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Estimation of girth of humeral head by measuring the biepicondylar distance: A validity and reliability study

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Abstract

Aim: The aim of this study was to estimate the girth of humeral head (GOHead) by analysing the reliability and validity of biepicondylar distance (BED).

Materials and Methods: The study was carried out on 66 dry humeruses (36 right and 30 left) at the Ondokuz Mayıs, Ordu and Erciyes Universities, Faculty of Medicine, Departments of Anatomy. The BED and the GOHead were measured, and the related ratio was determined. The validity between the obtained values was analysed by Bland Altman analysis and the reliability by intraclass correlation coefficient (ICC).

Results: The BED was measured to be 57.70±5.18 mm, while the GOHead was 132.77±12.17 mm. The relative ratio between the two data was determined to be (RR:2.30). The GOHeadRR (BED x RR) value was defined to be 132.82±12.01 mm. While the results of this study showed agreement in validity according to Bland Altman analysis, an excellent reliability ratio (Cronbach Alpha's: 0.930) was determined in this study. Estimation of the GOHead using the formula (BED x 2.30) shows agreement in terms of validity and reliability.

Conclusion: This result we obtained shows that the BED can be used to estimate the GOHead without requiring any imaging method. Based on the results of this study, it is expected to play an important role in reducing the use of radiological materials in GOHead measurements and reducing the radiological footprint.

Introduction

Defining the human arm, the humerus is the largest bone in the upper extremity. It articulates proximally with the socket via the glenohumeral joint and distally with the radius and ulna at the elbow joint [1]. Two necks exist in the proximal humerus. The anatomic neck of the humeral head is the ancient epiphysis, and the surgical neck is the metaphysis below the humeral head [2]. It is well known that the anterior circumflex artery (ACA) is the main arterial supply to the proximal humeral epiphysis. However, the role of the posterior circumflex artery (PCA) may be minimized in this description [3]. Because of the close connection between the shoulder joint and the brachial plexus, nerve damage is a possible complication of shoulder dislocation [4]. Between 5% and 6% of all fractures are proximal humeral fractures. In the older adult population, it is the third most common type of fracture [5]. Accurate delineation of the axillary and radial nerves is essential to avoid complications, as they can be injured during surgical exposure and fixation of the humerus [6]. Injuries of the axillary nerves remain the most common peripheral nerves injuries affecting the shoulder.

On the distal part of the humerus, there is a widening of the bone that forms the medial and lateral epicondyles. The distal part of the humerus ends in an area known as the condyle. The condyle is composed of the trochlea, capitellum, olecranon, coronoid, and radial fossa [1, 7]. Radial nerve palsy is a known complication of humeral fractures, particularly displaced fractures involving the medial shaft or distal humerus. At present, after a period of failed non-operative management, many surgeons choose to manage this type of injury in a conservative fashion with exploration of the radial nerve. Evidence supporting conservative management over early exploration is limited [8].

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The circumference of the humeral head provides valuable information about the size and morphology of the humeral head. This information is crucial in the evaluation of various shoulder pathologies such as arthrosis, rheumatoid Deviations from expected circumferences may indicate shoulder abnormalities or degenerative changes [9]. In cases requiring shoulder arthroplasty or hemiarthroplasty, accurate measurement of humeral head circumference is essential for selecting appropriately sized prosthetic components. The circumference of the humeral head will influence the selection of the implant size and its placement in the glenoid cavity to ensure optimal joint function and longevity of the prosthetic joint [10]. In the management of proximal humerus fractures, knowledge of the humeral head circumference is important in the determination of fracture stability and as a guide to surgical treatment decisions. By influencing the choice of fixation techniques, implant selection, and surgical approach, circumference measurement can affect patient outcomes and postoperative rehabilitation [5].

While the biepicondylar distance of the humerus (BED) can be easily measured using callipers, it is not possible to measure the girth of the humeral head (GOHead) from the outside.

The aim of this study is to estimate the GOHead by measuring the distance between the BED.

Materials and Methods

Calculating sample size

The sample size for this study was determined using Gpower 3.1.9.4. According to the power analysis (effect size: 0.3, α:0.05, β:0.80), it was decided to include at least 64 bones in the study.

Study design

This study was conducted at the Anatomy Departments of the Medicine Faculties of Ondokuz Mayıs University, Ordu University and Erciyes University. The 82 dry humeri bones were evaluated.16 of these bones were excluded from the study according to the following criteria.

Inclusion criteria;

- No fracture of the proximal humerus
- Integrity of humerus body
- No distal humerus fractures
- No erosion of the epicondyles

Exclusion criteria;

- Humeral neck fracture (due to proximal humeral fractures, 6 humeri were excluded from the study)
- Lack of humeral integrity (4 humerus were excluded from the study due to lack of humeral integrity)
- Have a fracture of the distal humerus (due to distal humeral fractures, 4 humeri were excluded from the study)

Figure 1. Measuring the BED with a digital calliper.

Figure 2. A: Measuring the GOHead circumference with the help of flexible wire B: Measuring the wire surrounding the humeral head using a digital calliper after straightening

- Erosion of epicondyles (due to epicondylar erosion, 2 humeri were excluded from the study)

While 36 of the humeri included in the study were right humerus, 30 were left humerus. The BED was measured using a 0.01 mm precision calliper (Figure 1). A flexible wire was used to measure the GOHead (Figure 2). The related ratio (RR) between the two measurements has been calculated. It was found as the GOHead / BED. By multiplying the BED by the RR, the estimated the GOHead was calculated.

Statistical analysis

Normal distribution analysis was performed using 5 parameters (Std/Mean, Skewness-Kurtosis, Histogram, Q-Q plots, and Shapiro-Wilk test). Data with 3 points over 5 parameters were considered normally distributed and presented as mean ± standard deviation. The Related Ratio (RR) value was calculated from the GoHead/BED ratio. It was determined by the formula GoHeadRR=BEDxRR.

The paired samples t-test was performed between GoHeadRR and GoHead parameters and the difference between the groups was analyzed and and α:0.05 was accepted and p< α significant p< α statistically insignificant. To examine the validity between the actual GOHead and the estimated GOHeadRR, Bland Altman analysis was used. Data were considered valid if at least 95% of the data fell within the upper limits of agreement (upper LOA) and lower limits of agreement (lower LOA). Since the data were compatible in terms of validity, we proceeded to reliability analysis. Cronbach's alpha value was calculated in the reliability analysis. Cronbach alpha 0.7 was considered acceptable [11].

Results

The right GOHead was measured as 132.83±13.09 mm and the left GOHead was measured as 132.70±11.20 mm. Total GOHead included in the study was calculated to be 132.77±12.17 mm. GOHead's minimum value was determined to be 109.11 mm and its maximum value was determined to be 156.80 mm, according to the measurement results.

The BED is 58.50±5.89 mm for the right humerus and 56.84±4.21 mm for the left humerus. The mean of all BEDs was calculated to be 57.75±5.22 mm. The minimum value of the BED was 46.54 mm, and the maximum value was 70.80 mm. RR between both was computed as 2.30. The data have been considered in Table 1.

The GOHead was estimated using the formula (RR x BED). The estimated GOHead was called GOHeadRR. The GOHeadRR value was measured to be 132.82±12.01 mm. Before assessing validity and reliability, paired samples t-test was used to assess whether there was a difference between the two sets of data. There was no statistically significant difference between the data (p: 0.946) (Table 2).

Table 1. Descriptive parameters of GOHead and BED.

	Mean±Std	95% CI	Minimum	Maximum	RR
GOHead	132.77±12.17	129.77-135.76	109.1	156.8	2.3
BED	57.70±5.18	56.46-59.03	46.54	70.8	

GOHead: Girth of head of humerus, BED: Biepicondylar distance, RR: related ratio, Mean ± Std: Mean± Standard deviation. Parametric data were shown as Mean±Std.

Table 2. Comparison of GOHead and GOHeadRR with Paired Samples T-Test.

	GOHead Mean±Std	GOHeadRR Mean±Std	Sig. (p)
Morphometric parameter	132.77±12.17	132.82±12.01	0.946

GOHead: girth of head of humerus, GOHeadRR: predicted GOHead, RR: related ratio Parametric data were shown as Mean±Std. The related samples t-test was used to make pair-wise comparisons between the paired groups. There is no differences between GOHead and GOHeadRR.

Table 3. Reliability analysis between GOHead and GOHeadRR.

	ICC	95% Coiffence	Sig. (p)
Measured Morphometric Parameter	0.930	0.885-0.957	<0.001

ICC: Intraclass Correlation Coeffidency, RR: Related Ratio, Mean ± Std: Mean± Standard deviation. There was excellent reliability between the data (0.9<r<1).

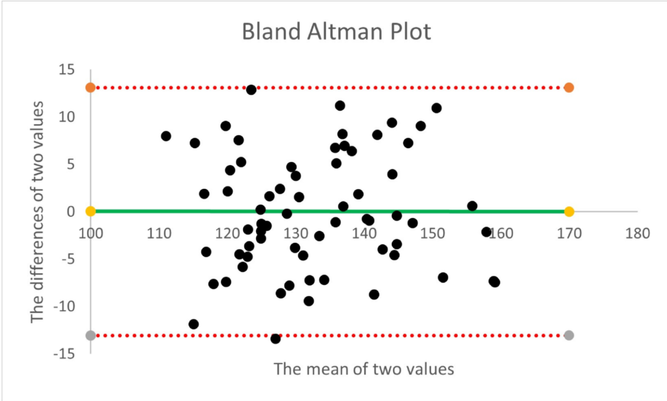

Figure 3. Analysis of the validity between GOHead and GOHeadRR.

Since the data did not differ, it was decided to start analysing the validity. Bland-Altman analysis was performed to determine validity agreement for actual and predicted GOHead. It was found that there was agreement between the predicted and actual values in terms of validity (Figure 3).

Reliability analysis was initiated as there was validity consistency between the data. The Intra-Class Correlation Coefficient (ICC) was used to analyse the reliability. There was excellent reliability between the data (Cronbach Alpha's: 0.930) according to the results of this test [12] (Table 3).

Discussion

Due to the structure of the human body, the distance between bone particles palpated under the skin can be measured with a caliper, whereas detailed imaging techniques must be used to measure structures surrounded by muscle and connective tissue. Performing these detailed examinations increases the time spent in hospital and delays examinations and results. Determining the proportion of bone fragments that may be associated with each other and estimating the size of bone fragments surrounded by muscle or tissue with subcutaneous palpable bone measurement is consistent with the principle of minimal invasion.

There are several clinical advantages to measuring the circumference of the humeral head by assessing the distance between the epicondyles for research purposes. This measurement may be used as a diagnostic tool to evaluate various musculoskeletal conditions affecting the shoulder and elbow. Abnormalities such as fractures, dislocations, or degenerative joint disease may be indicated by differences in humeral head circumference. Treatment planning can be aided by understanding the relationship between humeral head circumference and epicondylar distance. For example, this measurement can help determine appropriate implant sizes or surgical approaches for joint replacement or fracture fixation [13]. After surgery or injury, monitoring changes in humerus circumference and epicondylar distance can guide rehabilitation [14]. Radiographic imaging procedures are often time consuming and can result in long wait times due to crowded examination rooms. Because the biepicondylar distance method can be performed manually and provides rapid results, it can reduce these wait times. This can be particularly useful in emergency situations or when quick clinical decisions are required [15]. Radiologic imaging equipment and procedures are often expensive to acquire. Radiographic imaging procedures require radiation exposure and may present potential long-term health risks. Unnecessary radiation exposure can be avoided, and patient health risks reduced if humeral head circumference can be manually estimated using the biepicondylar distance method [16]. Radiographic imaging procedures can often cause patients discomfort and stress. Less invasive and potentially more comfortable for patients, the manual estimation method can improve patient comfort. For pediatric or geriatric patient populations, this may be particularly important [17]. In this study, we investigated the feasibility of calculating the GOHead, which is very difficult to measure, with BED, which can be measured with calipers. The fact that the humeral head rotates makes it difficult to calculate the measurement radiographically, which is difficult due to its position. According to the results of this study, the relative ratio (RR) between GOHead and BED was found to be 2.30. However, the results were supported by validity and reliability analyses to test the results. Bland Altman analysis was preferred for validity analysis and Intraclass Correlation (ICC) was preferred for reliability analysis. In the Bland Altman analysis, our results were considered valid as more than 95% of the data were within the upper and lower bounds. The ICC Corenbach's alpha of the study was calculated as 0.90 and it was found that the study had a very high reliability. It is not common in the literature to base another bone measurement on a bone measurement. The investigators of this study attach great importance to the principle of minimal invasion.

While the BED is easily measured in vivo using callipers, detailed MRI scans are required to measure the GOHead. The humeral head is the most proximal part of the humerus. It forms a ball and socket joint with the glenoid cavity of the shoulder blade [1]. A bimodal distribution accounts for 5% to 6% of all proximal humerus fractures, with high-energy trauma in young patients and low-energy falls in the elderly. Proximal humerus fractures are most common in patients over age 65, accounting for 10% of all fractures in this population [5]. For this reason, we thought it was important to estimate the GOHead from the BED.

In this study, the GOHead was found to be 132.77±12.17 mm and the GOHead index was determined to be (CI 95%: 129.77-135.76). Measurements of GOHead in previous studies are shown in the Table 4. The GOHead values obtained in other studies are 129.606±0.91 mm and 136.60±11.30 mm and are like our results [18, 19, 20, 21, 22]. Other studies in the literature show similar results to this study, although they were conducted in different races.

In this study, the BED was 58.50±5.89 mm for the right humerus and 56.84±4.21 mm for the left humerus, with a mean value of 57.75±5.22 mm. BED index is (CI 95%: 56.46 - 59.03). The BED to other in the literature is summarised in the Table 5 [23, 24, 25, 26, 27, 28, 29, 30, 31]. Except for the study by Gayatri et al., the results of the other studies are consistent with our results [26]. Among

Table 4. GOHead data reported in the literature.

References		GOHead (Mean±Std)	Population
Naqshi et al. 2017	Right	137.60±10.50	North Indian
	Left	135.40±12.20	
	Total	136.60±11.30	
Ndou and Scheparts 2016	White Male	139.96±8.19	South African
	White Female	124.92±6.96	
	Black Male	130.9±6.86	
	Black Female	117.15±6.44	
	Mixed Male	127.94±9.45	
	Mixed Female	120.84±11.75	
Ahmed et al. 2018	Male	131.83±6.15	India
	Female	115.2±7.88	
Sinha et al. 2017	Total	130.59±33.86	India
Lokanadham et al. 2013	Total	129.606±0.91	India

GOHead: girth of head of humerus, Mean ± Std: Mean± Standard deviation.

Table 5. Biepicondylar distance (BED) data reported in the literature.

References	Gender or Direction	BED (Mean±Std)	Population
Ahmed et al. 2018	Male	59.95±3.45	India
	Female	52.57±4.36	
Gayatri et al. 2014	Left	41.70±5.20	Indıa Telengana State
	Right	42.404±3.90	
Attia and Aboulnoor 2020	Male	61.29±4.53	Mixed
	Female	54.77±3.68	
Frutos 2005	Male	58.30±2.80	Guatemala
	Female	49.30±4.00	
Sakaue 2004	Male	59.18±2.80	Japan
	Female	51.11±2.49	
Steyn and İşcan 1999	Male	64.3±3.9	Africa
	Female	55.9±2.8	
Jaisval 2021	Total	56.80±5.69	India
Dittrick and Suchey 1986	Male	62.2±3.4	Central California
	Female	56.4±3.3	
Atamtürk et al. 2010	Male	65.21±4.63	Turkey
	Female	58.03±2.99	
	Total	61.24±5.22	
Lee et al. 2014	Male	59.3±4.3	Korean
	Female	54.5±3.3	

BED: biepicondylar distance, Mean ± Std: Mean± Standard deviation.

these studies, only Atamturk et al., studied radiological images in the Anatolian Turkish population [23]. Despite the difference in method, the results of the study are within the confidence interval of our study.

Predictions of humerus morphology have been found in the literature. These predictions usually use regression analysis and emphasise sex determination [30, 32]. In this study, the GOHead was estimated from the BED by performing validity and reliability analyses. This study is unique in that there is no other study in the literature using humerus morphology.

Limitations

This study has 2 limitations. 1- Only dry bone measurements in the study, not supported by radiological studies 2- As this study was conducted on humeri from anatomy departments of universities in 3 different provinces of Turkey, it cannot be generalized to the whole Turkish population.

Conclusion

According to the results of our study, RR: GOHead/BED=2.30 in our samples and GOHead can be estimated from BED. We believe that the results of this study will contribute to rapid clinical decision making and a reduction in the radiological footprint. The biepicondylar distance method may play an important role in clinical practice by providing an accessible, rapid, cost-effective and radiation exposure-reducing alternative.

Conflicts of interest/Competing interests

The authors declare that there are no conflicts of interest relevant to this study.

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Ethical approval

No ethical clearance was required as dry bones are used for teaching and research purpose.

Availability of data and material

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Authors contributions

HY: project development, data collection and management, data analysis, manuscript writing. BOK: data collection, manuscript writing and manuscript editing. OB: supervision, critical appraisal. ME: planning, manuscript editing. MN: project development and editing. All the authors have read and approved the manuscript.

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