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METHODS FOR QUANTITATIVE ASSESSMENT OF FEMORAL ANTROPOSCOPIC LANDMARKS USING HAND-HELD LASER SCANNER

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Abstract

This study is focused on an innovative approach to the numerical assessment of gluteal tuberosity through 3D visualization and its use as sex discriminant. The study was based on an aggregate of 40 right femora, male and female in equal proportion. The surface of tuberositas glutea femoris is captured in a 3D image, using a Hand-held Laser Scanner (FastSCAN). Afterwards, the assessment contains two ways. Firstly, the result is a 3D shape comprising two tetrahedrons with common base. Therefore, the volume of the roughness is approximately equal to the total of the volumes of these two tetrahedrons (volume). Secondly, several points (markers) are placed on the surface of the roughness of the 3D image. After that we create two-dimensional shape which is a function of the three-dimensional one. The area of the formed shape is measured (area) as well as its greatest elevation (elevation). The results were processed with SPSS 17.0 using Discriminant Function Analysis. If the predictors (volume, area and elevation) are included in the model, the percentage of cases classified correctly is 92.5%. This score coincides with world results based on various anthropometric indices of the femur.

Key words: sex determination, laser scanning, femur

Introduction. Each forensic anthropology examination of human skeletal remains is based on determining "the great four": sex, age, stature and race. When the whole skeleton, including pelvis and skull, is available, the accuracy rate of sex determination reaches 95%. In case of a single bone available, except for a femur, sex determination is seriously impeded.

The significant sexual dimorphism of the femur is based on several facts:

1) Men are relatively physically stronger than women and they use their muscles more actively.

2) Men's axial skeleton is heavier than women's and this weight is normally distributed in the upper end of the two femora.

3) Due to its reproductive function, the female pelvis differs in shape from the male's, which is expected to result in a change in the upper part of the femora, forming the pelvic bones [1].

This study aims to demonstrate a contemporary and innovative method for quantitative assessment of tuberositas glutea femoris through 3D visualization. The said method allows for its accurate mathematical estimation and can be used as a sex discriminant or as an additional predictor in models for the purpose of sex determination of the femur. Furthermore, it could be useful in the assessment of other osteoscopic landmarks.

Material and methods. The study was based on an aggregate of 40 right femora, male and female in equal proportion. They had been subject of forensic examination, and the sex of one part of the said femora was known, while that of the others was determined through pelvic bone analysis. Bones included in this study fulfill the following criteria: 1) show no anomalies, deformations or abrasions; 2) have no previously sustained fractures; 3) have reached skeletal maturity. The average age of the known male bones is 48.4 ± 13.44 years, and of the female ones 72.6 ± 13.97 years (Mean $\pm$ SD).

Tuberositas glutea femoris is the subject of scanning due to the following features:

1) the strongest extensor muscle, gluteus maximus, in the human body is inserted in it;

2) due to the fact that the effect of muscle action is more powerful on the point of insertion than on the point of origin [1, 2];

3) gluteus maximus stabilizes the hip joint, which in its turn shows great sexual dimorphism;

4) the activity and function of gluteus maximus are continuous and daily, for instance, 60% of the movements for taking a single stride when walking are performed by gluteus maximus along with gluteus medius [3];

5) muscle activity is higher in men than in women [3–5].

On the grounds of these features, the following conclusion may be drawn in advance – this anthroposcopic landmark will differ considerably in men and women in its size and impression and will be successfully used as a sex discriminant.

Firstly, the surface of tuberositas glutea femoris is captured in a 3D image, using a Hand-held Laser Scanner (FastSCAN) [6–8]. Afterwards, the following points (markers) are placed on the surface of the 3D image obtained. They are placed as follows – on the uppermost point, on the roughness – femoral surface margin (point a), on the lowest point of the roughness – femoral surface margin or on the margin where it meets labium laterale (point d), on the most medial point, on the roughness – femoral surface margin (point b), on the most lateral point, on the roughness – femoral surface margin (point f) and the uppermost point is empirically selected on the roughness itself (point *2*). Each of these points is defined by certain x, y and z values. The result is a 3D shape comprising two tetrahedrons (*abf2* and *dbf2*) with common base (*bf2*). Therefore, the volume of the roughness is approximately equal to the total of the volumes of these two tetrahedrons and it is the first predictor: $V = Vabf2 + Vdbf2$. 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 is applied, for example, in morphological assessment of lips and external nose in facial reconstruction [10, 11].

Secondly, on the roughness itself some uppermost projecting points, as well as lowest points, are 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 roughness is more accurately described). Besides, each point marked is defined by x, y and z values.

Afterwards the following stages are performed:

1) Finding the sectioning point of the straight line bf (point g).

2) Creating three planes – the first one A is 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 bf lies simultaneously on the three planes created.

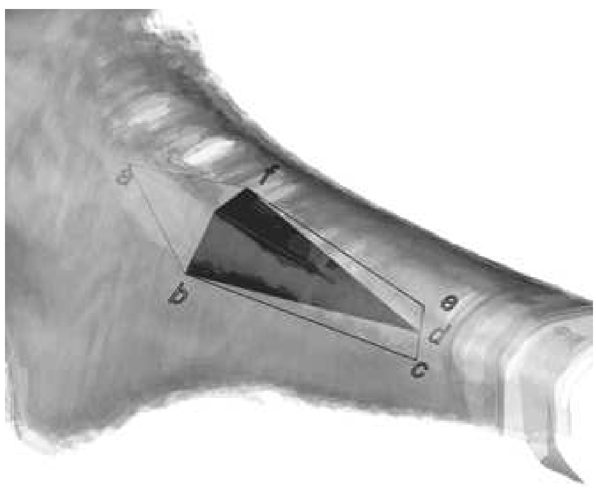

Fig. 1. Creation of two tetrahedrons ($abf2$ and $dbf2$) with common base ($bf2$)

3) Points *1*, *2*, *3*, *4*, *5* and *6* are transposed to the formed plane A, as the elevations at which they are positioned are respectively above planes B and C and are, respectively, equal to their elevations over the straight line ad in plane A.

This results 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*.

4) The newly created two-dimensional shape is a function of the three-dimensional one.The area of the formed shape is measured (area) as well as its greatest elevation (elevation), which are other predictors. The measurement units are in mm^2 and mm.

Why have we selected the above points?

1) Points a, d, b and f characterize the size of the point of insertion and the function of gluteus maximus, respectively, extension, external rotation, abduction and adduction.

2) Points *1*, *2*, *3*, *4*, *5* and *6* characterize the impression of the point of insertion.

3) Point g (the middle 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 area of the 2D polygonal shape will be larger and vice versa.

In women the point of insertion of the muscle in the bone is smaller in size and has less distinctive impression [3, 4]. Based on the above data, it could be concluded that the variables of the shape obtained will be indicative of sex differences.

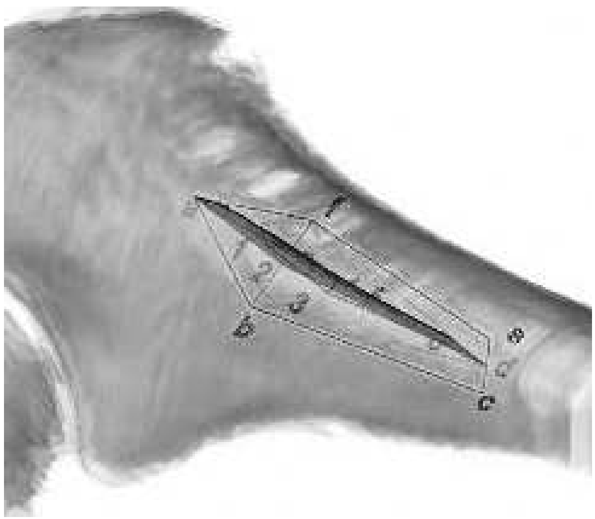

Fig. 2. The newly created two-dimensional shape is marked with a darker colour

Table 1

Sex	M	F	t	p
N	20	20		
A mean ± SD	1.32 ± 0.16	1.1 1± 0.16	4.682	$< 0,001$
E mean ± SD	0.43 ± 0.07	0.25 ± 0.07	7.318	< 0.001
V mean ± SD	0.72 ± 0.09	0.59 ± 0.14	3.416	$= 0.02$

Results. SPSS 17.0 is used. The means of the three independent variables (volume, area of the 2D shape and its greatest elevation (for both sexes) are shown on Table 1. By applying the Kolmogorov–Smirnov Test it was established that the following variables – area ($p = 0.218$), elevation ($p = 0.656$) and volume ($p = 0.60$) are normally distributed. The Independent Samples Test indicates significant difference in the variables between the two sexes ($p < 0.05$), which makes them suitable as successful sex discriminants, i.e. male indices exceed female ones.

The acquired data are subjected to Discriminant Analysis and the three discriminants are simultaneously involved as independent variables.

F = 1.905 × Area + 14.427 × Elevation − 3.842 × Volume − 4.805 in cases of F > 0 we accept that the bone is male and vice versa. As a result of this function the accuracy of determination is shown on Table 2.

Discussion. The yielded result of correct sex determination – 92.5% coincides with world results based on various anthropometric indices of the femur, both as independent variables and in combination with other variables, for instance, vertical and horizontal diameter of the head, circumference of the head, superior-inferior diameter of the femoral neck, width of the distal epiphysis, circumference in the middle of the diaphysis, dimensions of Purkait's triangle, etc. They give results within the range of about 82% to 95% [5, 9–12].

Conclusion. Muscle activity is higher in men than in women. This, in its turn, results in difference in both the anthropometric and anthroposcopic landmarks, in favour of the male sex. This study demonstrates innovative method for objective evaluation of the muscles' points of insertion which can be used

Table 2

Functions and variables	Raw coefficient	Standard coefficient	Structure coefficient	Sectioning point
Area	1.905	0.272	0.591	0
Elevation	14.724	1.123	0.924	
Volume	−3.842	−0.459	0.431	
Constant	−4.805			

successfully for sex determination, especially in case of highly fragmented bones that impede anthropometric analyses.

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