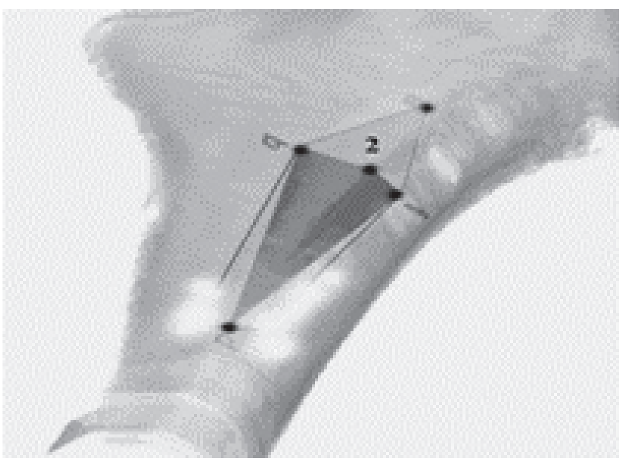


Fig.2. Creation of two tetrahedrons (abf2 and dbf2) with common base (bf2), using FastSCAN.

In the second step of the scanning analysis, several of the highest as well as the lowest points on the roughened area itself were selected (points 1, 2, 3, 4, 5 and 6; the bigger the number of these points, the more precise the method is, as the impression of the roughened area is more accurately described). Each point marked was defined by x, y and z values. Subsequently, the following steps were performed: 1. The midpoint of the straight line bf (point g) was found. 2. Three planes were created – (the first one A was determined by points a, g and d; the second one B – by points a, f and d; and the third one C – by a, b and d), so that the straight line ad lay simultaneously on all three planes created. 3. The angles a1 (between planes A/C), b1 (between planes A/B), and c1 (between planes C/B) were measured; they represented other 3D sex predictors and their measurement units were in degrees. 4. Points 1, 2, 3, 4, 5 and 6 were transposed to the newly formed plane A, as the elevations at which they were positioned were respectively above planes B and C and were, respectively, equal to their elevations over the straight line ad in plane A. This resulted in the formation of a 2D polygonal shape, defined within the following points a, g, d and transposed 1, 2, 3, 4, 5 and 6. 5. The newly created two-dimensional shape was a function of the three-dimensional one. The area of the resultant shape was measured (area) as well as its greatest elevation in relation to line ad (elevation) and these measurements represented other sex predictors. The measurement units were in mm^2 and mm (Figure 3 and 4).

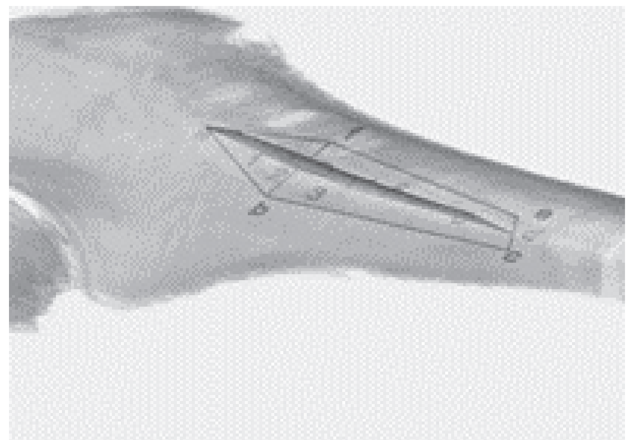


Fig.3. The newly created two-dimensional shape is marked with darker color, using FastSCAN.

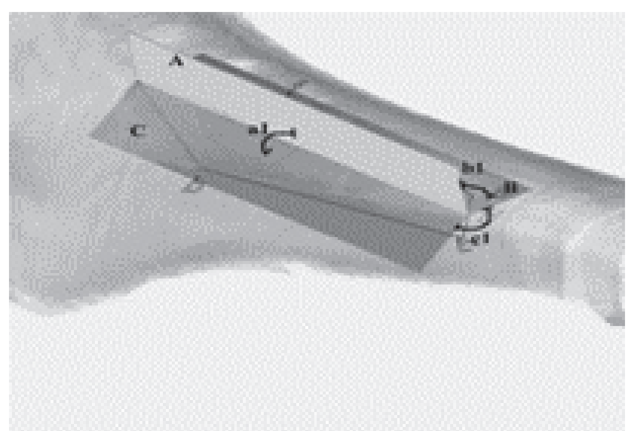
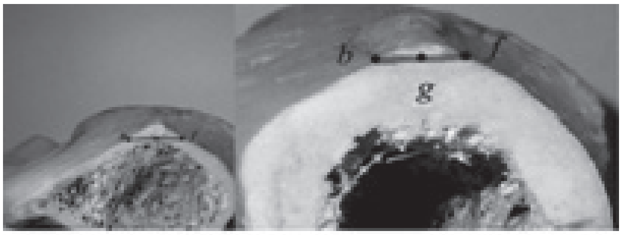


Fig.4. Location of the planes – A, C, B and their angles – a1, b1, c1, using FastSCAN.

Why were the above points and 3D predictors selected? 1. Points a, d, b, f, and angles a1,b1,c1 characterize the size of the point of insertion and the function of gluteus maximus (extension, external rotation, abduction and adduction) respectively. 2. Points 1, 2, 3, 4, 5 and 6 characterize the impression of the point of insertion. 3. Point g (midpoint of the line bf) also characterizes the functional activity of the muscle, especially the external rotation of the hip – the wider the roughness, the lower the position of point g under straight line ad, and the larger the area of the 2D polygonal shape and vice versa (Figure 5).



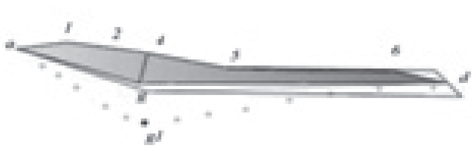


Fig.5. Showing the dependence between the location of point g/ g1 (and the area of 2D shape) and the width of the area of roughness.

The analysis of the scanned image (the creation of planes, lines, 2D shape, and calculation of 3D predictors) was performed by 3D CAD Design Software AutoCAD 2009, according to its instructions.

Statistical package for social sciences (SPSS 17.0) was used for statistical analysis. The 2D and 3D measurements were repeated three times by the same observer and the resulting mean value was used to reduce intra-observer error. For each side, the variables of the bones were tested for normality of the distribution by the Shapiro-Wilk test, which is sensitive enough to test a small sample. The Box's Test was utilized to assess whether the variance- and covariance- matrices were equal. 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 multivariate and stepwise methods.

Results

The distribution according to sex and age mean values of the population is detailed in Table 1.

TABLE 1

SEX DISTRIBUTION AND AGE MEAN VALUES

Sex	N	%	Mean Age	Range	SD
M	95 (L 30 R 65)	61	54.85	20 – 82	16.41
F	61 (L 30 R 31)	39	55.33	20 – 82	16.42

N – number of cases, SD – standard deviation,
M – male, F – female, L – left side, R – right side

Analysis of anthropometric dimensions

The p value was determined by Shapiro–Wilk test. It was greater than the chosen alpha level, therefore the null hypothesis that the data came from a normally distributed population was not rejected. No statistical difference was found between the right and left side for the mean values computed for both genders ($p>0.05$), thus bones from either side could be used in the study. Only one bone, either the left or right, from each individual was chosen randomly and included in the database. The mean values of all male variables were significantly greater than those of females $p<0.001$ (Table 2).

TABLE 2

SUMMARY STATISTICS OF ANTHROPOMETRIC VARIABLES

Variable	M (N=95)		F (N=61)			
	Mean	SD	Mean	SD	F factor	P value
Vertical head diameter	47.53	2.62	42.09	2.09	0.577	<0.001
Transverse head diameter	48.10	2.61	42.74	2.90	0.899	<0.001
Maximum head diameter	48.34	2.61	42.95	2.81	0.019	<0.001
Head circumference	156.22	8.23	138.36	9.15	1.053	<0.001
Sagittal subtrochanteric diameter	27.25	2.04	24.00	2.06	0.018	<0.001
Transverse subtrochanteric diameter	30.87	2.76	27.22	2.03	2.738	<0.001
Supero-inferior neck diameter	34.17	2.53	29.00	3.30	3.582	<0.001

Multivariate (combined) analysis

Based on Box's test, the significance value of 0.620 indicated that the data did not differ significantly from multivariate normal. Therefore one could proceed with discriminant analysis. The coefficients, constant and sectioning point for formulating the discriminant function score equation are shown in Table 3. The standardized coefficients indicated the relative importance of each variable in contributing to discrimination between the groups – the higher the coefficient the more it contributed to the discriminant score relative to the other variables. It conveyed the importance of each variable to the function as conditioned by the presence of the other variables[4]. Thus, the head circumference had the maximum discriminating power. The structure coefficient gave an idea as to how much a variable contributed to a function on its own. It defined the relationship between the function and the variables irrespective of the group difference[4]. The head circumference also had the highest contribution. The percentage of sex identification by this method was 88.0% (average classified).

Stepwise analysis

The results of this stepwise analysis are shown in Table 4. The head circumference, sagittal subtrochanteric diameter, transverse subtrochanteric diameter and supero-inferior neck diameter were the four variables selected out of the seven entered into the analysis for the proximal part of femur. The combination of these predictors showed the highest accuracy of 88.5% (average classified), 93.4% (females classified) and 85.3% (males classified).

Analysis of 3D- parameters of the tuberositas glutea femoris

The Shapiro-Wilk test could not reject the hypothesis of normality of the distribution of the mean values computed with the exception of the distribution of angle a1. Thus, this independent variable is not included in the discriminant models. No statistical difference was found between the right and left side for the mean values computed for both genders (p >0.05), thus bones from either side could be used in the study. Only one bone, either the left or right, from each individual was chosen randomly and included in the database. The mean values of all male variables were significantly different than those of females at p<0.001, except for the gender difference in the volume which was at p =0.020 (Table 5).

Multivariate (combined) analysis

Based on Box's test, the significance value of 0.790 indicated that the data did not differ significantly from multivariate normal. The coefficients, constant and sectioning point for formulating the discriminant function score equation are shown in Table 6. The angle b1 had the maximum discriminating power. It also had the highest contribution in the relationship between the function and the variables. The percentage of sex identification by this method was 92.0% (average classified), 90.6% (females classified) and 94.1% (males classified).

Stepwise analysis

The results of this analysis are shown in Table 7. The volume, angle b1 and elevation were the three variables selected out of the five entered into the analysis for the gluteal tuberosity. The combination of these parameters

TABLE 3

MULTIVARIATE (COMBINED) DISCRIMINANT FUNCTION COEFFICIENTS AND SECTIONING POINTS

Function variable*	Unstandardized coefficient*	Standardized coefficient*	Structure coefficient	Constant*	Group centroids	Sectioning point* (M+F/2)	Percentage classified
Vertical head diameter	–0.058	–0.161	0.823	18.273	M=0.933 F=–1.454	–0.2605	88.0%**
Transverse head diameter	–0.042	–0.141	0.828				
Maximum head diameter	0.069	0.186	0.839				
Head circumference	0.047	0.407	0.869				
Supero-inferior neck diameter	0.124	0.356	0.757				
Sagittal subtrochanteric diameter	0.149	0.307	0.661				
Transverse subtrochanteric diameter	0.160	0.402	0.610				

* – parameters used in formulating function score equation, M – male, F – female
** – correct combined (%)

TABLE 4

MULTIVARIATE (STEPWISE) DISCRIMINANT FUNCTION COEFFICIENTS AND SECTIONING POINTS

Function variable*	Unstandardized coefficient*	Standardized coefficient	Wilk's lambda	Structure coefficient	Constant*	Group centroids	Sectioning point *(M+F/2)	Pecentage classified
Head circumference	0.040	0.343	0.434	0.871	–18.299	M=0.932 F=–1.452	–0.2600	88.5%** 93.4%*** 85.3%****
Transverse subtrochanteric diameter	0.162	0.407	0.460	0.661				
Sagittal subtrochanteric diameter	0.147	0.301	0.438	0.662				
Supero-inferior neck diameter	0.117	0.333	0.436	0.758				

* – parameters used in formulating function score equation, M – male, F – female
** – correct combined (%)
*** – correct female (%)
**** – correct male (%)

TABLE 5

SUMMARY STATISTICS OF 3D VARIABLES

Variable	M (N=95)		F (N=61)			
	Mean	SD	Mean	SD	F factor	P value
Volume (V)	0.69	0.12	0.62	0.14	2.695	=0.020
Angle (a1)	88.63	15.34	58.49	21.90	U=323.0*	<0.001
Angle (b1)	149.36	27.82	208.45	25.60	0.396	<0.001
Angle (c1)	122.0	22.1	94.88	19.6	3.965	<0.001
Area (Ar)	1.37	0.2	1.17	0.14	4.877	<0.001
Elevation (E)	0.41	0.1	0.27	0.08	0.796	<0.001

N – number of cases, SD – standard deviation, M – male, F – female, * – using Mann-Witnney U-test for equality of means of male and female independent samples, which were abnormally distributed

TABLE 6

MULTIVARIATE (COMBINED) DISCRIMINANT FUNCTION COEFFICIENTS AND SECTIONING POINTS

Function variable*	Unstandardized coefficient*	Standardized coefficient*	Structure coefficient	Constant*	Group centroids	Sectioning point* (M+F/2)	Percentage classified
Volume (V)	3.990	0.540	–0.184	–6.561	M=–0.884	0.4975	92.0%**
						F=1.879	90.6%***
							94.1%****
Angle (b1)	0.037	1.002	0.788				
Angle (c1)	0.016	0.350	–0.459				
Area (Ar)	–0.886	–0.168	–0.378				
Elevation (E)	–8.145	–0.789	–0.516				

* – parameters used in formulating function score equation, M – male, F – female
** – correct combined (%)
*** – correct female (%)
**** – correct male (%)

TABLE 7

MULTIVARIATE (STEPWISE) DISCRIMINANT FUNCTION COEFFICIENTS AND SECTIONING POINTS

Function variable*	Unstandardized coefficient*	Standardized coefficient	Wilk's lambda	Structure coefficient	Constant* centroids	Group	Sectioning point *(M+F/2)	Pecentage classified
Volume (V)	3.928	0.531	0.424	–0.192		M=–0.847		93.0%**
					–4.296	F=1.799	0.476	90.6%***
								94.1%****
Angle (b1)	0.029	0.789	0.624	0.822				
Elevation (E)	–8.693	–0.842	0.484	–0.538				

* – parameters used in formulating function score equation, M – male, F – female
** – correct combined (%)
*** – correct female (%)
**** – correct male (%)

TABLE 8

RESULTS OF JACK KNIFE PROCEDURE

Function	Males% (N=95)		Females% (N=61)		Percentage identified
	Classified	Misclassified	Classified	Misclassified	
Volume + Angle b1 + Elevation	92.6%	7.4%	90.6%	9,4%	92.0%

N – number of cases

showed the highest accuracy of 93.0% (average classified), 90.6% (females classified) and 94.1% (males classified). Table 8 gives the result obtained by Jack knife method. The procedure was applied using this combination, because it provided the highest percentage of identification of sex. The result of the test supported the original accuracy (fairly equal result, 92.0% vs. 93.0% in the original analysis). Thus any doubt of overestimation in prediction accuracy of the original sample was dispelled.

Discussion

All seven anthropometric measurements of the proximal segment showed the presence of sexual dimorphism of the femur. The results of our study confirm that the upper end of Bulgarian femur is a fairly good sex predictor with classification accuracy reaching 88.5%. Stepwise discriminant function analysis selected four independent variables – head circumference, sagittal subtrochanteric diameter, transverse subtrochanteric diameter and supero-inferior neck diameter, to achieve this sex determination. Our results support previous studies based on the sexual determination of the upper end of femur. Asala et al.[18] found 85.1% accuracy of sex identification of the proximal end in South African black population, but this rate was derived from combined variable analysis including vertical head diameter, upper epicondylar length, supero-inferior neck diameter, sagittal subtrochanteric diameter and transverse subtrochanteric diameter. Šlaus et al.[19] showed that the proximal segment of Croatian femur was a good indicator for gender, with a classification rate reaching 94.4%, using only maximum head diameter. Trancho et al.[20] investigated Spanish femora and demonstrated classification accuracy of the discriminant functions based on two variables of the femurs upper end – transverse head diameter only (93.86% accuracy) and vertical head diameter only (91.23% accuracy). Purkait and Chandra[21] found 93.5% rate based on maximum head diameter only. Overall, the anthropometric analysis of the upper end of femur was successful in sex identification. But the utilizations of different variables and discriminant methods proof the need for the creation of population specific standards.

All 3D variables characterizing the gluteal tuberosity showed also significant differences in two sexes, which make them suitable for sex discriminants.

Muscle activity is higher in men than in women[12]. This, results in the osteometric landmarks being in favour of the male sex. Therefore, the volume, area and elevation of the roughness in males are higher than those in females.

The angle c1 in males is higher than in females, due to the fact that the subtrochanteric sagittal diameter of the male femur is higher than that of the female femur. The angle a1 of the female femur exhibit also significantly low value. The reason is that the greater force of the lower part of gluteus maximus performs adduction in the hip joint during female „aesthetic walking"[22]. Therefore it pulls plane A medially. Our explanation is based on studies of gender differences in walking by Chumanov et al.[23], who determined that females displayed significantly greater peak hip internal rotation and adduction during stance, compared to males. According to the mathematical rule {360°–(a1+c1)}, the angle b1 showed a sexual difference, contrary to other angles (Figure 6 and 7).

Conclusion

The present study found that for sex determination the quantitative assessment of femoral roughness displayed higher classification accuracy (93.0%) than anthropometric dimensions of the proximal end of femur (88.5%). Our 3D finding demonstrated innovative method for objective evaluation of the muscle's attachments which can be used successfully for sex determination, especially in case of highly fragmented bones that impede anthropometric analyses. This novel osteometric method will be effective for use in both archaeological and forensic contexts. The initial scanning of the skeletal remains by hand-held laser scanner could be performed by individuals without specific archaeological or anatomical training – a boon in the fraught circumstances of mass disasters and mass burials. Besides, other 3D scanning devices as computed tomography could be used with the proposed methodology as a substitute.

Acknowledgments

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REFERENCES

1. KROGMAN W, ISCAN M, The Human Skeleton in Forensic Medicine (Springfield IL, C Thomas, 1986). — 2. ALEXANDROV A, NIKOLOV D, GERGOV G, BRAINOVA I, GOSHEV M, KIRYAKOVA T, CHRISTOV A, HRISTOV S, A case of death, caused by exploded truck tire. In: Proceedings (The 9th annual meeting of the Balkan academy of forensic sciences, Istanbul, 2013). — 3. WILLIAM PL, WARWICK R, Gray's Anatomy, 36th ed. (Churchill Livingstone, Edingburgh, 1980). — 4. PURKAIT R, Forensic Sci Int, 147 (2005) 135, DOI: 10.1016/j.forsciint.2004.08.005. — 5. BREATHNACH A, Frazer's Anatomy of Human Skeleton, 5th edition (J.A. Churchill, London, 1958). — 6. KERRIGAN DC, TODD MK, DELLA CROCE U, Am J Phys Med Rehabil, 77(1) (1998) 2, DOI: 10.1097/00002060-199801000-00002. — 7. PAPALOUCAS C, FISKA A, PISTEVOU-GOMPAKI K, DEMETRIOU T, Aristotle University Medical Journal, 34(3) (2007) 45. — 8. HAMILL J, KNUTZEN K, Biomechanical Basis of Human Movement, 3rd edition (Lippincott Williams & Wilkins, 2009). — 9. MARTIN R, SALLER K, Lehrbuch der Anthropologie in systematicsher Darstellung (Band I. Fischer, Stuttgart, 1957). — 10. BRAUER G, Osteometrie. In: R. Knussman, Anthropologie:

Handbuch der Vergleichenden Biologie des Menschen, Ban I. Wesen und Methoden der Anthropologic. Teil I. Wissenschaftstheorie, Geschichte, Morphologische Methoden, (Gustav Fischer Verlag, Stuttgart, 1988). — 11. www.fastscan3d.com. — 12. TIMONOV P, SIVKOV S, PETLESHKOVA T, FUSOVA A, RADOINOVA D, KARASLAVOVA E, Comptes rendues de l'Academie bulgare des Sciences, 66(6) (2013) 893. — 13. SCHLOSSBERG L, ZUIDEMA G, The Johns Hopkins Atlas of Human Functional Anatomy, Fourth edition, (JHU Press, 1997). — 14. https://jonbarron.org/article/human-anatomy-physics-muscles. — 15. WILSON J, FERRIS E, HECKLER A, MAITLAND L, TAYLOR C, New Zeal J Physiother, 33(3) (2005) 95. — 16. SFORZA C, GRANDI G, BINELLI M, DOLCI C, DE MENEZES M, FERRARIO V, For Sci Int, 200 (2010) 182. — 17. SFORZA C, GRANDI G, DE MENEZES M, TARTAGLIA G, FERRARIO V, For Sci Int, 204 (2010) 205. — 18. ASALA S, BIDMOS M, DAYAL M, For Sci Int, 145 (2004) 25. — 19. ŠLAUS M, STRINOVIC D, ŠKAVIC J, PETROVECKI V, J Forensic Sci, 48(3) (2003) 1. — 20. TRANCHO G, ROBLEDO B, LOPEZ-BUEIS I, SANCHEZ J, J Forensic Sci, 42(2) (1997) 181. — 21. PURKAIT R, CHANDRA H, For Sci Int, 146(1) (2004) 25. — 22. HIROKAWA S, J Biomed Eng, 11 (1989) 449. DOI:10.1016/0141-5425(89)90038-1.— 23. CHUMANOV E, WALLSCHEFFLER C, HEIDERSCHEIT B, Clinical Biomechanics, 23 (2008) 1260, DOI: 10.1016/j.clinbiomech.2008.07.011.

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PROCJENA SPOLA NA GORNJEM OKRAJKU BEDRENE KOSTI U BUGARSKOJ POPULACIJI POMOĆU 3D RUČNOG LASERSKOG SKENERA

S A Ž E T A K

Cilj ove studije bio je utvrditi standarde za određivanje spola na gornjem okrajku femura u uzorku suvremene bugarske populacije. Metode su usmjerene na inovativni pristup numeričkoj procjeni glutealne tuberoze pomoću 3D vizualizacije i njezine uporabe kao prediktora spola. Uzorak se sastoji od 156 femura. Izvršeno je sedam mjerenja: okomiti promjer glave, poprečni promjer glave, maksimalni promjer glave, opseg glave, sagitalni subtrohanterni promjer, poprečni subtrohanterni promjer i supero-inferiorni promjer vrata. Površina glutealne tuberoze zabilježena je na 3D slici pomoću ručnog laserskog skenera. Izrađen je 3D oblik koji sadrži dva tetraedra sa zajedničkom bazom. Volumen hrapavog područja ulaza mišića bio je približno jednak zbroju volumena ova dva tetraedra. Na temelju točaka postavljenih na 3D slici hrapave površine stvoren je dvodimenzionalni oblik kao funkcija trodimenzionalnog. Volumen, površina novoformiranog oblika, njegova najveća visina i tri kuta između konstruiranih ravnina korišteni su za predikciju spola. Srednje vrijednosti svih metričkih i 3D mjerenja pokazale su značajne razlike s obzirom na spol ($p<0,001$) i volumen ($p=0,02$). Prema rezultatima diskriminantne analize, kombinacija varijabli opsega glave, sagitalnog subtrohanternog promjera, poprečnog subtrohanternog promjer a i supero-inferiornog promjera vrata dala je 88,5% točnosti. Upotrebom iste analize kombinacija volumena, visine i kuta b1 dala je najbolji rezultat s 93,0% točnosti.