Institute of Experimental Morphology, Pathology and Anthropology with Museum
Bulgarian Anatomical Society

Acta morphologica et anthropologica, 18
Sofia • 2012

Correlations between anthropometrical features of the human humerus

D. Toneva, S. Nikolova

Institute of Experimental Morphology, Pathology and Anthropology with Museum, Bulgarian Academy of Sciences, Sofia

The purpose of the study is to determine the structure, direction and degree of the dependences between the metrical features of the proximal end of humerus as well as between them and the humeral length and to assess the correlations in intersexual and bilateral plans. The anthropological investigation is performed on osteological material from archaeological excavations. A total of 142 humeri (35 pairs of male humeri, 36 pairs of female himeri), belonging to adult individuals, are investigated. Six metric features are measured. The metrical data are statistically analyzed by linear correlation analysis. The results obtained in both sexes show only positive relationships between the investigated features. As a whole, the significant relationships are more and stronger in the male humeri than in female ones. The correlation matrices of female humeri show more remarkable bilateral differences, as there are almost twice as many significant correlations in the right humeri.

Key words: humerus, correlation, metric features, length, proximal end

Introduction

The humerus is the longest and most robust bone of the arm. This bone has received due attention in the anthropological and forensic literature. The humerus length gives important evidence in forensic and archeological studies to indicate the characteristic features of a population [12]. Humeral measurements support the estimation of stature [5, 8, 11], sex [1, 4, 9, 14] and age of individuals [13]. However, there are no enough data about the relationships between length of the long bones and measurements of their fragments, as the strength of these relations namely characterizes the stability of separate bone structures, which has a relation to further analyses. The purpose of the study is to determine the structure, direction and degree of the dependences between the metrical features of the proximal end of humerus as well as between them and the humeral length and to assess the correlations in intersexual and bilateral plans.

Material and Methods

The anthropological investigation is performed on osteological material from archaeological excavations of mediaeval necropoles in the territory of Northeastern Bulgaria (Odartsi, X-XI Century; Batin, IX-X Century; Trastenik, IX-X Century; Durankulak, IX-X Century). Only adult skeletons with preserved pairs of humeri are chosen for the analysis. A total of 142 humeri (35 pairs of male humeri, 36 pairs of female himeri) are investigated. Skeletal sex and age are determined by standard anthropological methods [6, 15, 16].

The anthropological investigation includes six metric features of the humerus. Features with number in brackets are described by the classical methods of Martin-Saller:

1. Greatest length of humerus (1), GLH – the distance between the most proximal point of *caput humeri* and the most distal point of *trochlea humeri*, osteometric board.

2. Breadth of the proximal epiphysis of humerus (3), BPEH – the linear distance between the most medial point of *caput humeri* and the most lateral point of *tuberculum majus*, osteometric board.

3. Greatest diameter of the proximal epiphysis of humerus, GDPEH – the linear distance between the most prominent forward point on *tuberculum minus* and the outermost point from it on the opposite surface of the bone, osteometric board.

4. Greatest transversal diameter of *caput humeri* (9), GTDCH – the linear distance between the outermost points on the lateral edges of *caput humeri*, sliding caliper.

5. Greatest sagittal diameter of *caput humeri* (10), GSDCH – the linear distance between the highest point on the higher surface of *caput humeri* and the lowest point on its lower surface, sliding caliper.

6. Height of *caput humeri*, HCH – the distance from the most prominent point of *caput humeri* to the line, connecting points, between which is measured the sagittal diameter of *caput humeri*, coordinate caliper.

The metrical data are statistically analyzed by linear correlation analysis using SPSS version 16,0. A value of correlation coefficient (r) near 0 indicates little correlation between variables; a value near +1 or -1 indicates a high level of correlation. The strength of relationships is assessed by the scheme, published by Kalinov [17]: very low correlation ($r \leq 0,30$), low ($r = 0,31 \div 0,50$), moderate ($r = 0,51 \div 0,70$), high ($r = 0,71 \div 0,90$) and very high ($r \geq 0,91$). The significance of the correlations is evaluated at $P<0,05$ and $P<0,01$. The positive sign of correlation coefficient shows that an increase in the value of one variable indicates a likely increase in the value of the second variable. A correlation coefficient of less than 0 indicates a negative correlation.

Results and Discussion

The correlation data are presented in Tables 1, 2, 3 and 4.

Significance of the correlations between metric features of humerus

The correlation matrices of males show that all correlation coefficients in right humeri are statistically significant at a high significance level ($P < 0,01$). Thirteen of 15 correlation coefficients in the left male humeri are also significant at $P < 0,01$ and one is significant at $P < 0,05$.

The correlation matrices of females differ from these of males mainly in the left humeri. Twenty of all correlation coefficients in the right humeri of female skeletons are statistically significant, as 10 of them are significant at $P < 0,01$ and 2 – at $P < 0,05$.

Table 1. Significance, direction and degree of the correlations between anthropometric features of right male humeri

Features	GLH	BPEH	GDPEH	GTDCH	GSDCH	HCH
GLH	1	0.50**	0.57**	0.57**	0.61**	[illegible]
BPEH		1	0.72**	0.79**	0.91**	073**
GDPEH			1	0.86**	0.79**	0.65**
GTDCH				1	0.83**	0.68
GSDCH					1	0.77**
HCH						1
Low degree	Moderate degree		High and very high degrees		* P<0.05; ** P<0.01	

Table 2. Significance, direction and degree of the correlations between anthropometric features of left male humeri

Features	GLH	BPEH	GDPEH	GTDCH	GSDCH	HCH
GLH	1	0.55**	0.41*	0.65**	0.47**	0.33
BPEH		1	0.74**	0.79**	0.86**	0.58**
GDPEH			1	0.80**	0.79**	0.71**
GTDCH				1	0.76**	0.61**
GSDCH					1	0.71**
HCH						1
Low degree	Moderate degree		High and very high degrees		* P<0.05; ** P<0.01	

Table 3. Significance, direction and degree of the correlations between anthropometric features of right female humeri

Features	GLH	BPEH	GDPEH	GTDCH	GSDCH	HCH
GLH	1	0.39*	0.32	0.53**	0.45**	0.14
BPEH		1	0.87**	0.60**	0.59**	0.44**
GDPEH			1	0.58**	0.40*	0.18
GTDCH				1	0.82**	0.44**
GSDCH					1	0.68**
HCH						1
Low degree	Moderate degree		High and very high degrees		* P<0.05; ** P<0.01	

Table 4. Significance, direction and degree of the correlations between anthropometric features of left female humeri

Features	GLH	BPEH	GDPEH	GTDCH	GSDCH	HCH
GLH	1	0.52**	0.50**	0.16	0.48**	0.18
BPEH		1	0.95**	0.22	0.77**	0.17
GDPEH			1	0.22	0.68**	0.14
GTDCH				1	0.26	0.12
GSDCH					1	0.54**
HCH						1
Low degree	Moderate degree		High and very high degrees		* P<0.05; ** P<0.01	

However, the significant dependences in the left female humeri are vastly less in number and only seven of them are significant, as the significance level is $P < 0,01$.

Direction and degree of the correlations between metric features of humerus

The results of the comparative analysis of the dependences between the investigated humeral features in both sexes show that only positive correlations are available.

The **humeral length** in **male humeri** correlates significantly with the investigated features of the proximal end of low and moderate degrees and only the correlative dependence between humeral length and height of *caput humeri* in left male humeri is insignificant. The **humeral length** in **females** correlates statistically significant with the proximal epiphyseal breadth and both diameters of *caput humeri* in right humeri and with both features of the proximal epiphysis and the greatest sagittal diameter of *caput humeri* in left ones. These dependences are also of low and moderate degrees. According to the results obtained by Salles et al. [12] the humeral length is in statistically significant correlation with both diameters of *caput humeri*, as the dependence on the right side is stronger than this one on the left side. The purpose of their study is to estimate the maximum length of humerus from measures of its proximal and distal fragments, as in this way they create perspectives to forensic and archaeological investigations, because the estimate could be extended to living height of individuals. With regard to these results many authors have found out relationship between humeral length and living stature too [7, 8, 10]. Auerbach and Ruff [2] have estimated that one of the highest correlations in the upper limb is between humeral and radial lengths in both sexes. Salles et al. [12] notice that the relationships between living stature and long bones length are dependent of genetic and environmental factors, also considering sexual dimorphism and secular trend of human groups.

The **breadth of the proximal epiphysis** in **male humeri** correlates with the other features of proximal end of high and very high degrees. The correlative dependence with the height of *caput humeri* in left male humeri is an exception of a moderate degree of correlation. The strongest correlation is established between the breadth of the proximal epiphysis and the greatest sagittal diameter of *caput humeri* (right $r = 0.91$; left $r = 0.86$). The correlation coefficients of **the greatest diameter of the proximal humeral epiphysis** with the features of *caput humeri* show that they are in close relationships, mainly of a high degree. An exception is the correlation between the greatest diameter of the proximal humeral epiphysis and the height of *caput humeri* in right male humeri with a correlation coefficient of a moderate degree. The relationships between

the **breadth and the greatest diameter of the proximal epiphysis** in **female humeri** are very strong, as the degree is "high" on the right (r = 0.87) and "very high" on the left side (r = 0.95). Both features of the proximal epiphysis in right female humeri correlate with the features of *caput humeri* of low and moderate degrees. However, both features of the proximal epiphysis in left female humeri correlate statistically significant only with the sagittal diameter of *caput humeri*, as these correlations are stronger than those in right female humeri.

The **features of *caput humeri*** in **male humeri** depend on each other of high and moderate degrees. A high degree of correlation is established between both trnasversal and sagittal diameters of *caput humeri*, and between the sagittal diameter and the height of *caput humeri*. The correlation coefficients between the transversal diameter and height of *caput humeri* in both right and left male humeri have lower values and the degree of correlation is moderate. The relationships between the **features of *caput humeri*** in right **female humeri** are stronger than these in left ones. The degree of the correlation between transversal and sagittal diameters of *caput humeri* is high and the degrees of the correlations between these two features and the height of *caput humeri* are low and moderate respectively. Statistically significant correlation in left female humeri is only this one between the sagittal diameter and the height of *caput humeri* and its degree is moderate. Bukov et al. [3] have performed an osteometrical study of the articular surface of *caput humeri*. Their study includes five humeral measurements, calculation of two indexes and a method of measuring the area of articular surface of *caput humeri*, but the sample is not divided into male and female groups. The results show high correlation between *caput humeri* articular surface area and the breadth of proximal epiphysis, as well as between the sagittal and transversal diameters of *caput humeri*, which confirms that the larger bones have larger articular surfaces.

The greater stability observed between the metrical features in male humeri makes them more suitable for statistical analysis than female ones, by which should take into consideration greater bilateral differences.

Conclusion

As a whole, the significant relationships are more and stronger in the male humeri than in female ones. The correlation matrices of female humeri show more remarkable bilateral differences, as there are almost twice as many significant correlations in the right humeri. The dependences established between the humeral length and measurements of the proximal end of humerus, as well as between the actually features of the proximal end provide an appropriate basis for subsequent statistical analyses.

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