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Analysis of bilateral asymmetry of some anthropometric measurements of humerus used in Forensic practice

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The aim of the present study is to evaluate the manifestation of bilateral asymmetry in the proximal and distal end of humerus among the contemporary Bulgarian population. A total of 113 pairs of complete humeri from 54 females and 59 males were studied. Measurements of humerus include circumference of head, vertical diameter of head, transverse diameter of head and epicondylar breadth analyzed with SPSS 23.0. The Paired Sample T test was used to compare the right and the left sides. For each side the values of the bones were tested for normality of distribution by the Kolmogorov-Smirnov test. No statistical difference was found between right and left side for the mean values computed for both genders. We concluded that the bilateral asymmetry is not present in the humeral dimensions, thus, allowed the bones of both sides to be grouped together for further analysis, especially in forensic medicine, anthropology, normal morphology, and archeology.

Key words: bilateral asymmetry, humerus, Bulgarian population

Introduction

The sex differences in the quantitative and qualitative features of the human humerus and femur are a good and reliable indicator for sex, age and stature determination from skeletal remains in Forensic anthropology. In addition, due to their structure, size, location, strength, they or their fragments are common objects of study in Forensic anthropological practice, especially in cases of mass disasters or murders in which the corpses are often decapitated or dismembered. Some authors emphasize the need of anthropometric studies on fragmented bones, as in anthropology it is much more often necessary to determine sex by fragments than by structurally preserved bones.

Symmetry is defined as correspondence in size, shape, and relative position of parts on opposite sides of a dividing line or median plane while asymmetry is described as a lack or absence of symmetry. Although bilateral symmetry in paired morphological traits is evident in humans, significant deviation from this is observed in internal organs, human brain, and especially upper limb [23].

In their anthropological studies of humerus, Pavlov and Matev, Sato and Noriyasu, Charisi et al., Atamturk et al., Ross and Manneschi, Shehri and Siloman, Reddy and Doshi [1,3,12,14,15,17,19] did not establish statistically significant lateralization in both sexes.

The examination of the upper and lower limb asymmetry can be useful to medical scientists, archeologists, anthropologists [6,7,11] and forensic experts for medicolegal studies [9,20,24].

The **aim** of the present study is to determine the presence or lack of symmetry between some parameters of pairs of left and right human humerus.

Materials and Methods

The present study included 59 pairs of complete dry male humeri and 54 pairs of complete dry female humeri of Bulgarian origin. The bones were collected from the Department of General and Clinical Pathology and Forensic Medicine, Medical University of Plovdiv and the Department of General and Clinical Pathology and Forensic Medicine, Medical University of Varna, Bulgaria. The bones included in this study fulfill the following criteria: show no anomalies, deformations or abrasions; have sustained no fractures previously; have reached skeletal maturity. They belong to Bulgarians born after 1920. The mean age of the male bones is 56,8 years, and of the female ones 64.3 years. The bones were the subject of forensic examinations in cases of identification of dead bodies with late postmortem changes or in stage of skeletonization. The study has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinski). A total of four humeral dimensions were taken using sliding caliper and steel tape. Measurements include **circumference of the head (M8)**, **vertical diameter of the head (M10)**, **transverse diameter of the head (M9) and epicondylar breadth (M4)** and were taken according the standard technique of Martin and Saller [10]. We have chosen these measurements of the humerus because these are the most frequently studied parameters in Forensic practice and in most anthropological studies, and this will allow us to compare our results. Statistical analysis was performed using SPSS 23.0. Means and standard deviations of the results of individual factors were calculated and statistically analyzed to identify any significant differences. We defined the protocol as follows: for each pair, the humeral parameters were measured on both left and right humeri to assess if a statistically significant difference between the two sides could be recorded. 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. Basic descriptive statistics were computed.

Results

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. The Kolmogorov-Smirnov test found that all variables have a normal empirical distribution ($p > 0.05$). The data obtained from the anthropometric humeral measurements were subjected to Paired Sample T test to compare the right and the left sides. The results show lack of significant difference between the mean values of the left and right sides calculated for both sexes ($p > 0.05$).

The min and max values of the measurements are shown in **Table 1** and **Table 2.**

Table 1. Min and max values of the measurements (mm) of the male humeral bones.

Variables	Left			Right			Indicators of asymmetry		
	N	Min	Max	N	Min	Max	Absolute difference	t	P
Circumference of the head	59	123.58	171.82	59	120.79	174.37	0.12	0.191	0.850
Vertical diameter of the head	59	38.41	57.43	59	38.59	56.83	0.21	0.756	0.458
Transverse diameter of the head	59	35.66	51.98	59	34.70	51.80	0.57	2.373	0.162
Epicondylar breadth	59	49.82	78.62	59	49.88	78.20	0.18	1.476	0.153

Table 2. Min and max values of the measurements (mm) of the female humeral bones.

Variables	Left			Right			Indicators of asymmetry		
	N	Min	Max	N	Min	Max	Absolute difference	t	P
Circumference of the head	54	99.01	154.27	54	101.52	153.18	-0.71	-1.461	0.163
Vertical diameter of the head	54	30.59	51.17	54	30.50	51.02	0.12	1.725	0.104
Transverse diameter of the head	54	29.32	46.78	54	29.42	46.34	0.17	1.852	0.083
Epicondylar breadth	54	41.42	67.22	54	40.01	68.51	0.06	0.107	0.916

Circumference of humeral head

The circumference of the humeral head in the male skeletons is greater by 0.12 mm in the left humerus. In female skeletons, the difference between the mean values on the right and left is 0.71 mm, respectively, in favor of the right humerus. No significant bilateral differences between the examined parameters for both sexes were detected (males: $p = 0.850$; females: $p = 0.163$).

Vertical diameter of humeral head

The vertical diameter of the male humeral head in the left is 0.21 mm larger than the right one. In female skeletons, this size is also larger in the left humeri, with a difference of 0.12 mm. Bilateral differences were not statistically significant for both sexes (males: $p = 0.458$; females; $p = 0.104$).

Transverse diameter of humeral head

This measurement in males and females shows higher values in the left humerus than the right. The absolute differences between their mean values are 0.57 mm and 0.17 mm, respectively, but without statistical significance (males: $p = 0.162$; females: $p = 0.083$).

Humeral distal epicondylar breadth

The data of the humeral distal epicondylar breadth show that in both sexes the left humerus has higher values than the right one by 0.18 mm in the male skeletons and 0.06 mm in the female skeletons. Bilateral differences were not statistically significant (males: $p = 0.153$; females: $p = 0.916$).

The comparative assessment of the direction of the manifested asymmetry in the anthropometric measurements of humerus shows that both sexes have left-handed asymmetry. In one of the parameters, a discrepancy of the direction for both sexes is found – this is the circumference of the head of the humerus. Regardless of directions of lateralization, all humeral variables show statistically insignificant bilateral variation ($p > 0.05$) in both males and females.

Discussion

The anthropometric characteristic of the paired humeri allows considering the manifestations of bilateral asymmetry. The lack of such will ensure us to create a "mixed" sample in the intersex plan, which will be subjected to mathematical and statistical processing. This in turn is not a methodological error. Similar studies on bilateral samples are often found in the literature, especially in forensic studies.

More recent population studies show diminishing of the directionality and magnitude of asymmetry, probably reflecting changes in external factors, such as division of labor. An osteometric study of the long bones of the upper limb in the modern Greek population of the second half of the 20th century was conducted by Charisi et al.

[3] in 204 individuals (111 men and 93 women) from the skeletal collection of the University of Athens. The authors examined the humerus, radius and ulna by comparing the maximum bone length, width of the proximal and distal end on the left and right side. In most cases, the measurements on the right are slightly larger than those on the left in absolute values, but no bilateral asymmetry was found. This is confirmed by the results of the t-test, in which all the mean values of the studied parameters between the two sides are not statistically significant.

According to Trinkaus et al. [22] bilateral asymmetry is best observed in the diaphyses and especially in their circumference or other cross sections. The analysis of humeral asymmetry in recent human skeletal samples and an extant tennis-player sample documents minimal asymmetry in bone length, little asymmetry in distal humeral articular breadth, but pronounced and variable asymmetry in mid- and distal diaphyseal crosssectional geometric parameters [22].

Studies on other skeletal parts have shown that the preferential use of one arm is best reflected on other bones, such as the scapula [4,5,18]. The mechanical load caused by the movements of the upper limb leads to differences in the morphology of the glenoid fossa. Other studies have found that bilateral asymmetry is more common in metacarpal bones than in other skeletal elements of the arm because they are used more frequently in daily activities [8,13,16].

Sato and Noriyasu [17] investigate the morphological and functional relationships between the head of the humerus and the glenoid cavity. They examined a total of 173 sets of humeri and their corresponding scapulae. The dimensions of the head in the right humerus in both sexes are generally larger than in the left, but no significant bilateral differences have been found. The size of the glenoid cavity is also larger in the right scapula. The authors explain the larger dimensions on the right with greater range of motion in the right shoulder, due to the more frequent use of the dominant arm.

Stirland [21] in his study of the attachment points of muscles on the humerus based on radiographic studies proved that there is no statistical significance in the lateralization of these points.

In 2010 Atamtyrk et al. [1] present a retrospective study of 84 X-ray radiographs of 46 women and 38 men aged between 20 and 79 years from Istanbul. The collected sample contains both left and right humeri belonging to different patients. The authors did not establish statistical significance between bilateral osteometric parameters. The studied parameters of the humerus are: maximum length, vertical diameter of the head, maximum breath in the middle of the body, distal epicondylar breadth.

In Bulgaria Pavlov and Matev in 1975 [12] investigated the morphometric characteristic of humerus in Bulgarian men. The authors examined 143 pairs of humeri that belong to men who died in the Serbian, Balkan, and First World War with a mean age of 29.6 years. The examined parameters are maximum length of the humerus, the largest and smallest width in the middle of the body, midshaft circumference, head circumference, epicondylar breadth, maximum diameter of the head, vertical diameter of the hea. Although the authors found that the right humerus was longer and more massive than the left one, they confirmed a statistically insignificant bilateral difference. These data confirmed our results.

Behavioral evidence for sex differences in upper limb preference are mixed, and potentially confounded by cultural factors. Benjamin et al. [2] found evidence for decreasing sexual dimorphism in upper limb lateralization in industrial versus pre-industrial European samples, which could indicate more strongly defined sex-related differences in limb lateralized behavior in the earlier group.

Conclusions

No statistical difference was found between the right and left side for the mean values computed for both sexes. More recent populations show reduction of the directionality and magnitude in asymmetry, probably reflecting changes in exogenous factors, such as division of labor.

We concluded that the bilateral asymmetry is not present in the examined humeral dimensions, thus, allowed the bones of both sides to be grouped together for further analysis. The bones could be subjected to statistical analysis to determine important anthropometric indicators in the Forensic practice such as age, sex, and stature. Their estimation plays a key role for the forensic analysis of human skeletal remains. On the other hand, when fragmentary and incomplete bones are all that are available to the forensic anthropologist for use in sex, age and stature determination, non-metric and metric discriminating parameters that have been derived from complete bones may be of little use. In such circumstances, the discriminating metric methods in the proximal and distal end of the humerus are of specific application to fragmentary bones and could be more useful.

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