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Human bicipital groove: a morphometric study on dry humerus

Mehmet Ülkir[1], Mehmet Yılmaz[2], Aybegüm Balcı[2], Burcu Erçakmak Güneş[1], Ceren Günenç Beşer[1]

[1]*Department of Anatomy, Faculty of Medicine, Hacettepe University, Ankara, Türkiye*
[2]*Department of Anatomy, Faculty of Medicine, Ankara University, Ankara, Türkiye*

Abstract

Objectives: The aim of this study is to evaluate the morphometry of the bicipital groove on dry humeri, which is closely associated with the long head of the biceps tendon, a key component in shoulder biomechanics.

Methods: This study involved 109 adult human dry humeri (56 right, 53 left). The humerus length (HL), bicipital groove length (BGL), bicipital groove width (BGW), bicipital groove depth (BGD), opening angle (OA) and medial wall angle (MWA) were measured.

Results: The mean value of HL was measured 30.97±2.01 cm and the mean value of BGL was 89.70±8.09 mm. The mean value of BGW was 10.31±1.51 mm and BGD was 3.98±0.79 mm. The mean value of OA was 99.85±14.53° and MWA was 42.31±8.25°. No significant differences were observed between the right and left sides in the measured parameters. Positive correlations were found between BGW and BGD, BGW and OA, MWA and BGD, and HL and BGL. Negative correlations were observed between BGL and BGD, OA and BGD, and MWA and BGW.

Conclusion: We believe the detailed morphometric evaluation of the bicipital groove presented in this study provides valuable insights into the pathologies of the long head of the biceps tendon and its implications for shoulder arthroplasty.

Keywords: anatomy, bicipital groove, long head of biceps, morphometry

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Introduction

The bicipital groove (BG), also referred to as the intertubercular sulcus, is a depression that extends distally and is situated between the greater and lesser tubercles on the anterior surface of the proximal humerus.[1,2] The lesser and greater tubercles are connected by a wide transverse humeral ligament, which turns this groove into a tunnel.[3] The long head of biceps tendon (LHBT) passes through this groove before inserting to the supraglenoid tubercle, crossing the capsule of shoulder joint.[4] This tunnel also provides passage for the synovial sheath of the LHBT and the anterior circumflex humeral artery.[5] The medial and lateral lips of the BG serve as attachment points for the tendons of the teres major and pectoralis major muscles, respectively, while the floor of the BG provides attachment for the latissimus dorsi tendon. Also, the muscle fibers of pectoralis major, supraspinatus and subscapularis form the superior border of the BG. Along with the transverse humeral ligament and surrounding muscle fibers, the BG helps stabilize the LHBT, ensuring proper muscle function and preventing dislocation during arm movements.[6]

Anterior shoulder pain is a common condition that affects a significant number of individuals, including the elderly population. Injuries involving the LHBT have been proposed as one of the most common reasons for shoulder disability and pain.[7] Shoulder pain associated with LHBT injuries is believed to be due to impingement, pre-rupture, inflammation, or tendon instability at the point of entry into the BG.[6] The morphometric characteristics of the BG may significantly affect the functionality of the adjacent structures in the shoulder joint[4] and some authors stated that injuries of LHBT caused by the significant anatomical variabilities of the

BG, were the primary reasons for shoulder pain and dysfunction.[8] Bicipital groove width, depth and angulations are crucial parameters in the prevention of subluxation or impingement of the LHBT which can lead to shoulder pain.[4] Understanding the morphometry of BG is extremely beneficial for prosthetic design, sizing and placement and it is a crucial landmark for replacing the humeral head in proximal end fractures and for positioning the lateral fin of the prosthesis during shoulder arthroplasty.[9]

The aim of this study was to evaluate the BG morphometry on the dry humeri, which is important in shoulder biomechanics and has a significant relationship with LHBT.

Materials and Methods

This study involved 109 adult human dry humeri (56 right, 53 left) which were obtained from the Department of Anatomy, Faculty of Medicine, Hacettepe University. The age and sex of the specimens were not identified. Humeri with cortical deformity and fracture were excluded. Ethical approval was obtained from Hacettepe University Health Sciences Research Ethics Committee (30.07.2024, decision number: 2024/13-01).

The following parameters were assessed:

1. **The humerus length (HL):** the distance from the most proximal point of head of humerus to the most distal point of trochlea of humerus (**A–B**) (**Figure 1**).
2. **The bicipital groove length (BGL):** the distance from the point between the lesser and greater tubercles to the end of the bicipital groove depression on the shaft (**C–D**) (**Figure 2**).
3. **The bicipital groove width (BGW):** the distance between the top of the lesser tubercle and top of the greater tubercle (**E–F**) (**Figure 3**).
4. **The bicipital groove depth (BGD):** the distance from the line connects the top of the lesser tubercle and top of the greater tubercle to the deepest point of bicipital groove (**EF–G**) (**Figure 3**).
5. **Opening angle (OA):** the angle between the line connects the deepest point of bicipital groove and top of lesser tubercle and the line connects the deepest point of bicipital groove and top of greater tubercle (**EG-FG**) (**Figure 4**).
6. **Medial wall angle (MWA):** the angle between the line passes from the deepest point of bicipital groove which is parallel to the line connects the top of lesser

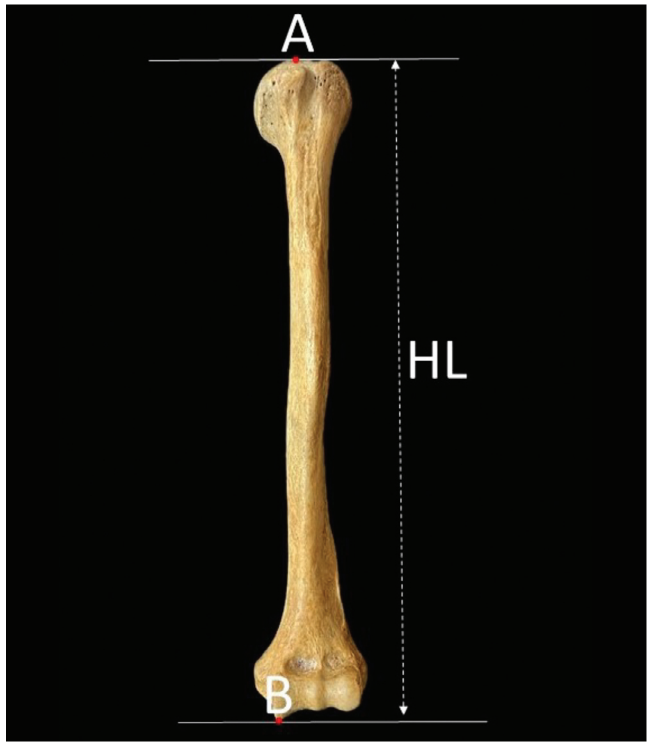

Figure 1. Demonstration of humerus length (**HL**) measurement. **A:** the most proximal point of head of humerus, **B:** the most distal point of trochlea of humerus.

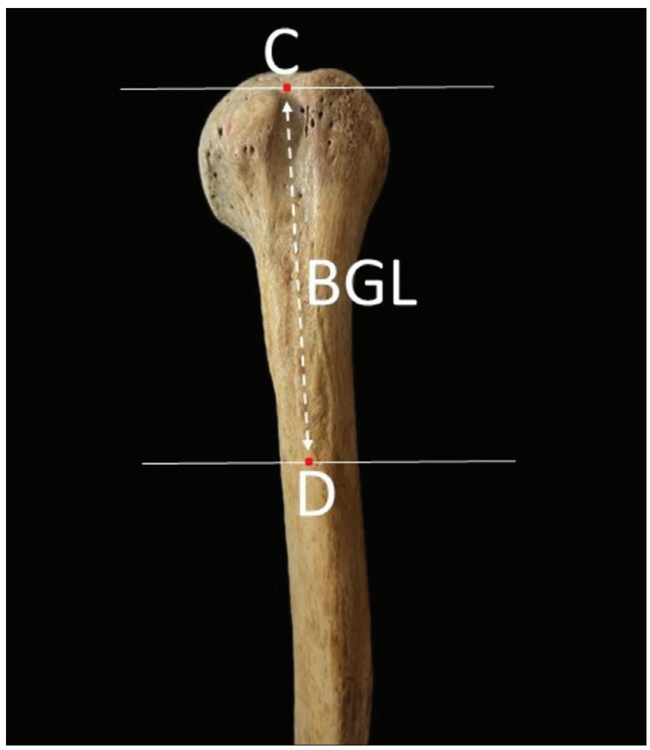

Figure 2. Demonstration of bicipital groove length (**BGL**) measurement. **C:** the point between the lesser and greater tubercles, **D:** end of the bicipital groove depression on the shaft.

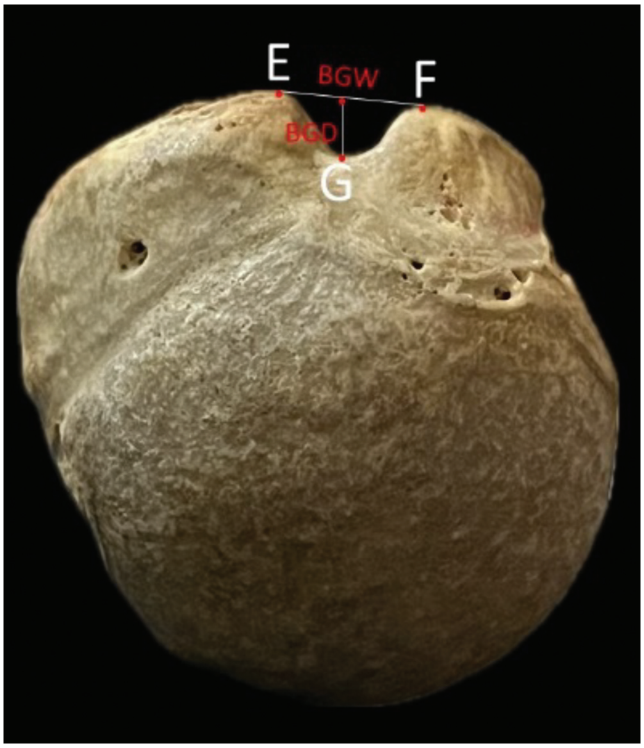

Figure 3. Demonstration of bicipital groove width (**BGW**) and bicipital groove depth (**BGD**) measurements. **E:** top of the greater tubercle, **F:** top of the lesser tubercle, **G:** deepest point of bicipital groove.

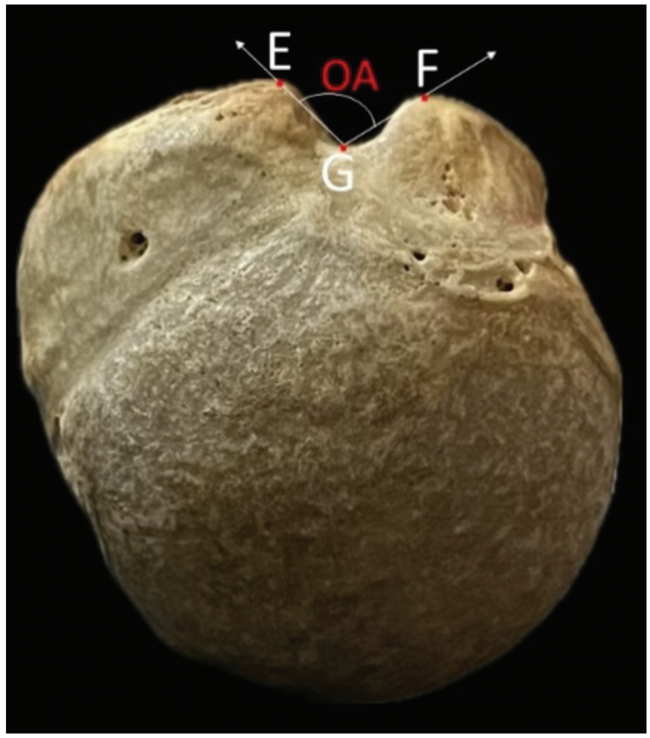

Figure 4. Demonstration of opening angle (**OA**) measurement. **E:** top of the greater tubercle, **F:** top of the lesser tubercle, **G:** deepest point of bicipital groove.

tubercle and top of greater tubercle and the line connects the deepest point of bicipital groove and top of lesser tubercle (**Figure 5**).

The HL was measured with tape measure (150 cm). The BGL, BGW and BGD was measured with 0.01 mm accuracy digital Vernier caliper (150 mm). OA and MWA was measured by angle meter application. For minimizing intra observer error, measurements was performed 3 times with a one-week interval and average values were calculated.

Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS), version 19 (Chicago, IL, USA). The measurements were presented as mean values and standard deviations. The Kolmogorov-Smirnov test was used to analyze the distribution of the data set. Pearson correlation test was used for normally distributed data and the Spearman correlation test for non-normally distributed data. The student's t-test and Mann-Whitney U test were used for comparison of right and left side measurements. For correlation analysis, Pearson correlation test was used. A p-value less than 0.05 was accepted as statistically significant. Sample size was

Figure 5. Demonstration of medial wall angle (**MWA**) measurement. **F:** top of the lesser tubercle, **G:** deepest point of bicipital groove.

calculated using GPower 3.1 program. The study will find a statistical difference of medium effect size (d=0.50, Cohen, J) among the effect sizes recommended in the literature between the means of the two groups (right and left side) with 90% power at 95% confidence level, when samples with a size of at least 100 (50 right, 50 left) are selected from each group.

Results

A total of 109 human dry humeri (56 right, 53 left) from the bone collection of Hacettepe University were examined in this study. The mean value of HL was 30.81±1.72 cm on the right side, 31.21±2.24 cm on the left side, and 30.97±2.01 cm in total. The mean value of BGL was 88.47±6.84 mm on the right side, 91.04±9.14 mm on the left side, and 89.70±8.09 mm in total. The mean value of BGW was 10.10±1.21 mm on the right side, 10.57±1.76 mm on the left side, and 10.31±1.51 mm in total. The mean value of BGD was 3.93±0.69 mm on the right side, 4.01±0.88 mm on the left side, and 3.98±0.79 mm in total. The mean value of OA was 101.70±14.14° on the right side, 98.20±14.86° on the left side, and 99.85±14.53° in total. The mean value of MWA was 41.43±7.90° on the right side, 42.97±8.46° on the left side, and 42.31±8.25° in total (**Table 1**).

There were no statistically significant differences observed between the right and left sides in any of the measured parameters. Positive correlations were observed between BGW and BGD (r=0.232, p=0.15), BGW and OA (r=0.474, p<0.01), MWA and BGD (r=0.533, p<0.01), and HL and BGL (r_s=0.598, r=0). The negative correlations were detected between the BGL and BGD (r=-0.260, p=0.006), OA and BGD (r=-0.682, p=0.0), MWA and BGW (r=-0.370, p=0.0).

Discussion

Anatomical variations in the BG that involve the LHBT were predisposing factors for common sources of shoulder pain, resulting in shoulder joint disability.[8] It is quite common for individuals with a shallow BG to experience subluxation of the long head of the biceps, especially in the medial region. Lateral dislocation or subluxation is relatively uncommon. Besides subluxation and dislocation, a narrow and deep BG can often be the main reason for compressing the long head of the biceps tendon within it, resulting in impingement syndrome, a prevalent functional impairment of the shoulder joint.[4] BGW was measured 10.1 mm by Wafae et al.[1] in Brazil, 8±2 mm by Rajani and Man[6] in India , 9.12±2.18 mm by Kumar et al.[4] in India, 6.79±0.53 mm on the right side and 7.56±1.05 mm on the left side by Karmali and Modi[3] in India, 8.53±1.56 mm on the right side and 7.96±1.39 mm on the left side by Ashwini and Venkateshu[10] in India, 8.42±0.85 mm on the right side and 7.7±0.50 mm on the left side by Srimani et al.[5] in India, 8.99±1.51 mm by Venkatesan et al.[11] in India, 10.3±2.5 mm by Cardoso et al.[12] in Portugal, 12.3±2.1 mm by Tang et al.[13] in China, 11.8±1.7 mm in <55 years old group and 10.9±1.6 mm in >55 years old group by Song and Kim[14] in Korea. In our study BGW was 10.31±1.51 mm, which was higher than majority of previous studies and lower than the studies of Tang et al. and Song and Kim.[1,3–6,10–14] BGD was measured 4.0 mm by Wafae et al.,[1] 6±1 mm by Rajani and Man,[6] 5.49±1.56 mm by Kumar et al.,[4] 4.17±0.56 mm on the right side, 5.01±1.02 mm on the left side by Karmali and Modi,[3] 5.06±0.54 mm in males and 4.51±0.54 mm in females by Duran et al.,[15] 6.48± 1.13 mm on the right side and 6.14±1.04 mm on the left side by Ashwini and

Table 1
Morphometric properties of bicipital groove.

Measurement	Right	Left	Total	p-value
HL (cm)	30.81±1.72	31.21±2.24	30.97±2.01	0.241
BGL (mm)	88.47±6.84	91.04±9.14	89.70±8.09	0.092
BGW (mm)	10.10±1.21	10.57±1.76	10.31±1.51	0.089
BGD (mm)	3.93±0.69	4.01±0.88	3.98±0.79	0.673
OA (°)	101.70±14.14	98.20±14.86	99.85±14.53	0.248
MWA (°)	41.43±7.90	42.97±8.46	42.31±8.25	0.196

BGD: bicipital groove depth; **BGL:** bicipital groove length; **BGW:** bicipital groove width; **HL:** humerus length; **MWA:** medial wall angle; **OA:** opening angle.

Venkateshu,[10] 5.1 mm by Abboud et al.,[7] 4.63±0.38 mm on the right side and 4.45±0.30 mm on the left side by Srimani et al.,[5] 4.6±1.09 mm by Venkatesan et al.,[11] 4.1±1.5 mm by Cardoso et al.,[12] 4.9±1.4 mm by Tang et al.,[13] 4.6±0.7 mm in <55 years old group and 4.6±0.8 mm in >55 years old group by Song and Kim.[14] BGD was measured 3.98±0.79 mm in our study, which was lower than previous studies. Ulucakoy et al. evaluated 200 magnetic resonance imagines and they measured BGD as 5.6 ± 0.8 mm in stable LHBT patients and 5.7 ± 0.9 mm in unstable LHBT patients. No significant difference was detected between the stable and unstable LHBT patients for BGD measurement in their study.[16] Also, no correlation was detected between the BGW and BGD measurements and LHBT pathologies in the studies of Cardoso et al.[12] and Tang et al.[13] Song and Kim[14] compared the BGW and BGD values between the <55 years old group and >55 years old group and statistically significant difference was detected between these groups for BGW measurement. We measured HL and BGL as 30.97±2.01 cm and 89.70±8.09 mm, respectively, which were consistent with previous studies. Measurement differences may result from geographical variations and differing measurement techniques, such as dry bone assessment versus magnetic resonance imaging, radiography and computed tomography imaginations. Radiological imaging techniques are developing and measurements can be done on radiological images in 3D, but we think that measurements done on dry bones are still the most valuable materials since measurements done by touching the hand. Moreover, it is known that morphometric values may differ between populations. We can conclude from **Table 2** that the measurement differences in studies performed with dry bones may be due to the studies being performed in various geographical regions or the studies performed with various measurement techniques.

The LHBT is greatly influenced by the size and dimensions of the bicipital groove (BG). Multiple authors have documented a higher occurrence of dislocation and subluxation of the LHBT when the BG is shallow. The LHBT instability could be caused by the dimension of MWA that vary based on the depth and width leading to a shallow bicipital groove.[10] While it is not known if there is a specific critical MWA value for LHBT instability, Ahovuo[17] demonstrated that 22% of patients with LHBT instability had a MWA below 30° and Hitchcock and Bechtol[8] found that a smaller than 35° MWA was seen in 8% of patients with LHBT instability. In a study of Venkatesan, no bone had MWA lower than 30°.[11] Ashwini and Venkateshu[10] detected humeri with MWA lower than 30° in 6 of 87 humeri which were left sided. In a study of Cardoso et al.[12] MWA lower than 30° was detected in 4 patients (9.1%) and similar to the study by Tang et al.,[13] they did not find a significant difference between MWA and LHTB pathologies. Also, Song and Kim detected no significant difference between the age groups (<55 years old group and >55 years old group) for MWA parameter.[14] In our study MWA was measured 42.31±8.25°, which was lower than majority of previous studies and 4 of 109 bones had MWA below 30° and 22 of 109 bones were between 30–35°. This finding shows us that individuals in the Turkish population may be more prone to LHBT instability due to their lower MWA. Duran et al.[15] measured MWA as 50.01±5.55° in males and 47.91±5.70° in females and no significant difference was detected between sex for MWA measurement. Also, there was no significant difference between the stable LHBT (51.0±8.6°) and unstable LHBT (49.9±8.4°) patients for MWA measurement in a study of Ulucakoy et al.[16]

Pfahler et al.[18] detected a noticeable increasing of damaged LHBT in the presence of a flat groove angle. Several authors have stated that dislocation and subluxation of the biceps tendon are more frequent when the BG is not deep enough. It is also indicated that a shallow BG can make the tendon more prone to chronic injury from being compressed by the coracoacromial arch, rotator cuff and acromion during shoulder movements.[19] Smith[20] categorized different types of BG based on their mean OA being less than 66°, 94°, and 118° into narrow, normal, and shallow classifications. In a study of Abboud et al.,[7] majority of BG had normal OA (38/75) and 20 of 75 were shallow and 17 of 75 were narrow. Cardoso et al.[12] detected majority of BG as normal OA 26 (59.1%). Unlike these studies we detected majority of BG as shallow OA (68 of 109), 1 of 109 was narrow and 40 of 109 were normal. Since individuals in Turkish population have a higher opening angle, they may be exposed to more pressure from the structures around the LHBT, which may cause chronic damage. No significant difference was detected between the LHBT pathologies and OA parameter in the studies of Cardoso et al. and Tang et al.[12,13] The comparison of morphometric properties of BG was summarized in **Table 2**.

Table 2
Comparison of the morphometric properties of the bicipital groove.

Study (year)	Population	N	Method	HL (cm)	BGL (mm)	BGW (mm)	BGD (mm)	OA (°)	MWA (°)
Wafae et al. (2010)[1]	Brazil	50 (25 R, 25 L)	DB	-	81	10.1	4.0	106	-
Rajani and Man (2013)[6]	India	101 (56 R, 45 L)	DB	-	R: 85±0.9 L: 83±10.1	8±2	6±1	82.20±20.62	48.91±10.31
Kumar et al. (2021)[4]	India	100 (57 R, 43 L)	DB	-	72.98±7.54	9.12±2.18	5.49±1.56	72.27±18.12	65.27±10.71
Karmali and Modi (2019)[3]	India	86 (49 R, 37 L)	DB	31.14±2.41	R: 83.93±5.68 L: 86.59±6.28	R: 6.79±0.53 L: 7.56±1.05	R: 4.17±0.56 L: 5.01±1.02	-	-
Duran et al. (2023)[15]	Turkey	110 (50 M, 60 F)	MRI	-	-	-	M: 5.06±0.54 F: 4.51±0.54	M: 78.73±7.90 F: 80.53±8.71	M: 50.01±5.55 F: 47.91±5.70
Ulucakoy et al. (2021)[16]	Turkey	200	MRI	-	-	-	SLHBT: 5.6±0.8 ULHBT: 5.7±0.9	SLHBT: 83.3±12.5 ULHBT: 82.3±12.6	SLHBT: 51.0±8.6 ULHBT:49.9±8.4
Ashwini and Venkateshu (2017)[10]	India	87 (39 R, 48 L)	DB	R: 32.49±1.83 L: 31.72±2.03	R: 89.94±6.35 L: 88.88±8.11	R: 8.53±1.56 L: 7.96±1.39	R: 6.48± 1.13 L: 6.14±1.04	-	R: 66.15±13.20 L: 64.37±18.81
Abboud et al. (2010)[7]	USA	75	MRI	-	-	-	5.1	81	47
Srimani et al. (2016)[5]	India	107 (59 R, 48 L)	DB	R: 30.37±2.12 L: 29.46±2.43	R: 71.59±3.78 L: 70.78±5.04	R: 8.42±0.85 L: 7.7±0.50	R: 4.63±0.38 L: 4.45±0.30	R: 81.41±10.90 L: 79.31±11.32	R: 50.22±5.35 L: 53.83±6.80
Venkatesan et al. (2017)[11]	India	200 (106 R, 94 L)	DB	29.74±2.19	81.8±9.77	8.99±1.51	4.6±1.09	-	56.46±4.32
Cardoso et al. (2023)[12]	Portugal	60	RG	-	-	10.3±2.5	4.1±1.5	80±26	53±15
Tang et al. (2023)[13]	China	126	CT	-	-	12.3±2.1	4.9±1.4	89.8±18.4	40.6±7.9
Song and Kim (2024)[14]	Korea	111	CT	-	-	<55 years old: 11.8±1.7 >55 years old: 10.9±1.6	<55 years old: 4.6±0.7 >55 years old: 4.6±0.8	-	<55 years old: 58.9±11.3 >55 years old: 62.2±10.1
This study (2024)	Turkey	109 (56 R, 53 L)	DB	30.97±2.01	89.70±8.09	10.31±1.51	3.98±0.79	99.85±14.53	42.31±8.25

BGD: bicipital groove depth; **BGL:** bicipital groove length; **BGW:** bicipital groove width; **CT:** computed tomography; **DB:** dry bone; **F:** female; **HL:** humerus length; **L:** left; **M:** male; **MRI:** magnetic resonance image: **MWA:** medial wall angle, **N:** sample size, **OA:** opening angle; **R:** right; **RG:** radiography; **SLHBT:** stable long head of biceps tendon; **ULHBT:** unstable long head of biceps tendon.

In a study of Duran et al.,[15] they detected negative correlation between BGD and OA and positive correlation between BGD and MWA which was accordance with our study. It means that, If BGD increases, OA decreases and MWA increases, this condition results in a deeper and narrower groove. Also, we found positive correlation between the HL and BGL and negative correlation between BGL and BGD. Our findings suggest that individuals who are taller tend to have a groove that is longer and shallower, along with a larger OA, which could lead to a higher risk of subluxation and dislocation of the LHBT.

Moreover, BG serves as a key landmark for guiding retroversion during shoulder prosthesis implantation. In cases of osteoarthritis, the proximal portion of the groove is utilized, while the distal portion is preferred for fractures. There is considerable variation in the orientation of the groove, so caution is advised regarding the reliance on the bicipital groove as a consistent reference in shoulder replacements for fractures.[21] Angular and morphometric properties of BG was evaluated in our study and we believe that findings of our study will be beneficial in shoulder prosthesis implications for understanding the morphometric properties of BG.

There are certain limitations in this study. One of the primary limitations in this research is the lack of data on the sex and age of the humeri. Therefore, the effects of these parameters on the BG morphometry was not assessed. An additional limitation is that this study was conducted using 109 humeri. In further studies, it is important to analyze the morphometry of the BG on CT or MRI scans using larger sample sizes with patients of known sex and age.

Conclusion

Knowing the morphometric properties of BG is essential for pathologies of LHBT. In our study, we evaluated BG morphometry in detail. The positive correlations were detected between the BGW and BGD, BGW and OA, MWA and BGD, HL and BGL. The negative correlations were detected between the BGL and BGD, OA and BGD, MWA and BGW. No significant differences were detected between the right and left side for measured parameters. We believe our findings are valuable for understanding LHBT pathologies and their relevance to shoulder arthroplasty.

Conflict of Interest

There are no conflict of interest.

Author Contributions

MÜ: Project development, data collection, data analysis, manuscript writing and editing; MY: data collection, data analysis, manuscript writing and editing; AB: data collection, manuscript writing and editing; BEG: data collection, manuscript writing and editing; CGB: data collection, manuscript writing and editing.

Ethics Approval

Ethical approval was obtained from Hacettepe University Health Sciences Research Ethics Committee (30.07.2024, decision number: 2024/13-01).

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ORCID ID:
M. Ülkir 0000-0001-5615-8913; M. Yılmaz 0000-0001-8395-4675; A. Balcı 0000-0002-6345-1082; B. Erçakmak Güneş 0000-0001-6936-0766; C. Günenç Beşer: 0000-0002-8230-3974

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Correspondence to: Mehmet Ülkir, MD, PhD
Department of Anatomy, Faculty of Medicine,
Hacettepe University, Ankara, Türkiye
Phone: +90 312 310 71 69
e-mail: mehmet.ulkir@hotmail.com

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