RESEARCH PAPER

Morphological Classification and Related Parameters of the Glenoid Cavity among Jordanian People using Magnetic Resonance Imaging

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ABSTRACT

Background: Glenoid morphology varies across populations and has important implications for shoulder arthroplasty. However, normative MRI-based glenoid measurements remain underreported in Middle Eastern populations. This study aimed to evaluate glenoid cavity morphology and its associated factors in a Jordanian adult population.

Methods: A retrospective cross-sectional study was conducted on 100 shoulder MRI scans from healthy adult individuals. Glenoid height, width, and humerus width were measured. Demographic data including sex, shoulder laterality, and body mass index (BMI) were recorded. Univariate comparisons were conducted using t-tests and correlation analysis. Multivariable linear regression models were used to identify independent predictors of glenoid dimensions.

Results: The mean glenoid height was 3.96 ± 0.46 cm, width was 2.54 ± 0.30 cm, and humerus width was 4.21 ± 0.46 cm. Males exhibited significantly greater glenoid height (4.27 vs. 3.62 cm), width (2.72 vs. 2.35 cm), and humerus width (4.53 vs. 3.87 cm) compared to females (all $p < 0.001$). BMI and shoulder side were not significantly associated with glenoid measurements. In multivariable analysis, male sex remained the only independent predictor of increased glenoid height ($\beta = 0.67$), width ($\beta = 0.36$), and humerus width ($\beta = 0.67$; all $p < 0.001$).

Conclusions: Glenoid cavity dimensions in the Jordanian population are smaller than those reported in Western cohorts and comparable to Asian populations. These findings highlight the importance of incorporating region-specific anatomical data into preoperative planning and implant design for shoulder arthroplasty, particularly in populations with smaller skeletal anatomy.

Keywords: Glenoid cavity; Glenoid morphology; Sex differences; Anatomical variation.

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Introduction

The glenoid cavity of the scapula, which articulates with the humeral head to form the shoulder joint, exhibits considerable variability in shape, size, and orientation across individuals and populations. Recognition of glenoid anatomy is crucial for restoring normal shoulder biomechanics and understanding joint instability or degenerative changes [1]. Anatomical studies have shown that glenoid dimensions, typically measured as superoinferior height and anteroposterior width, and glenoid version (the angle of retroversion or anteversion) can differ significantly by sex and ethnicity [1–3]. In general, males tend to have larger glenoids than females [4].

For example, a cadaveric study in Europe reported average glenoid height and width of about 39.5 × 30.3 mm in men versus 34.8 × 26.2 mm in women [4]. Similarly, a recent systematic review in India found male glenoids to be on average 3.6 mm taller and 2.7 mm wider than female glenoids [5].

Global population differences in glenoid morphology are well documented. Churchill et al. noted that while glenoid size was similar between African-American and white North American subjects, the glenoid version differed between these groups [6]. Piponov et al. further reported that Hispanic shoulders had, on average, 6.4° more glenoid anteversion compared to African-American shoulders, and also found that men's glenoids were slightly more retroverted (i.e. oriented more posteriorly) and larger than women's [3]. Broadly, East Asian populations tend to have smaller and slightly less retroverted glenoids compared to Western populations. In a direct 3D imaging comparison, the mean Japanese glenoid measured 33.3 mm in height and 25.5 mm in width with 2.3° of retroversion, whereas the average French glenoid was larger (35.4 mm by 26.7 mm) and more retroverted (6.0°) [7]. The Turkish population appears intermediate: one study found that mean glenoid widths in Turks were comparable to European and American values, while glenoid heights were closer to those of East Asians; notably, Turkish glenoid version angles were similar to Asian norms and more anteverted (less retroverted) than those reported in Western datasets [1]. In South Asian populations, glenoid dimensions are consistently smaller. A comprehensive review of Indian studies found a pooled average glenoid height of 34.7 mm and width of 23.7 mm [5], which is markedly below reported averages in Europeans and North Americans. Indeed, the mean maximum glenoid width in the Indian population may even be slightly smaller than the smallest baseplate size of some commercial shoulder implants, underscoring how population differences can exceed assumptions built into implant design.

In terms of shape, the glenoid articular surface is commonly classified as pear-shaped, oval (round), or "inverted comma"-shaped, depending on the presence and degree of a notch on the superior rim. Most populations show a predominance of the pear shape (which has a slight notch), with oval being the next most frequent and the pronounced "inverted comma" shape relatively rare [8,9]. For example, in a North Indian dry bone series the pear shape was the most common glenoid morphology while the inverted comma was least common [8]. Similarly, an analysis of Egyptian scapulae found roughly half of glenoids to be oval and 45% pear-shaped, with only 5% exhibiting the distinct comma-shaped notch [9]. These normal anatomic variations, in size, version angle, and shape highlight the importance of population-specific reference data. Understanding the range of glenoid morphology in diverse ethnic groups and between sexes is not only of anthropologic interest but is also directly relevant to clinical practice and orthopedic surgical planning.

Despite the growing body of literature on glenoid morphology in North American, European, and East Asian populations, there remains a significant lack of data from Middle Eastern and specifically Jordanian populations. Moreover, most previous studies have relied on dry bone specimens or CT scans, while MRI-based assessments, which provide high-resolution, radiation-free visualization of cartilage and bone, remain underreported in this context. This gap limits our understanding of glenoid variability in the Jordanian population and may have implications for surgical planning and implant sizing.

The aim of this study was to characterize the glenoid cavity morphology, including height, width, and humerus width, using MRI in a healthy Jordanian adult population, and to evaluate the influence of gender, body mass index (BMI), and shoulder laterality on these anatomical parameters. By establishing population-specific normative data, we hope to contribute to better-informed clinical decisions and encourage future anatomical and biomechanical studies in underrepresented populations.

Materials and Methods

Study Design and Participants

This was a cross-sectional study conducted to assess glenoid cavity morphology and its associations with demographic and anatomical variables in a Jordanian population. A total of 100 shoulder magnetic resonance imaging (MRI) scans were retrospectively reviewed. All images were obtained as part of routine clinical imaging at a tertiary hospital. Inclusion criteria were adults aged ≥18 years with no history of shoulder trauma, fracture, arthrosis, prior surgery, or congenital deformity. Participants were included consecutively, with nearly equal representation of left and right shoulders. The study protocol was reviewed and approved by the Institutional Review Board (Reference Number: 36025).

Imaging and Measurements

All measurements were obtained using shoulder MRI scans analyzed via the Visa Imaging platform. Glenoid height was measured on coronal slices, while glenoid width and humerus width were assessed on axial slices. A trained team of reviewers performed all measurements using the ISI View application, with values recorded in centimeters (cm). The following parameters were collected:

- Glenoid height (superoinferior dimension)
- Glenoid width (anteroposterior dimension)
- Humerus width

Demographic variables included gender, height (cm), weight (kg), body mass index (BMI, kg/m²), and shoulder side (left or right).

Representative images of the glenoid and humerus measurements are shown in **Figure 1 and 2**.

Figure 1. Axial view showing measurement of glenoid width (3.56 cm) and humeral width (2.56 cm).

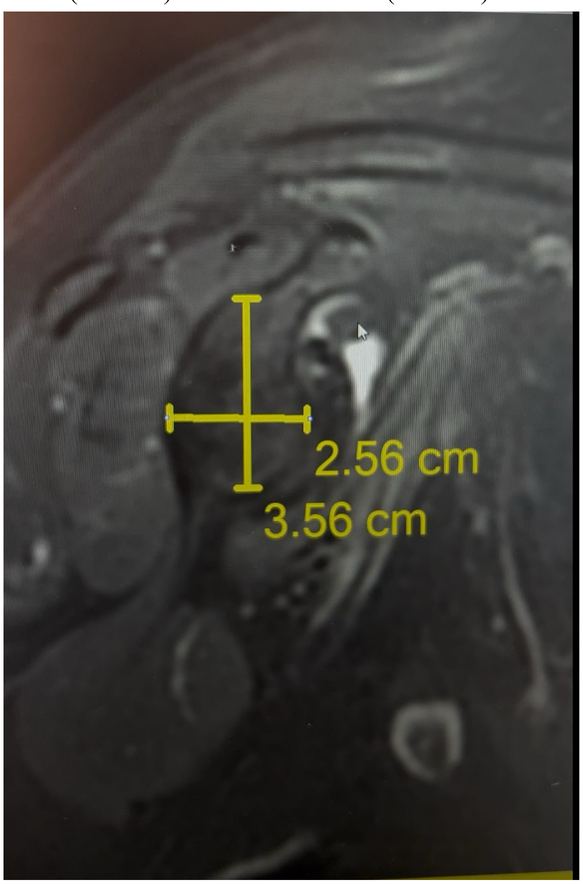
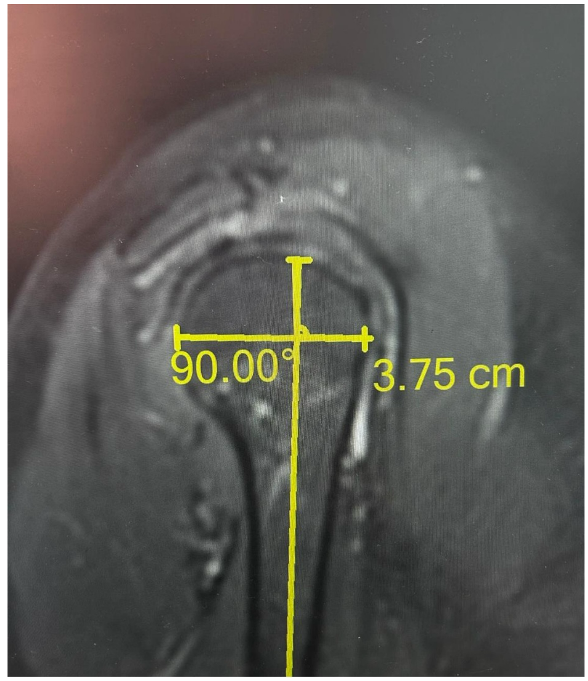


Figure 2. Coronal view demonstrating glenoid height (3.75 cm) and the measurement angle (90°) used to standardize orientation.



Statistical Analysis

Statistical analyses were conducted using Jamovi version 2.6.26, and visualizations were created with Microsoft Power BI. Categorical variables were summarized as frequencies and percentages, while continuous variables were reported as means with standard deviations and medians with ranges. Group comparisons for categorical variables (gender and shoulder side) were assessed using independent samples t-tests. Spearman's rank correlation coefficient (rho) was used to evaluate associations between continuous variables. A significance threshold of $p < 0.05$ was used for all tests.

Multivariable linear regression models were constructed for each glenoid parameter (height, width, humerus width) to assess the independent effects of gender, BMI, and shoulder side. Regression coefficients (β), 95% confidence intervals (CI), and p-values were reported.

Results

A total of 100 participants were included in the study. The sample was nearly evenly distributed by gender (52 males and 48 females) and by shoulder side (53 right and 47 left). The mean BMI was 28.70 ± 6.09.

The mean glenoid height was 3.96 ± 0.46 cm, while the mean glenoid width was 2.54 ± 0.30 cm. The mean humerus width measured 4.21 ± 0.46 cm, with a median of 4.25 cm (range: 3.03–5.25). An overview of patient characteristics is shown in **Table 1**.

Table 1: Patients characteristics (N = 100).

Variable	N (%)
Gender	
Female	48 (48.0)
Male	52 (52.0)
BMI	
Mean (SD)	28.70 (6.09)
Median [Minimum, Maximum]	28.20 [18.90, 65.70]
Side of shoulder	
Left	47 (47.0)
Right	53 (53.0)
Glenoid height	
Mean (SD)	3.96 (0.46)
Median [Minimum, Maximum]	3.95 [3.20, 5.87]
Glenoid width	
Mean (SD)	2.54 (0.30)
Median [Minimum, Maximum]	2.49 [1.82, 3.26]
Humerus width	
Mean (SD)	4.21 (0.46)
Median [Minimum, Maximum]	4.25 [3.03, 5.25]

Univariate analysis revealed that gender significantly influenced all three glenoid cavity parameters. Males exhibited greater glenoid height (4.27 ± 0.40 cm vs. 3.62 ± 0.23 cm, P < 0.001), glenoid width (2.72 ± 0.28 cm vs. 2.35 ± 0.20 cm, P < 0.001), and humerus width (4.53 ± 0.32 cm vs. 3.87 ± 0.33 cm, P < 0.001) compared to females (**Figure 3**). No significant associations were observed between BMI or side of shoulder and glenoid measurements (**Table 2**).

Figure 3. Comparison of mean glenoid cavity parameters between male and female participants.

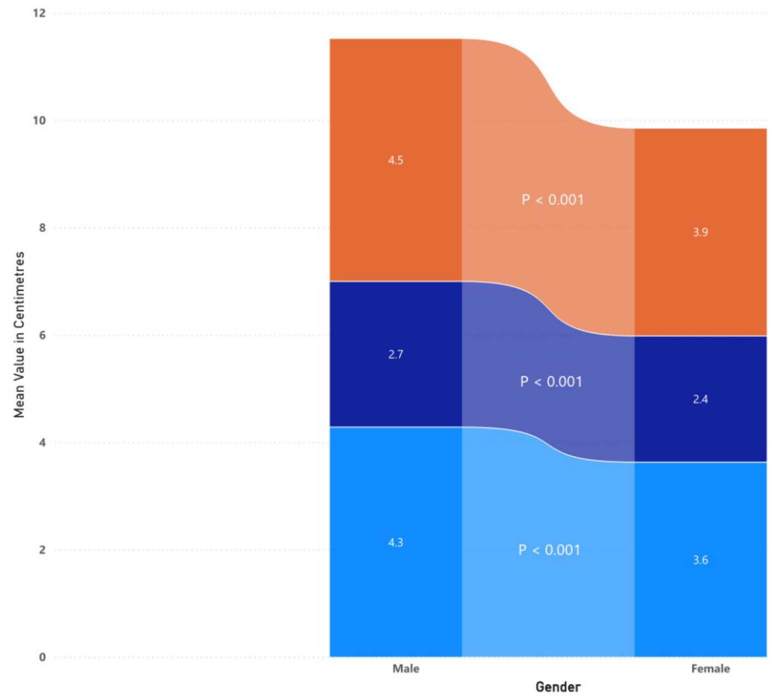


Table 2: Univariate analysis of the effect of patients' characteristics on glenoid measurements.

	Mean (SD)					
Variable	**Glenoid height**	**P-value**	**Glenoid width**	**P-value**	**Humerus width**	**P-value**
Gender		P < 0.001		P < 0.001		P < 0.001
Female	3.62 (0.23)		2.35 (0.20)		3.87 (0.33)	
Male	4.27 (0.40)		2.72 (0.28)		4.53 (0.32)	
BMI		0.544		0.946		0.541
Spearman's Rho	- 0.06		- 0.01		- 0.06	
Side of shoulder		0.780		0.236		0.631

Left	3.94 (0.42)	2.50 (0.30)	4.19 (0.41)
Right	3.98 (0.50)	2.57 (0.30)	4.23 (0.50)

A multivariate linear regression analysis was performed adjusting for gender, BMI, and side of shoulder (**Table 3**). After adjusting for BMI and side of shoulder, gender remained a significant predictor of glenoid parameters. Compared to females, males exhibited significantly greater glenoid height (β = 0.67, 95% CI: 0.53 to 0.80, P < 0.001), glenoid width (β = 0.36, 95% CI: 0.26 to 0.46, P < 0.001), and humerus width (β = 0.67, 95% CI: 0.54 to 0.80, P < 0.001). BMI was not significantly associated with any of the measured anatomical parameters (P > 0.05 for all). Similarly, no significant differences were found based on the side of the shoulder, with all P-values exceeding 0.05.

Table 3: Linear regression model of factors related to glenoid parameters.

Variable	Estimate [95% CI: Lower, Upper]		
	Glenoid height	**Glenoid width**	**Humerus width**
Gender			
Female	Reference	Reference	Reference
Male	0.67 [0.53, 0.80]	0.36 [0.26, 0.46]	0.67 [0.54, 0.80]
P-value	P < 0.001	P < 0.001	P < 0.001
BMI			
Estimate	- 0.001 [-0.01, 0.01]	0.002 [-0.01, 0.01]	0.0001 [-0.01, 0.01]
P-value	0.859	0.703	0.984
Side of shoulder			
Left	Reference	Reference	Reference
Right	- 0.08 [-0.21, 0.05]	0.01 [-0.09, 0.11]	- 0.07 [-0.21, 0.06]
P-value	0.224	0.866	0.261

Discussion

The documented variability in glenoid morphology has significant clinical implications, especially for shoulder arthroplasty and other reconstructive surgeries. Perhaps most importantly, differences in glenoid size can lead to implant sizing mismatches if standard prostheses are used indiscriminately. Many shoulder implant systems were historically designed around Caucasian anatomy [5]. Consequently, patients from populations with smaller average glenoid dimensions (such as South Asians) may face a risk of the glenoid component overhanging or inadequately fitting the native bone. Notably, a recent review found that the mean Indian glenoid width (23.7 mm) is about 1.3 mm less than the smallest available baseplate in common reverse shoulder arthroplasty (RSA) systems [5]. Even a few millimeters of discrepancy can be critical, a disproportionally large glenoid component can lead to abnormal stress and has been linked to early loosening and failure of the implant. This has prompted calls for region-specific and sex-specific implant designs. Designing smaller glenoid baseplates or adjustable components for markets where patients have smaller bony anatomy could improve implant seating and longevity. Likewise, surgeons need to be aware of such differences during preoperative planning, for instance, choosing a implant size that maximizes cortical bone contact without excessively reaming away subchondral bone in a smaller scapula [5].

In our Jordanian population, the average glenoid height was 3.96 cm and the width was 2.54 cm, as measured by MRI. These values are generally smaller than those reported in European or North American populations and are more comparable to measurements from East Asian and South Asian populations [4–7]. For instance, Indian studies report mean glenoid dimensions around 3.47 cm in height and 2.37 cm in width, which closely align with our findings [5]. Similarly, glenoid dimensions in Japanese patients have been reported at approximately 3.33 cm in height and 2.55 cm in width, again consistent with the present study [7]. In contrast, studies from Turkey, using CT, showed larger dimensions, mean glenoid height of 4.27 cm and width of 2.72 cm in males, and 3.62 cm × 2.35 cm in females [1]. These sex-specific measurements closely mirror our own male–female subgroup differences, reinforcing the consistency of sex-based variation. The similarity of Jordanian glenoid size to Asian populations may reflect regional and ethnic skeletal characteristics and underscores the need for population-specific data to guide implant design and surgical planning.

Glenoid version and shape abnormalities also heavily influence surgical strategy. Excessive retroversion of the glenoid (as seen in biconcave “Walch B2” glenoids in osteoarthritis) presents a challenge: if an implant is inserted on a severely retroverted surface, it may predispose to posterior instability, edge-loading, and early loosening of the component [10]. Clinical studies have indeed shown that poor glenoid component alignment (too much retroversion or superior inclination) leads to uneven load distribution, micromotion, and bone loss at the implant–bone interface, which are common causes of glenoid component failure in RSA [11]. To mitigate these issues, surgeons must often correct a patient’s glenoid version intraoperatively. Traditional techniques involve eccentric reaming of the high (anterior) side of a retroverted glenoid to bring it closer to neutral version, but this sacrifices subchondral bone stock and can weaken implant fixation [11]. Bone grafting or augmented glenoid components are alternatives that address version or bone deficiencies while preserving more native bone [10]. For example, posterior wedge augment implants are specifically designed to compensate for a retroverted or eroded posterior glenoid, allowing the baseplate to be seated in a corrected orientation without excessive bone removal [10]. The clinical significance of using these augmented glenoid implants is supported by early results showing improved component seating and alignment in patients with mismatched anatomy (e.g., B2 glenoids) [11]. In essence, patient-specific glenoid morphology, whether a small size or a pathological shape/version, must be addressed to avoid complications like instability, impingement, and premature loosening of the prosthesis.

Modern preoperative planning tools and intraoperative technologies have become invaluable in managing glenoid variability. Three-dimensional imaging and planning software now allow surgeons to virtually reconstruct the patient’s scapula, accurately measure glenoid height, width, version, and inclination, and template the optimal implant size and position [7,11]. This is particularly important for identifying when standard implants may not fit, for instance, planning might reveal the need for a smaller component or augmented baseplate in a given patient [5,7]. Patient-specific instrumentation (PSI) and computer navigation are increasingly used during shoulder arthroplasty to ensure the glenoid component is placed as intended. These technologies improve the precision of achieving a target version and inclination angle and help maximize screw fixation in the best-quality bone [11]. For example, one study showed that using preoperative 3D planning with PSI or navigation led surgeons to employ augmented glenoid baseplates more often (to correct anatomy while minimizing bone loss) and achieved glenoid baseplate positioning much closer to neutral alignment, with longer screws for secure fixation, compared to conventional techniques [11] By enabling real-time feedback on implant orientation and screw placement, navigation can effectively translate a patient’s unique glenoid anatomy into an optimized surgical result. In light of the anatomical differences among populations, such individualized planning is critical – a point emphasized by comparative studies that conclude surgeons should tailor their approach based on the patient’s ethnic or gender-specific anatomy [7,12]. Ultimately, incorporating detailed knowledge of glenoid morphology into surgical planning improves the likelihood of proper implant fit and alignment, which is crucial for the longevity and success of shoulder arthroplasty [11].

Conclusions

This study provides the first MRI-based assessment of glenoid morphology in a Jordanian adult population. Our findings demonstrate that glenoid dimensions in this population are generally smaller than those reported in Western cohorts and closely resemble values observed in East and South Asian populations. Male participants consistently exhibited larger glenoid height, width, and humerus width than females, while no significant associations were found with shoulder side or BMI. These results underscore the importance of considering sex and population-specific anatomical variations during preoperative planning for shoulder arthroplasty. As many commercially available implants are designed based on Western anatomical data, our findings highlight the potential need for smaller or customized implant options tailored to regional populations. Establishing normative glenoid morphometry in diverse ethnic groups is essential to improving surgical precision, implant fit, and long-term outcomes in shoulder reconstruction.

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