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Dimensional analysis of the bicipital groove and its associated pathology in a South African population

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ABSTRACT

The bicipital groove (BG) forms an indentation between the greater and lesser humeral tubercles and lodges the long head of biceps brachii tendon (LHBBT) along with the ascending branch of the circumflex humeral artery. This study aimed to determine the dimensions (length, width, depth) of the BG in a select South African population. The dimensions of the BG in one hundred and sixty (n = 160; Right: 80; Left: 80, Male: 100; Female: 60) unpaired dry bone humerii were measured with a digital caliper (Linear Tools 2012, 0–150 mm, LIN 86500963) and was analyzed using SPSS (V25). *Results*: Bicipital groove dimensions: (a) Length (mm): Right 66.64 ± 9.06, Left 68.31 ± 11.52; Male 67.44 ± 9.12, Female 67.53 ± 12.25; (b) Width (mm): Right 8.98 ± 1.49, Left 9.27 ± 1.30; Male 9.18 ± 1.45, Female 9.05 ± 1.31; (c) Depth (mm): Right 7.73 ± 1.31, Left 7.20 ± 1.18; Male 7.43 ± 1.29, Female 7.53 ± 1.24. The mean BG length observed in this study disagreed with previous studies where smaller lengths were reported. In addition, the comparison of the mean BG depth in this study also revealed a statistically significant difference which may suggest that increased depth in the BG is a common finding in right side of BG specimens. This finding was unique as BG depth is associated with biceps tendon pathology and augments South African shoulder-related literature. Since biceps tendon pathology is associated with decreased biceps activity and pain, investigation of the BG may provide useful data to evaluate individuals with potential abnormality of the bicep tendon. It may also be used as a landmark for humeral head replacement in the treatment of proximal humerus fractures.

1. Introduction

According to the World Health Organization (WHO), approximately 2% of the general population presents with some instability of the shoulder joint, with a total of 1.7% of these individuals experiencing shoulder dislocation.[1] The morphology of the bicipital groove (BG) has been observed to present with significant variability which is considered to affect the transverse humeral ligament (THL) and the biomechanics of the long head of biceps brachii tendon (LHBBT).[2] The BG, located within the proximal part of the humerus, forms an indentation between the greater and lesser humeral tubercles.[3] The medial border and lateral lip of the BG are bound by the lateral edge of the lesser tubercle and the proximal one-third of the anterior border of the greater tubercle, respectively.[3] In addition to the lateral and medial walls, the BG may also be identified by the presence of a floor.[3,4] These three boundaries receive bilaminar insertions from the pectoralis major, teres major and lattismus dorsi muscles.[4] The BG is also converted into a canal by the fibrous THL which extends between the greater and lesser humeral tubercles.[5] The ensheathed LHBBT, which passes through the glenohumeral joint (GHJ) to the humeral head then lodges with the ascending branch of the circumflex humeral artery within the canal of the BG before it enters the arm.[6] The presence of the THL, situated over the LHBBT, prevents subluxation during biomechanical movements of the arm, thus providing stability and allowing for optimal function.[7] Although abnormalities of the LHBBT and its synovial sheath have been identified in numerous causes of shoulder pain and disability, few studies have documented the morphometry of the proximal humerus.[8,9] Moreover, this particular region remains unreported in South African literature. The morphology of the BG has been observed to present with significant variability (deep and narrow grooves vs. wide and shallow grooves) which is considered to affect the biomechanics of the LHBBT, associated pathologies (tenosynovitis and pulley lesions) and traumatic

Abbreviations: BG, bicipital groove; I, inferior; L, lateral; LHBBT, long head of biceps brachii tendon; M, medial; S, superior; THL, transverse humeral ligament

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Table 1
Intra observer Reliability.

Descriptive Statistics			Multivariate Analysis: Effect			
Parameter	Dataset	Mean ± Std. Deviation (mm)	Pillai's Trace	Wilk's Lambda	Hotelling's Trace	Roy's Largest Root
BG Length	**1**	62.20 ± 4.93	0.026	0.974	0.026	0.026
	2	62.15 ± 4.98				
	3	62.28 ± 4.97				
BG Width	**1**	8.78 ± 0.92	0.000	1.000	0.000	0.000
	2	8.78 ± 0.94				
	3	8.79 ± 0.92				
BG Depth	**1**	7.65 ± 0.77	0.039[a]	0.961[a]	0.040[a]	0.040[a]
	2	7.79 ± 0.81				
	3	7.71 ± 0.65				

Key: BG: bicipital groove.
[a] Statistically significant.[1,2]

injuries (viz. proximal tears of the biceps brachii muscle and subluxation).[2] Individuals participating in sporting activities that require repetitive overhead motions are also at risk.[10] While the structures related to the BG serve as important anatomical landmarks in shoulder replacement procedures, the morphometric data of the BG is also required in design of prosthesis.[11] Therefore, this study aimed to determine the dimensions of the BG in a select South African population.

2. Methods

2.1. Study design

The study sample was comprised of one hundred and sixty (n = 160; Right: 80; Left: 80) unpaired dry bone humerii. Specimens were obtained from the existing osteological bank at the Discipline of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, University of KwaZulu-Natal, South Africa. The study was conducted under the auspices of the institutional ethical clearance review committee (Ethical Clearance Number: (BE308/18). Dry bone humerii displaying no evidence of previous damage and/or fracture were included in this study. The dimensions of the dry bone humerii were measured with a digital caliper (Linear Tools 2012, 0–150 mm, LIN 86500963). The mean values with standard deviations were calculated from the three measurements recorded for each parameter of the BG. Intra observer reliability was determined using the multivariate analysis test of the general linear model (Table 1).

2.2. Study parameters

Dimensional parameters (viz. length, width and depth) of the BG on the proximal humerus were quantified according to the method of Rajan and Kumar (2016)[5] (Fig. 1):

a) Length of BG (mm) (l): This was measured from the midpoint between the humeral tubercles to the end of the medial lip of the BG.
b) Width of BG (mm) (w): This was measured between the mid-point of the medial and lateral lips of the BG.
c) Depth of BG (mm) (d): This was measured as the distance between the greater and lesser humeral tubercles and their midpoint.

2.3. Data analysis

The statistical analysis (viz. Independent Sample T-test and Pearson Chi Square Test) was performed using the Statistical Package for Social Sciences (SPSS) (Copyright IBM corporation 1989, 2017, Chicago, Illinois, USA). A p value < 0.05 was statistically significant.

3. Results

3.1. Intra-observer reliability

Intra-observer reliability is reported in Table 1. Only one parameter, viz. BG depth, yielded statistically significant p-values for different effects of the multivariate analysis test. The descriptive statistics also indicated that the mean value, deduced from the first set of measurements, is dissimilar to the mean values of the second and third sets of

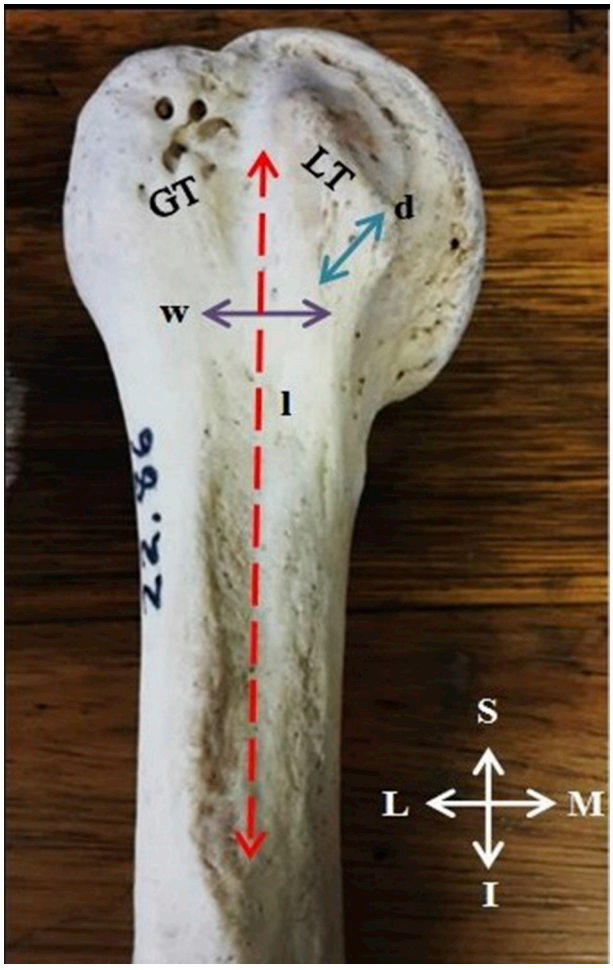

Fig. 1. Antero-lateral view of right dry bone humerus. Key: d-depth; GT-greater tubercle; I- inferior; L-lateral; l-length; LT-lesser tubercle; M-medial; S- superior; w-width.

Table 2
Mean dimensional parameters of the BG.

Parameters		Mean ± SD of BG Dimensions (mm)		
		Length	Width	Depth
Laterality	**Right (n = 80)**	66.64 ± 9.06	8.98 ± 1.49	7.73 ± 1.31
	Left (n = 80)	68.31 ± 11.52	9.27 ± 1.30	7.20 ± 1.18
p-value		0.309	0.189	0.008*
Gender	**Male (n = 100)**	67.44 ± 9.12	9.18 ± 1.45	7.43 ± 1.29
	Female (n = 60)	67.53 ± 12.25	9.05 ± 1.31	7.53 ± 1.24
p-value		0.955	0.573	0.622

Key: * - statistically significant p-value.

measurements (Table 1). This discrepancy in readings may be due to presence of one or more outliers in the respective dataset. The difference in readings was further confirmed by the statistically significant p-value of 0.044, indicating the reduced reliability of the values recorded for this BG parameter (Table 1). As the biostatistician verified the accuracy of the sample size, the reduced reliability may be due to investigator fatigue. The mean parameters of the BG length and width did not yield any statistically significant differences, thus indicating optimum intra-observer reliability of the respective values as similar readings were recorded for all these parameters (Table 1).

3.2. Laterality

Dimensions of the BG are reported in Table 2. The mean length and width of the BG were observed with larger dimensions on the left side and was statistically insignificant ($p < 0.05$) (Table 2). The mean BG depth was observed to be larger on the right side and was found to be statistically significant ($p < 0.05$) (Table 2).

3.3. Gender

The mean length and depth of the BG were observed larger in female specimens as compared to male specimens and was found to be statistically insignificant ($p < 0.05$) (Table 2). On the contrary, the mean width of the BG was observed larger in male specimens as compared to female specimens reported with no statistical significance ($p < 0.05$) (Table 2).

4. Discussion

The World Health Organization (WHO) has identified musculoskeletal conditions as the second highest contributor to global disability.[1] Approximately 20–33% of the population is known to live with a painful musculoskeletal condition, the prevalence of which varies with age and diagnosis.[1] Shoulder pain plays a pivotal role in shoulder pathology of the population, especially in athletes and the elderly.[4] Such cases of pathology of the LHBBT include tenosynovitis, impingement and tendon instability at the entry site into the BG. The BG, together with the THL, provides stability and promotes smooth functioning of the LHBBT, thereby preventing subluxation during biomechanical movements of the GHJ.[12] Factors such as BG morphology and rotator cuff pathologies have been associated with LHBBT disorders as these structures are intricately associated in stability of the LHBBT.[13] The morphometry (i.e. length, width, depth) of the BG may affect the function of its surrounding structures thus leading to various conditions, viz. pulley lesions, tenosynovitis and proximal tears.[12]

The present study observed the BG length as 66.64 ± 9.06 mm (right) and 68.31 ± 11.52 mm (left), thereby agreeing with the study by Srimani et al. (2016) (Table 3), however, studies conducted by Kaur and Gupta (2015) and Arunkumar et al. (2016) were observed with considerable smaller BG lengths as compared to the current study (Table 3).[4,10,12] The mean BG width observed in this study agreed with previous studies outlined in Table 3 of similar reported mean BG widths. However, the study by Rajan and Kumar (2016) were reported with smaller mean BG widths as compared to previous studies (Table 3) and the current study.[5] The mean BG depth was reported in this study as 7.73 ± 1.31 mm (right) and 7.20 ± 1.18 mm (left) and was found to be statistically significant ($p < 0.05$). This finding thereby disagrees with previous studies as outlined in Table 3 where smaller BG depths were observed. In this study, the mean BG width was observed to be slightly larger in male individuals. On the contrary, the mean BG length and depth were increased in female individuals which may be attributed to the unequal sample size of males and females in this study which may have affected the distribution of the mean (Table 3). According to gender-based differences, males have larger and heavier bones; however, the results of this study depict otherwise.

The biceps brachii muscle is hypertrophied in individuals that are manual laborers and has been reported that 90–95% of individuals show dominance of the right hand with the LHBBT of the dominant side presenting with a larger length and width.[14,15] Consequently, the mean BG length and width were found to be greater on the left sides, suggesting left-handedness. However, the mean BG depth was increased on the right side and presented with a statistically significant p value ($p < 0.05$) which suggests that an increased depth is a common finding on the right side of the BG (Table 2).

The LHBBT may develop attritional damage due to continuous mechanical stress at anatomically narrow sites beneath the acromion, coracohumeral ligament or the distal BG.[16] This degenerative change arises from mechanical strain and impingement of the biceps tendon in the coracoacromial arch during flexion.[16] Width of the BG can influence

Table 3
Summary of mean BG dimensions in the literature reviewed.

Author (year)	Population	Sample Size (n)	Mean BG Dimensions (mm ± SD)					
			BG Length		BG Width		BG Depth	
			Right	Left	Right	Left	Right	Left
Murlimanju et al. (2012)	India	104	86.00 ± 10.10	83.30 ± 11.50	8.30 ± 2.40	8.70 ± 2.20	4.70 ± 2.00	4.20 ± 1.60
Rajani & Man (2013)	India	101	85.00 ± 0.90	83.00 ± 10.10	9.00 ± 2.10	8.90 ± 1.10	5.00 ± 1.00	6.00 ± 1.00
Kaur & Gupta (2015)	India	100	30.65 ± 3.19	29.64 ± 2.87	8.49 ± 1.45	7.87 ± 1.67	3.83 ± 0.92	3.92 ± 0.86
Arunkumar et al. (2016)	India	98	30.00 ± 2.00	32.00 ± 6.00	8.70 ± 0.10	8.30 ± 0.40	5.00 ± 1.00	6.00 ± 1.00
Rajan & Kumar (2016)	India	100	84.79 ± 5.84	87.33 ± 6.40	6.84 ± 1.01	7.74 ± 1.96	4.21 ± 0.58	5.01 ± 05
Srimani et al. (2016)	India	107	71.59 ± 3.78	70.78 ± 5.04	8.42 ± 0.85	7.70 ± 0.50	4.63 ± 0.38	4.45 ± 0.30
Ashwini & Venkateshu (2017)	India	87	89.94 ± 6.35	88.88 ± 8.11	8.53 ± 1.56	7.96 ± 1.37	6.48 ± 1.13	6.14 ± 1.04
Venkatesan et al. (2017)	India	200	84.40 ± 1.03	78.80 ± 0.82	9.12 ± 1.37	8.86 ± 1.65	4.65 ± 1.04	4.55 ± 1.15
Present Study (2018)	**South Africa**	**164**	**66.64 ± 9.06**	**68.31 ± 11.52**	**8.98 ± 1.49**	**9.27 ± 1.30**	**7.73 ± 1.31**	**7.20 ± 1.18**

the pathology of the biceps tendon as it is ensheathed within the BG where a wider groove allows the tendon to move more freely with lesser chances of damage or trauma.[7] According to Cone et al. (1983), a BG depicting a width larger than 17.00 mm wide is shallow in depth and may be a predisposing factor to tendon dislocation.[17] DePalma (2008) further opined that a shallow BG predisposes the GHJ to chronic trauma due to impingement by surrounding structures.[18] Although considerably dated, the radiographic study of Cone et al. (1983) concluded that BG depths of 3 mm or less were indicative of pathological shoulder conditions.[17] In this study, only 4% of BG mirrored a depth of 3 mm or less and while this may suggest that 4% of dry bone humerii included in this study were subjected to pathological conditions, one should also account for the bone maceration process, during which bone debris is lost. Furthermore, the presence of pathological conditions was not documented in dry bone records. Moreover, the study conducted by Venkatesan et al. (2017) recorded that 86% of BG presented with depths that were 3 mm or less.[19] The difference between the incidences reported in the current study and that of Venkatesan et al. (2017) may be the result of many external factors, viz. geographic location, presence of pathology, occupation of the individual (i.e. hard manual labor vs. desk job) and age of bones in bone storage.[19]

Granted that previous studies are yet to document the dimensions of the BG in South African literature, gender and side difference in the BG remain completely unreported. This study documented larger BG lengths, widths and depths on the right side. Interestingly, the comparison of the BG depth between right and left sides yielded a statistically significant difference which may indicate that increased BG depth is a common finding in the right side of the BG. Female individuals presented with larger BG lengths and depths, while male individuals has larger BG widths. As LHBBT pathology is associated with anterior shoulder conditions and pain, investigation of the BG may provide important information in evaluating individuals with potential abnormality of the LHBBT. The data from this study may also be used as a surgical landmark for humeral head replacement in fractures of the proximal humerus and may aid in prosthetic design, position and shape.

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Declaration of competing interest

None.

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