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MORPHOMETRIC ANALYSIS OF HUMAN BICIPITAL GROOVE: A STUDY ON DRY HUMERI

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The bicipital groove (BG) of the humerus exhibits marked anatomical variability, influencing the biomechanics of the long head of the biceps tendon. Such morphometric differences predispose to tendon pathology and have direct implications for surgical planning and prosthetic design. This study aimed to define the morphometric characteristics of BG in 30 human dry humeri (15 left, 15 right) from the Department of Anatomy, Faculty of Medicine, University of Niš. Length, width, depth, and medial angle were measured with a digital Vernier caliper and analyzed using Student's t-test and Pearson's correlation, with statistical significance set at $p < 0.05$. No significant side-to-side differences were observed in bicipital groove morphology. The mean groove length measured 76.6 mm (left 76.5 mm; right 76.6 mm), ranging from 59.9 to 86.9 mm. Average width was 6.9 mm (left 6.8 mm; right 7.0 mm), spanning 5.2–9.0 mm. Groove depth averaged 4.5 mm (left 4.6 mm; right 4.5 mm), with values between 3.2 and 5.9 mm. The medial angle showed a mean of 53.7° (left 54.3°; right 53.0°), ranging from 40.6° to 63.9°. Importantly, statistical analysis revealed a significant negative correlation between groove width and medial angle on the right humerus ($p < 0.05$). These findings indicate stable morphometric parameters with minimal asymmetry, while the observed correlation highlights how groove shape and angle may affect tendon stability and have clinical importance.

Key words: anatomic variation, shoulder joint, humerus, biceps brachii, tendon

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MORFOMETRIJSKA ANALIZA MEĐUKVRŽNOG ŽLEBA ČOVEKA: STUDIJA NA HUMERUSIMA

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Međukvržni žleb humerusa pokazuje izraženu anatomska varijabilnost koja utiče na biomehaniku tetive duge glave bicepsa nadlaktka. Takve morfometrijske razlike mogu stvoriti uslove za patološke procese na tetivi i imati direktne implikacije na hirurško planiranje i dizajn proteza. Ova studija imala je za cilj da definiše morfometrijske karakteristike žleba na 30 suvih humerusa (po 15 levih i desnih) iz zbirke Katedre za anatomiju Medicinskog fakulteta Univerziteta u Nišu. Dužina, širina, dubina i medijalni ugao mereni su digitalnim šublerom i analizirani Studentovim t-testom i Pirsonovom korelacijom, pri čemu je statistička značajnost postavljena na $p < 0,05$. Nisu uočene značajne razlike između leve i desne strane u morfologiji bicipitalnog žleba. Srednja dužina žleba iznosila je 76,6 mm (levo 76,5 mm; desno 76,6 mm), u rasponu od 59,9 do 86,9 mm. Prosečna širina bila je 6,9 mm (levo 6,8 mm; desno 7,0 mm), u opsegu 5,2–9,0 mm. Dubina žleba u proseku je iznosila 4,5 mm (levo 4,6 mm; desno 4,5 mm), sa vrednostima između 3,2 i 5,9 mm. Medijalni ugao imao je srednju vrednost od 53,7° (levo 54,3°; desno 53,0°), u rasponu od 40,6° do 63,9°. Statistička analiza je pokazala značajnu negativnu korelaciju između širine žleba i medijalnog ugla na desnom humerusu ($p < 0,05$). Ovi nalazi ukazuju na stabilne morfometrijske parametre sa minimalnom asimetrijom, dok uočena korelacija ističe kako oblik i ugao žleba mogu uticati na stabilnost tetive i imati klinički značaj.

Ključne reči: anatomska varijacija, rameni zglob, humerus, dvoglavi mišić nadlaktka, tetiva

INTRODUCTION

The bicipital groove (BG) of the humerus, or intertubercular sulcus, lies between the greater and lesser tubercles at the proximal end of the bone, extending distally and bounded by their respective crests. The greater tubercle occupies the lateral aspect of the humeral head, whereas the lesser tubercle is positioned anteriorly. These structures are joined superiorly by the transverse humeral ligament, traditionally described as forming the roof of the groove and functioning as a retinaculum (1,2). Some authors, however, argue that this role is fulfilled by fibres of the subscapularis tendon rather than the ligament itself (3,4). The outer margin of the groove is defined by the crest of the greater tubercle together with the tendon of the pectoralis major, while the crest of the lesser tubercle and the tendon of the teres major form the inner margin. Along its floor, the tendon of the latissimus dorsi courses, and within the groove itself, the long head of the biceps brachii is accommodated, covered by a synovial sheath and accompanied by the ascending branch of the anterior circumflex humeral artery (5).

The morphological features of the bicipital groove demonstrate considerable variability, and these differences can alter the biomechanics of the long head of the biceps tendon, predisposing to tendinitis or tendon instability during shoulder rotation (6,7). From an anthropological perspective, Rockwood and Matsen (8) emphasized that humans are unique among primates in manifesting notable variations in the intertubercular groove. More recent investigations have confirmed that a shallow and widened groove is strongly associated with dislocation of the long head of the biceps tendon (9–11), whereas a deep and narrow groove contributes to tendon impingement and shoulder impingement syndrome (7). The tubercles, particularly the lesser tubercle, also have a role in pathological changes when the normal anatomical relationship with the biceps tendon is disrupted during flexion and extension. Radiological studies have further clarified how morphometric variations of the groove contribute to these disorders (12). Importantly, detailed knowledge of groove morphology and its anatomical relationships may be useful for optimizing prosthetic design, placement, and sizing in shoulder arthroplasty, as well as for surgical management of proximal humeral fractures (13,14).

Given that anatomical variations of the shoulder may potentially affect joint function and stability, this study aims to define the morphometric characteristics of the bicipital groove by assessing its length, width, depth, and medial angle degree, with side-to-side comparisons. Establishing these

osteometric correlations could assist in bridging anatomical knowledge with clinical practice, that may be of use in studying tendon pathology and improving surgical methods.

MATERIAL AND METHODS

The study was conducted on 30 adult humeri (15 left, 15 right) of unknown age and sex that are part of the osteological collection of the Department of Anatomy, Faculty of Medicine, University of Niš. The inclusion criteria were the absence of pathological changes or fractures in adult bones. The humeri were labeled as H01 to H30. The following parameters were measured in mm using a digital vernier caliper with an accuracy of 0.01 mm (Figure 1):

- length of the bicipital groove: from the highest point on the upper end of the groove between the greater and lesser tubercles to the lowest point on the body of the humerus between the lateral and medial crests;
- width of the bicipital groove: distance between the medial border of the greater and lateral border of the lesser tubercles, at the junction between the proximal horizontal and distal vertical parts (15);
- depth of the bicipital groove: distance between the lowest point of the groove and the plane connecting the highest points of both tubercles at the junction between the proximal horizontal and distal vertical parts.

Using the Image J software v1.54d, the medial angle of the groove (the angle formed by the vertical plane following the medial border of the lesser tubercle and the horizontal plane running along the bottom of the groove) was determined on the photographs (Figure 1).

Using Sigmastat 3.5, the mean and standard deviation for each parameter were determined, as well as the correlations between same-side parameters. The normality of the data was assessed using the Kolmogorov-Smirnov test. The homogeneity of variances was determined by Levene's test. Student's t-test was used to analyze the side differences. Pearson's test was used to check if there are same-side correlations between the parameters. Statistical significance was set at $p < 0.05$.

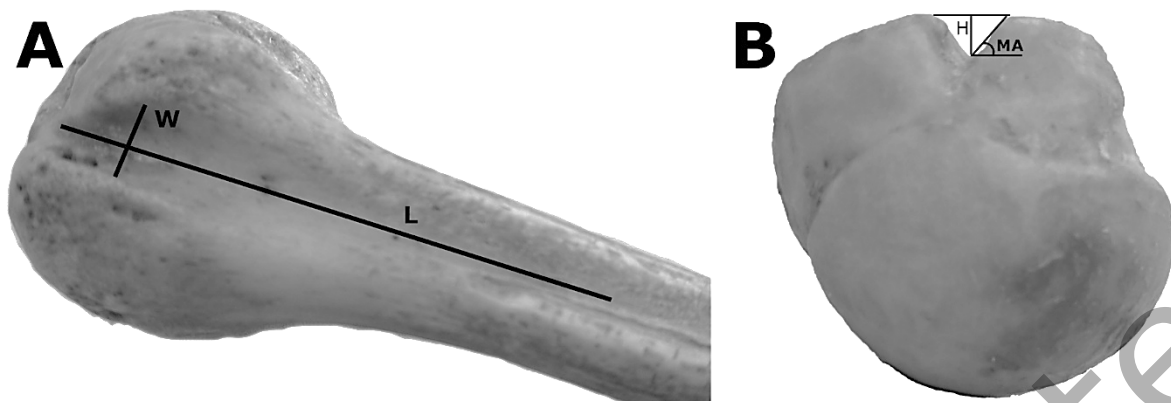


Figure 1. Representation of the parameters measured on dry humerus. A: L – length of the bicipital groove; W – width of the bicipital groove. B: H – height of the bicipital groove. MA – medial angle of the bicipital groove.

RESULTS

The mean values and standard deviations for groove length, width, and depth are presented in millimeters in Table 1, while medial angle measurements are expressed in degrees. No significant side-to-side differences were observed. The average groove length was 76.6 mm (left: 76.5 mm; right: 76.6 mm), with a range of 59.9 to 86.9 mm. The mean width measured 6.9 mm (left 6.8 mm; right 7.0 mm), spanning 5.2–9.0 mm. Groove depth averaged 4.5 mm (left 4.6 mm; right 4.5 mm), with a range of 3.2–5.9 mm. The medial angle showed a mean of 53.7° (left: 54.3°; right: 53.0°), ranging from 40.6° to 63.9°. A statistically significant negative correlation was identified between groove width and medial angle on the right side of the humerus ($p < 0.05$).

Table 1. Results of descriptive statistics of measured morphometric parameters of the bicipital groove according to side and in total

Side		Length (mm)	Width (mm)	Depth (mm)	Medial angle (°)
Left (N: 15)	Mean	76.5	6.8	4.6	54.3
	SD	7.0	1.1	0.6	6.7
	Minimum value	59.9	5.2	3.8	40.6
	Maximum value	86.9	9.0	5.7	63.9
Right (N: 15)	Mean	76.6	7.0	4.5	53.0
	SD	7.0	0.8	0.7	5.3
	Minimum value	64.6	5.5	3.2	42.7
	Maximum value	84.6	8.5	5.9	61.1
Total (N: 30)	Mean	76.6	6.9	4.5	53.7
	SD	6.9	1.0	0.6	6.0
	Minimum value	59.9	5.2	3.2	40.6
	Maximum value	86.9	9.0	5.9	63.9

N – number of samples; SD – standard deviation.

DISCUSSION

Morphological variations of the bicipital groove may have clinical significance because they could directly affect the position and function of the LHBT, thereby predisposing it to the most common sources of shoulder pain and subsequent joint dysfunction. In people with a shallow groove, LHBT subluxation occurs more often, especially in the medial part, while lateral dislocations are much less common (16). Conversely, a deep and narrow groove can lead to compression of the LHBT, which can result in impingement syndrome (13). Despite years of research, shoulder pain remains a diagnostic challenge, and the exact role of LHBT pathology remains a matter of debate (17). Altered BG morphology is often suggested as a possible etiological factor (18), but the results are unclear whether variations actually contribute to the development of these lesions. These findings further confirm the need to relate anatomical features to clinical practice to potentially improve diagnosis and therapeutic approaches for biceps tendon pathology and shoulder surgical procedures.

The mean groove length observed in our study matches closely with the values reported by van Deurzen (3), who documented a range of 81–87.33 mm, and by Ulkir et al., (13) who reported slightly higher measurements averaging 89.70 ± 8.09 mm. Yet, they differ from data obtained in a Serbian population (2), where mean lengths were considerably greater— 105.8 ± 16.1 mm in males and 101.5 ± 8.9 mm in females. Such variations may be partly attributable to methodological differences, as our measurements extended from the midpoint of the groove to the termination of the medial crest, producing comparatively shorter values. Beyond methodological variation, occupational demands and hand dominance have been suggested as contributing factors to groove width, with tendon hypertrophy in manual workers and the predominance of right-handedness cited as possible explanations for a wider sulcus (2,3). Conversely, Murlimanju et al. (19) reported no significant side-to-side differences, suggesting that lifestyle and demographic factors may complicate interpretations of groove morphology. The data on professional activities or dominant arms were not available for the subjects in our study, so we may only speculate by comparing our results to literature where such variables were considered. In terms of width, our findings fall within the ranges noted in previous reports (3, 20), but are lower than the radiographic data on patients, where the reported mean width of 10.3 ± 2.3 mm was found in non-dominant arms (21), and a study on the CT reported the width at 11.8 ± 1.8 mm in a non-injured group (22).

The average groove depth in this study can be compared with that of Venkatesan et al. (7), who reported 4.6 mm, and with Cone et al. (20), who reported 4.3 mm. According to their findings, 90% of patients had a groove deeper than 3 mm, and 86% had a groove in the 4-6 mm range. This would indicate possible differences in the study populations between our studies, assuming the subjects in our studies were healthy, or the potential for injury development in the study population.

The medial angle value we obtained is similar to a study of the Serbian population which reported values of 52.5° on the right humeri and 55.7° on the left (2), as well as to the study of Cardoso, who reported it at 56° in the subjects with normal LHBT (21). On the other hand, it was 51° in the patients with abnormal LHBT, thus suggesting that injuries to the long head of the biceps brachii tendon may be correlated to a potential tendon tear or a shallow groove (23), which was in line with our finding of negative correlation between the groove width and a degree of median angle.

There are several limitations to this study. Our sample size was relatively small, which limits the generalizability of the results. We lacked precise information on cadaver age, sex, and hand dominance, which can influence bone morphology through differential mechanical loading. All specimens were adult dry humeri, restricting direct clinical correlation with *in vivo* tendon–bone relationships, and the absence of occupational and lifestyle data prevented analysis of activity-related remodeling. Future investigations should incorporate occupational histories and employ standardized radiographic or CT protocols within prospective cohorts to enhance preoperative planning and to more accurately track temporal changes in bicipital groove dimensions.

CONCLUSION

The results of the study provide new information on the osteometric characteristics of the humeral bicipital groove in the Serbian population sample. The morphometric results suggest a similarity between the left and right bones and indicate a negative correlation between BG width and medial angle.

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