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METHOD FOR QUANTITATIVE ASSESSMENT OF OLECRANON FOSSA USING 3D HAND-HELD LASER SCANNER IN THE FIELD OF FORENSIC ANTHROPOLOGY

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Abstract

The study is based on a creation of virtual model of olecranon fossa through 3D visualization and its usage as a sex discriminant. The study was focused on an assessment of 135 complete humeri from 47 females and 88 males. The surface of olecranon fossa was captured in a 3D image, using a Hand-held Laser Scanner (FastSCAN). The result was a 3D shape comprising two tetrahedrons with a common apex and a common lateral face. This 3D model was determined by five landmarks: the most superior point of the olecranon fossa, the most lateral point of the olecranon fossa seen on the posterior surface, the most medial point of the olecranon fossa, the point on the inferior edge of the olecranon fossa, directly in the middle, and the deepest point into the fossa. Therefore, the volume of the virtual model was equal to the total of the volumes of these two tetrahedrons. The results were processed with SPSS 17.0 using Discriminant Function Analysis. The percentage of cases classified correctly is 92.5% according to the sex determination. This study demonstrates a 3D method which can be used successfully for sex determination, especially in case of highly fragmented bones that impede traditional anthropometric analyses.

Key words: sex determination, laser scanning, humerus, olecranon fossa

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Introduction. The estimation of sex is the cornerstone of the forensic analysis of human skeletal remains. The correct determination of age as well as stature depends on the sex of the deceased. The pelvis and cranium are considered the most accurate bones for sex estimation [1,2]. The sexual dimorphism of the pelvis has a major advantage because of the fact that it is non-specific to populations compared to other skeletal parts [2]. In the forensic cases when it is not possible to analyze pelvis and/or cranium data, the metric and non-metric anthropological characteristics of long bones have demonstrated effective sex assessment discrimination [3–5]. Diverse studies have shown variability in these osteometric dimensions between populations. Regional variations in the standard statistical values for determination of sex are an established fact.

The estimation of sex by an osteometric method is a quick procedure applied in cases of mass disasters, burned skeletal remains, mass burials, etc. In the accidents like mass disasters, burned skeletal remains, mass burials, etc., the forensic anthropologist is confronted with fragmentary, mixed, or scattered skeletons. This makes sex estimation very difficult. Thus, it is necessary to create 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; 3. Their frequent use as a sex discriminant from skeletal remains [6].

In general, the lower part of humerus like the upper end of the femur possesses such features. The significant sexual dimorphism of this part is based on several facts. The carrying angle, which is the angle of the long axis of the arm relative to the angle of the long axis of the forearm in a supinated and fully extended position is often considered a secondary sex characteristic [7,8]. It impacts on both soft and hard tissue structures. Females generally have statistically greater carrying angles ($15.07 \pm 4.95°$) than males ($10.97 \pm 4.27°$) [9]. Females were found to exhibit a more constricted trochlea, a more symmetrical trochlea, a deep and oval-shaped olecranon fossa, and a raised (posteriorly oriented) medial epicondyle. Males exhibited a less constricted trochlea, an asymmetrical trochlea, a shallow and triangular olecranon fossa, and a flat medial epicondyle [10].

The aim of this study is to demonstrate a method for quantitative assessment of olecranon fossa of humerus among the contemporary Bulgarian population through 3D visualization and its use as a sex predictor.

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, supratrochlear holes, 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 $\pm$ SD).

The olecranon fossa was scanned using a Hand-Held Laser Scanner (FastSCAN) [11]. Afterwards, the following points (markers) were placed on the surface of the 3D image in physiological position of the humerus as follows: four landmarks along the surface of its margin and one landmark which is the deepest point into the fossa:

1. Landmark A is the most superior point of the olecranon fossa [12].
2. Landmark B is the most lateral point of the olecranon fossa seen on the posterior surface. This landmark was not placed within the fossa itself, but on the lateral edge of the fossa [12].
3. Landmark C is the most medial point of the olecranon fossa, also placed on the surface of the bone as opposed to within the fossa itself [12].
4. Landmark D is the inferior edge of the olecranon fossa, directly in the middle. This landmark was placed halfway between landmarks B and C and was placed on the smooth bone "ridge" that begins there [12].
5. Landmark E is the deepest point into the fossa.

The distance between landmarks A and D coincided with olecranon height and between B and C – with olecranon breadth, respectively.

The result is a 3D shape comprising two triangular pyramids (ADCE and ABDE) with a common lateral face (ADE) and a common apex E. Therefore, the volume of the 3D shape is equal to the total of the volumes of these two pyramids: $V = V_{ADCE} + V_{ABDE}$. The measurement unit is in mm^3 (Fig. 1). The analysis of the scanned image (the creation of the pyramids, and calculation of their volumes) was performed by 3D CAD Design Software AutoCAD 2009, according to its instructions.

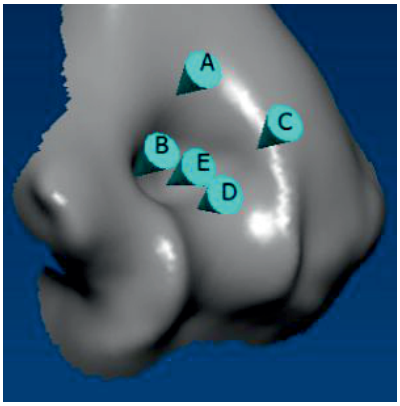

Fig. 1. 3D image of olecranon fossa and the landmarks A, B, C, D, E

Statistical package for social sciences (SPSS 17.0) was used for statistical analysis. The creation of the 3D shape and calculation of its volume were repeated three times by the same observer and the resulting mean value was used to reduce intra-observer error. The Paired Sample T test was used to compare the right and the left sides. Basic descriptive statistics were computed. For each side, the value of the bones was 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 the measured variable. The volumes were also subjected to discriminant function analysis using univariate method. Additionally, Pearson's correlation coefficients (r) and standard error of estimate (SEE) were obtained. As a rule of thumb, we shall consider correlation coefficient between 0.00 and 0.30 as weak, those between 0.30 and 0.70 as moderate and coefficients above +0.70 as high. The correlation of the olecranon height to the maximum length and the correlation of the olecranon breadth to the epicondylar breadth of humerus were studied individually.

Results. The means of the independent variable (volume of 3D shape for both sexes) are shown in Table 1. By applying the Kolmogorov–Smirnov test it was established that the volume ($p = 0.60$) is normally distributed. No statistical difference was found between the right and left sides for the mean values computed for both sexes ($p > 0.05$), 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. The Independent Samples Test indicates significant difference in the variable between the two sexes ($p < 0.001$), which makes them suitable as successful sex discriminants, i.e., male indices exceed female ones.

The acquired data are subjected to Univariant Discriminant Analysis and the volume is simultaneously involved as independent variable. F = Volume × 0.019 − 19.760 in cases of $F > 1047.9$ we accept that the bone is male and vice versa (Table 2). As a result of this function the accuracies of sex determination are shown in Table 3.

Table 1

Summary statistics of 3D variable. N – number of cases, SD – standard deviation, M – male, F – female

Variable	M ($N = 88$)		F ($N = 47$)		F factor	P value
	Mean	SD	Mean	SD		
Volume	1142.65	62.75	953.15	41.06	0.943	< 0.001

Table 2

Univariate discriminant analysis

Function	Unstandardized coefficient	Discriminant constant	Male group centroids	Female group centroids	Cut point
Volume	0.019	−19.760	1.787	−1.787	1047.9

Table 3

Percentage of correct sex classification

Males		Females		Total
Classified	Misclassified	Classified	Misclassified	
90%	10%	95%	5%	92.5%

The olecranon height showed a moderate positive correlation with maximum length (0.652 at 0.001 level), while the olecranon breadth showed a moderate positive correlation with epicondylar breadth (0.653 at 0.001 level).

Discussion. Diverse studies have shown that the humerus is a useful bone for metric estimation of sex [4,5] as well as for nonmetric estimation of sex [10,12–16]. The results of our study confirm that the lower end of Bulgarian humerus is a fairly good sex predictor with classification accuracy reaching 92.5% using a method for quantitative assessment of olecranon fossa. The volume of this virtual model is considered a strong sex indicator because male indices significantly exceed female ones. The olecranon fossa in males has greater olecranon height and breadth compared to the olecranon fossa in females. Thus, the areas of the bases of pyramids in males could be greater than the areas of the bases of pyramids in females, which determine greater volumes in males, irrespective of that the female olecranon fossa is deeper than male olecranon fossa [13]. This supports previous studies based on the sexual dimorphism of the fossa. The morphological characteristics of the posterior distal humerus are used as solid indicators for determining the sex of an unidentified individual [13,16]. The olecranon fossa shape and size, orientation of the medial epicondyle and shape of the trochlea all determine the carrying angle of the arm – a secondary sex characteristic. The results reported by this 3D method suggest that it is possible to determine the sex of skeletal remains in cases of mass disaster, disarticulated bodies or buried remains when the other bones are fragmented.

Conclusions. The creation of virtual models in order to assess the most frequently used skeletal remains in forensic anthropology is a fruitful approach for finding new sex predictors. This study demonstrates a 3D method which can be used successfully for sex determination, especially in cases of highly fragmented bones that impede traditional anthropometric analyses.

REFERENCES

[1] Murail P., J. Brůžek, F. Houët, E. Cunha (2005) DSP: A tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements, Bull. Mem. Soc. Anthropol. Paris, **17**(3–4), 167–176.

[2] Steyn M., M. Patriquin (2009) Osteometric sex determination from the pelvis – Does population specificity matter?, Forensic Sci. Int., **191**, 113.e1–113.e5.

[3] Krüger G., E. L'Abbé, K. Stull (2017) Sex estimation from the long bones of modern South Africans, Int. J. Legal Med., **131**, 275–285.

[4] Frutos L. R. (2005) Metric determination of sex from the humerus in a Guatemalan forensic sample, Forensic Sci. Int., **147**, 153–157, PMID: 15567620.

[5] Kshirsagar S., S. Chavan, C. Makhani, S. Kamkhedkar (2009) Sexual dimorphism of humerus: a study in Marathwada region, Indian J. Forensic Med. Pathol., **2**(4), 45–151.

[6] Timonov P., A. Fusova (2019) Sex estimation from the upper end of Bulgarian femur using 3D hand-held laser scanner, Coll. Antropol., **43**(2), 111–118.
[7] Van Roy P., J. Baeyens, D. Fauvart, R. Lanssiers, J. Clarijs (2005) Arthro-kinematics of the elbow: study of the carrying angle, Ergonomics, **48**(11–14), 1645–1656.
[8] Steel F., J. Tomlinson (1958) The 'carrying angle' in man, J. Anat., **92**(Pt 2), 315–317.
[9] Paraskevas G., A. Papadopoulos, B. Papaziogas, S. Spanidou, H. Argiriadou et al. (2004) Study of the carrying angle of the human elbow joint in fell extension: a morphometric analysis, Surg. Radiol. Anat., **26**(1), 19–23.
[10] Rogers T. (1999) A visual method of determining the sex of skeletal remains using the distal humerus, J. Forensic Sci., **44**(1), 57–60.
[11] `www.fastscan3d.com`
[12] Vance V., M. Steyn (2013) Geometric morphometric assessment of sexually dimorphic characteristics of the distal humerus, HOMO, **64**(5), 329–340.
[13] Vance V., M. Steyn, E. L'Abb (2011) Nonmetric sex determination from the distal and posterior humerus in black and white South Africans, J. Forensic Sci., **56**(3), 710–714.
[14] Ndou R., P. Smith, R. Gemell, O. Mohatla (2013) The supratrochlear foramen of the humerus in a South African dry bone sample, Clin. Anat., **26**, 870–874.
[15] Ammer S., J. d'Oliveira Coelho, E. Cunha (2019) Outline shape analysis on the trochlear constriction and olecranon fossa of the humerus: insights for sex estimation and a new computational tool, J. Forensic Sci., **64**, 1788–1795.
[16] Kranioti E., M. Bastir, A. Sánchez-Meseguer, A. Rosas (2009) A geometric morphometric study of the Cretan humerus for sex identification, Forensic Sci. Int., **189**(111), e1–e8.

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