Original Article / Özgün Araştırma

Examination of the Correlation of Distal End Parameters of the Humerus with Other Parameters

Humerus Distal Uç Parametrelerinin Diğer Parametrelerle İlişkisinin İncelenmesi

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Abstract

Objective: The aim of this study is to determine the correlation between all osteometric parameters obtained from the humerus and parameters obtained from the distal end of the humerus.

Materials and Methods: A total of 16 parameters were measured in 67 dry bones using the Image-J program.

Results: Groove for the ulnar nerve width (GUW) and the angle of the groove of the ulnar nerve (GUA) parameters were found to be higher on the left side and the difference was found to be statistically significant ($p<0.05$), GUA and intertubercular groove width were not significantly correlated with any parameter ($p>0.05$).

Conclusion: We believe that the results of the study will provide osteometric data of the humerus in distal end fracture treatment, comminuted fractures, and reconstructive surgery of the humerus, anthropological and forensic studies and increase the anatomical knowledge levels of experts interested in the region.

Keywords
Dry bone, distal end of the humerus, osteometry

Öz

Amaç: Bu çalışmanın amacı humerustan elde edilen tüm osteometrik parametreler ile humerus distal ucundan elde edilen parametreler arasındaki korelasyonu bulmaktır.

Gereç ve Yöntemler: Toplam 67 kuru kemikten, 16 parametre ölçümü Image-J programıyla yapıldı.

Bulgular: Sulcus ulnaris genişliği (GUW) ve sulcus ulnaris açısı (GUA) parametreleri sol tarafta daha yüksek bulundu ve aradaki fark istatistiksel olarak anlamlı bulundu ($p<0,05$), GUA ve sulcus intertubercularis genişliği herhangi bir parametre ile anlamlı olarak korelasyon göstermedi ($p>0,05$).

Sonuç: Çalışmanın sonuçlarının humerus distal uç kırıklarının tedavisi, parçalı kırıklar ve humerus rekonstrüktif cerrahisi, antropolojik ve adli çalışmalarda osteometrik veriler sağlayacağı ve bölgeyle ilgilenen uzmanların anatomik bilgi düzeylerini artıracağı kanaatindeyiz.

Anahtar Kelimeler
Kuru kemik, humerus distal ucu, osteometri

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Introduction

As in all biological structures, bone structure is driven by phylogenetic, structural, and functional factors (1,2).

The structure of the bone and its connection with its function is central to all inquiries that target or involve the bone. This includes deductive and inductive applications of skeletal biology both in medical science and also in archaeological or forensic sciences. Bone lengths and correlations have been studied by anthropologists, forensic scientists and orthopaedists for surgery and prosthetic design (3).

Distal humerus fractures account for 0.5-7% of all fractures, and approximately 30% of elbow fractures (4). Various implants are available for fracture patterns in the distal of humerus and these implants have been shaped according to the general anatomy knowledge of the elbow region (5).

The aim of this study is to investigate the relationship between humeral morphometry and humeral distal end parameters and other parameters of the humerus by digital measurements made on the dry bones of the humerus.

Materials and Methods

This study was initiated with 2021/797 numbered approval from Karabük University Ethics Committee (date: 24.12.2021). In the study, a total of 67 humerus bones, 35 left and 32 right, of unknown gender, were used from the bone collections in the anatomy laboratories of the medical faculty of the three universities. Deformed bones were not included in the study.

Morphometric Measurements

The bones placed on a measuring ruler were photographed with a professional digital camera (Nikon® - model D5300) parallel to the ground and from a height of 40 cm. The taken photos were transferred to Image-J (version 1.8 for Windows) program and they were calibrated. On the calibrated photos, 16 parameters were measured and recorded 2 times for each bone at different dates by the same observer.

Parameters;

The maximum length of the humerus (HML),

The vertical diameter of the humeral head (HVD),

Intertubercular groove width (GIW),

Deltoid tuberosity diameter (TDD),

Capitulum of the humerus width (CHW),

Trochlea of humerus width (THW),

Capitulum of humerus + trochlea of humerus transverse length,

Coronoid fossa width (TCW),

Radial fossa width,

The length between medial epicondyle and lateral epicondyle (FRW),

Groove for the ulnar nerve width (GUW),

The angle of the groove of the ulnar nerve (GUA),

Capitulum of humerus length (CHL),

Trochlea of humerus length (THL),

Olecranon fossa length (transverse plane) (FOL) and Olecranon fossa width (coronal plane) (FOW). All parameters showed in Figure 1.

Statistical Analyses

The data obtained in the study was analysed by using SPSS (Released: 2016, IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) software. In data evaluation, mean, standard deviation, minimum and maximum values were used as descriptive statistical methods. Normality of the continuous variables was evaluated with Shapiro-Wilk test. Two Sample t-test and Mann-Whitney

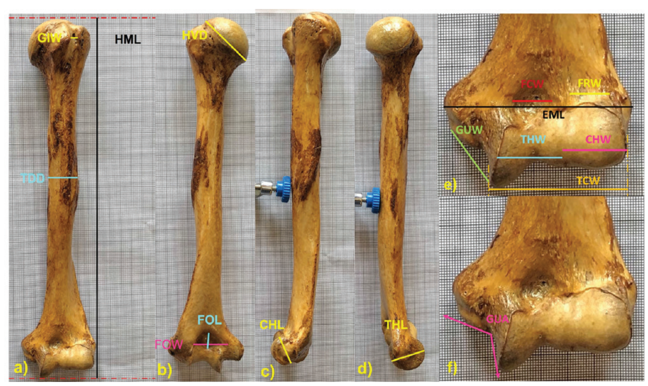

Figure 1. Parameters taken from the a) anterior, b) posterior, c) lateral, d) medial, e) and f) end of the humerus.
CHW: Capitulum of humerus width, EML: The length between medial epicondyle and lateral epicondyle, FCW: Coronoid fossa width, FOL: Olecranon fossa length (transverse plane), FRW: Radial fossa width, FOW: Olecranon fossa width (coronal plane), GIW: Intertubercular groove width, GUA: The angle of the groove of the ulnar nerve, GUW: Groove for the ulnar nerve width, HML: The maximum length of the humerus, HVD: The vertical diameter of the humeral head, TCW: Capitulum of humerus + trochlea of humerus transverse length, TDD: Deltoid tuberosity diameter, THL: Trochlea of humerus length, THW: Trochlea of humerus width

U test were used in the comparison of continuous variables between two groups. The linear correlation between the continuous variables was evaluated with Spearman and Pearson correlation test. P<0.05 level was considered as statistically significant.

In order to assess intra-observer precision and measurement accuracy, technical error of measurement (TEM), relative technical error of measurement (rTEM) and reliability coefficient (R) were calculated by using Microsoft Excel program.

RESULTS

The means of the first and second measurements were used in the study. TEM, rTEM, and R of the measurement parameters are shown in Table 1. TEM values are between 0.04 and 1.69. rTEM values are between 0.36% and 12.49%. R values are between 0.83 and 0.99, and the values are close to 1.

Table 1. Intra-observer error analysis (TEM, rTEM, R) (n=67)

Parameters	TEM	rTEM (%)	R
GIW	0.11	12.49	0.83
FRW	0.07	5.56	0.88
THW	0.08	3.63	0.90
THL	0.10	3.82	0.91
FOW	0.06	3.53	0.93
TDD	0.06	3.10	0.94
FCW	0.06	3.47	0.94
GUW	0.07	5.18	0.94
CHW	0.05	2.82	0.95
FOL	0.06	2.30	0.96
CHL	0.05	2.18	0.97
TCW	0.04	0.95	0.98
GUA	1.69	1.44	0.98
HVD	0.05	1.05	0.98
HML	0.11	0.36	0.99
EML	0.05	0.84	0.99

TEM: Technical error of measurement, rTEM: Relative technical error of measurement, R: Reliability coefficient, GIW: Intertubercular groove width, FRW: Radial fossa width, THW: Trochlea of humerus width, THL: Trochlea of humerus length, FOW: Olecranon fossa width (coronal plane), TDD: Deltoid tuberosity diameter, FCW: Coronoid fossa width, GUW: Groove for the ulnar nerve width, CHW: Capitulum of humerus width, FOL: Olecranon fossa length (transverse plane), CHL: Capitulum of humerus length, TCW: Capitulum of humerus + trochlea of humerus transverse length, GUA: The angle of the groove of the ulnar nerve, HVD: The vertical diameter of the humeral head, HML: The maximum length of the humerus, EML: The length between medial epicondyle and lateral epicondyle

GIW, TDD, FCW, FOL, and FOW parameters were not distributed normally. No significant difference was found between the right and left side in these parameters (p>0.05) (Table 2). The other parameters were normally distributed; GUW and GUA parameters were found to be higher on the left side and the difference was found to be statistically significant (p<0.05) (Table 3).

Correlation Analysis Results

The correlation analysis is shown in Table 4. GUA and GIW were not significantly correlated with any parameter (p>0.05) (Table 4).

Table 2. Non-normally distributed parameters (n=67)

Parameters	Left	Right	p-value
GIW (cm)	0.89 (0.25-1.93)	0.92 (0.35-1.69)	0.252
TDD (cm)	2.17 (0.60-2.83)	2.20 (1.74-2.72)	0.497
FCW (cm)	1.84 (1.11-2.19)	1.73 (1.40-2.45)	0.250
FOL (cm)	2.76 (1.82-3.38)	2.85 (1.82-3.38)	0.748
FOW (cm)	1.91 (0.94-2.50)	1.93 (1.40-2.65)	0.713

GIW: Intertubercular groove width, TDD: Deltoid tuberosity diameter, FCW: Coronoid fossa width, FOL: Olecranon fossa length (transverse plane), FOW: Olecranon fossa width (coronal plane)

Table 3. Normally distributed parameters (n=67)

	Left	Right	p-value
FRW (cm)	1.401±0.213	1.384±0.243	0.765
THW (cm)	2.458±0.265	2.446±0.320	0.868
THL (cm)	2.724±0.335	2.740±0.394	0.859
GUW (cm)	1.559±0.301	1.328±0.292	0.003
CHW (cm)	1.962±0.251	1.886±0.233	0.207
CHL (cm)	2.404±0.267	2.411±0.351	0.932
TCW (cm)	4.478±0.417	4.403±0.386	0.459
GUA (°)	121.4 ±14.6	113.0±15.4	0.028
HVD (cm)	4.678±0.479	4.813±0.511	0.270
HML (cm)	32.37±2.68	31.99±2.29	0.534
EML (cm)	6.129±0.563	5.988±0.594	0.333

FRW: Radial fossa width, THW: Trochlea of humerus width, THL: Trochlea of humerus length, GUW: Groove for the ulnar nerve width, CHW: Capitulum of humerus width, CHL: Capitulum of humerus length, TCW: Capitulum of humerus + trochlea of humerus transverse length, GUA: The angle of the groove of the ulnar nerve, HVD: The vertical diameter of the humeral head, HML: The maximum length of the humerus, EML: The length between medial epicondyle and lateral epicondyle

Table 4. Spearman-Pearson correlation test results of humerus parameters (n=67)

Variables	HML	HVD	GIW	TDD	CHW	THW	TCW	FCW	FRW	EML	GUW	GUA	CHL	THL	FOL
1. HML (cm)															
2. HVD (cm)	0.675**														
3. GIW (cm)	0.189	0.157													
4. TDD (cm)	0.496**	0.598**	-0.286												
5. CHW (cm)	0.454**	0.419**	0.072	0.379**											
6. THW (cm)	0.526**	0.553**	0.084	0.421**	0.073										
7. TCW (cm)	0.716**	0.665**	0.168	0.503**	0.600**	0.730**									
8. FCW (cm)	0.399**	0.383**	0.193	0.299*	0.153	0.502**	0.423**								
9. FRW (cm)	0.252*	0.279*	0.086	0.342**	0.295*	0.159	0.277*	0.092							
10. EML (cm)	0.665**	0.577**	0.220	0.537**	0.444**	0.654**	0.798**	0.492**	0.158						
11. GUW (cm)	0.442**	0.372**	0.033	0.253	0.254*	0.325**	0.400**	0.341*	0.065	0.541**					
12. GUA (°)	-0.108	-0.218	-0.141	0.045	0.050	-0.199	-0.196	0.074	0.005	-0.240	0.084				
13. CHL (cm)	0.442**	0.539**	0.012	0.543**	0.553**	0.433**	0.665**	0.381**	0.241	0.610**	0.334**	-0.116			
14. THL (cm)	0.591**	0.631**	0.164	0.489**	0.406**	0.462**	0.591**	0.453**	0.069	0.608**	0.514**	-0.062	0.563**		
15. FOL (cm)	0.378**	0.345**	0.253	0.196	0.305*	0.278*	0.441**	0.185	0.278*	0.376**	0.148	-0.135	0.351**	0.234	
16. FOW (cm)	0.210	0.219	0.218	0.186	0.095	0.271	0.275*	0.277	0.098	0.301*	0.179	0.013	0.192	0.210	0.597**

**$p<0.01$, *$p<0.05$, HML: The maximum length of the humerus, HVD: The vertical diameter of the humeral head, GIW: Intertubercular groove width, TDD: Deltoid tuberosity diameter, CHW: Capitulum of humerus width, THW: Trochlea of humerus width, TCW: Capitulum of humerus + trochlea of humerus transverse length, FCW: Coronoid fossa width, FRW: Radial fossa width, EML: The length between medial epicondyle and lateral epicondyle, GUW: Groove for the ulnar nerve width, GUA: The angle of the groove of the ulnar nerve, CHL: Capitulum of humerus length, THL: Trochlea of humerus length, FOL: Olecranon fossa length (transverse plane), FOW: Olecranon fossa width (coronal plane)

Discussion

This study aimed to examine the correlation between measurement parameters of the distal end of humerus and all humerus parameters by making anthropometric measurements on dry bones of the humerus showed that HML parameter was associated with most of the distal end parameters. It was also found that parameters on distal end were generally correlated with each other. Another result was the finding that GUW and GUA parameters were higher on the left side when compared with the right side.

In this study, the measurements of which were repeated twice, TEM, rTEM, and R values of 16 parameters were calculated. R values of all parameters were found to be between 0.83 and 0.99, and they were interpreted to have almost perfect reliability (6,7). The highest rTEM percentage was calculated as 12.49% in GIW parameter. The reason why this parameter had high rTEM value is the fact that it had a mean lower than 1 cm (8).

Fractures to the long bones are common (9). In such cases, samples are needed to evaluate the methods used in implants. In the literature, various fixation experiments have been performed on these specimens for clinical use based on screw-plate positioning. Knowing both the proximal and distal end of the humerus very well will increase the success in experiments such as biomechanical adjustment and durability on samples with various devices (10-13). Distal humeral prosthesis hemiarthroplasty used in comminuted distal humerus fractures should be designed to provide anatomical prerequisites and should be compatible with natural humeral anatomy. Having detailed knowledge of elbow anatomy will increase the design and success of new prostheses (14). At this point, the results obtained in this study will create an important anatomical resource.

Segmental studies of the humerus, especially in forensic medicine and archeology, there are studies that estimate the height from the humerus by using various formulas to determine the height of the people in the population (15,16). We think that HML will be a reference for such studies.

Kastamoni et al. (17) stated that GUW was positively significantly correlated with humeral retroversion angle and HML and negatively significantly correlated with olecranon fossa depth. Since the parameters of humeral retroversion angle and olecranon fossa depth were not included in our study, no inferences were made in our study on this. Although Vettivel et al. (18) found positively significant correlation with GUW and HML in their study, no significant correlation was found in the present study. Wafae et al. (19) stated that intertubercular groove morphology was not correlated with humeral morphometry. Measurements were made from the middle level of intertubercular groove both in this study and in Wafae et al.'s (19) study, while measurement was made from the proximal of the groove in Kastamoni et al.'s (17) study. We think that the difference in the results may be due to this reason.

Kastamoni et al. (17) concluded that there were no significant differences between olecranon fossa width and HML, EML, and THW parameters. On the other hand, a statistically significant correlation was found between FOW and EML in our study.

There are studies in literature which report correlation between HML and EML (20-22). There are also studies reporting a significant correlation between HML and THW parameters (22, 23). Similar results found in our study support the existing literature. While Kastamoni et al. (17) stated that HML parameter is not significantly correlated with EML and THW parameters, this result is not consistent with the results of our study and other studies. On the other hand, Kastamoni et al. (17) found statistically significant positive correlation between EML and THW and this result was found to be consistent with the results of our study.

There are studies in literature which show statistically significant positive correlation between HML and HVD parameters and this result is consistent with the results of our study (21,22). Similar to the results of our study, Çini and Arı (21) found significant positive correlation between HML and CHW parameters. However, although they found significant correlation between HML and GUW parameters, no significant correlation was found between these parameters in our study.

de Queiroz Chaves et al. (24) conducted by using the computed tomography images of the right sides of 30 individuals, they found mean GUA parameter as 92.7±10. In our study, this parameter was found as 113.0±15.4° on the right side. The fact that we had no recorded information about general health state since our study was conducted on dry bones, uncertain gender distribution and age, demographic differences and differences in sample size may be the reasons for the difference between studies. GUA parameter was found to be higher on the left side when compared with the right side in our study and the difference was found to be statistically significant. Since the same person was not compared bilaterally in our study, this difference was weak in terms of evidence. This parameter was not found to be correlated with any of our parameters. It has been stated in literature that bone structure is important in cubital tunnel syndrome factors (25). GUA is also the parameter that can determine the shape of cubital tunnel and we believe that it is clinically important.

This study has some limitations. Not having information about the age and gender of the dry bones used, about general health state and about whether the right and left bones belonged to same people are important limitations of the study.

Conclusion

Nevertheless, the anatomical information found in this highly reliable study will guide clinicians in studies evaluating humeral segments, especially in the treatment of elbow instability, the treatment and reconstruction of distal humeral fractures. It will help the multidisciplinary team to produce a more suitable prosthesis both biomechanically and kinesiologically by correlating it with radiological data. The results of this study will contribute to studies in the fields of anatomy, biomechanics, forensic sciences, and anthropology.

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Ethics

Ethics Committee Approval: This study was initiated with 2021/797 numbered approval from Karabük University Ethics Committee (date: 24.12.2021).

Informed Consent: Informed consent is not required.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept: R.S.B., Design: R.S.B., Data Collection or Processing: Ş.T., R.S.B., N.E.Ş., Analysis or Interpretation: Ş.T., R.S.B., N.E.Ş., Literature Search: Ş.T., R.S.B., N.E.Ş., Writing: Ş.T., R.S.B., N.E.Ş.

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