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The impact of laterality on the morphometric angular features of the scapula

Seda Sertel Meyvacı[1], Handan Ankaralı[2], Beyza Çelik[1]

[1]*Department of Anatomy, Faculty of Medicine, Bolu Abant İzzet Baysal University, Bolu, Türkiye*
[2]*Department of Anatomy, Faculty of Medicine, Istanbul Medeniyet University, Istanbul, Türkiye*

Abstract

Objectives: This study aimed to analyze the angular measurements and morphological characteristics of the scapula, providing insights to enhance surgical interventions and clinical research requiring detailed anatomical knowledge, such as total shoulder arthroplasty, fracture fixation via screw placement, and scapular arthroscopic procedures.

Methods: Twenty dry scapula (13 right, 7 left) of unknown age and sex, obtained from the bone archive of the Anatomy Department at Bolu Abant İzzet Baysal University Faculty of Medicine, were analyzed. Angular measurements were conducted using a digital angle gauge. Due to the limited sample size, normality testing was not performed. Statistical comparisons between the right and left scapula were made using the Mann-Whitney U test, with a significance level set at $p \leq 0.05$.

Results: Among the six angular parameters measured, only the lateral angle demonstrated a statistically significant difference between the right and left sides ($p=0.033$).

Conclusion: The findings indicate that, except for the lateral angle, the scapula's angular measurements are predominantly symmetrical between the right and left sides. The glenoid profile angle (GPA) may serve as a valuable marker for assessing fracture risk in the glenoid fossa, aiding orthopedic surgeons in clinical decision-making. A detailed understanding of scapular morphology is expected to advance both surgical practices and anatomical research.

Keywords: angular assesment; forensic anthropology; scapula morphometry; Turkish population

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Introduction

The scapula, a critical component of the pectoral girdle, features a distinct irregular, flat triangular shape with two primary surfaces: the costal (anterior) surface and the dorsal (posterior) surface. The dorsal surface is characterized by the scapular spine, which divides it into the supraspinous fossa and infraspinous fossa. This spine originates medially and extends laterally to culminate at the acromion. The scapula also includes three borders—superior, medial (vertebral), and lateral (axillary)—and three angles formed at the junctions of these borders: the superior, inferior, and lateral angles. The superior angle, situated at the intersection of the superior and medial borders, aligns with the second rib and serves as the attachment site for the levator scapula muscle. The inferior angle, where the medial and lateral borders converge, is located at the level of the seventh rib or seventh intercostal space and provides an attachment point for the serratus anterior muscle. The lateral angle, the thickest portion of the scapula, houses the glenoid fossa, the articulation site for the humeral head. These anatomical landmarks significantly influence the musculature associated with the scapula, underscoring its pivotal role in shoulder girdle movement and its clinical relevance.[1,2]

Scapular fractures, although rare, account for 3–5% of shoulder girdle injuries and less than 1% of all fractures.[3] Among these, the glenopolar angle (GPA) is of particular clinical importance in scapular neck fractures. The GPA, which quantifies the glenoid's inclination relative to the scapular body on an anteroposterior plane, typically ranges between 36° and 43° in healthy individuals. Values outside this range, such as a GPA of 20°–22°, often indicate a need for surgical intervention to prevent long-term complications, including pain, weakness, and impaired daily activities.[4–7]

Bestard et al.[8] were the first to establish the standard GPA range of 30°–45°, identifying deviations as indicators of scapular neck fracture dysplasia. Furthermore, Labler et al.[9] recommended surgical treatment when the GPA falls below 3°, as this suggests potential ligament rupture Kim et al.[10] emphasized the GPA's role in both the planning and postoperative evaluation of floating shoulder treatments.

The objective of this study is to analyze the angular measurements and morphological characteristics of the scapula, contributing to the anatomical knowledge required for surgical procedures and clinical research, including scapular arthroscopic interventions.

Materials and Methods

Measurements were obtained using a digital angle gauge from 20 dry scapula (13 right, 7 left) of unknown sex and age, sourced from the bone archive of the Anatomy Department at Bolu Abant İzzet Baysal University School of Medicine. The specific morphometric measurements performed on the scapula are as follows and are illustrated in Figure 1:

- **Inferior Angle (AI):** The angle formed between the medial and lateral borders of the scapula.
- **Superior Angle (AS):** The angle formed between the medial and superior borders of the scapula.
- **Lateral Angle (AL):** The angle formed between the lateral and superior borders of the scapula.
- **MSU:** The angle between the portion of the medial border above the scapular spine and the spine itself.
- **MSA:** The angle between the portion of the medial border below the scapular spine and the spine itself.
- **Glenopolar Angle (GPA):** The angle between the axis passing through the supraglenoid and infraglenoid tubercules, and the axis drawn from the apex of the supraglenoid tubercle to the most caudal point of the scapular body.

Descriptive statistics for the collected data included mean±standard deviation, median, quartiles, minimum, and maximum values for numerical measurements. Categorical variables were analyzed as percentages (%). Due to the limited sample size, normality testing was not conducted, and comparisons between right and left scapula were performed using the Mann-Whitney U test. Statistical analysis was conducted using SPSS for Windows, version 29.0 (IBM, Armonk, NY, USA). A significance level of $p<0.05$ was considered statistically significant.

Results

The results of the comparison between the measurements of the right and left scapula are summarized in Table 1. And Table 2 presents the descriptive statistics of angular measurements for all 20 scapula combined, without differentiating between the right and left sides. The results suggested that the lateral angle (AL) is significantly greater on

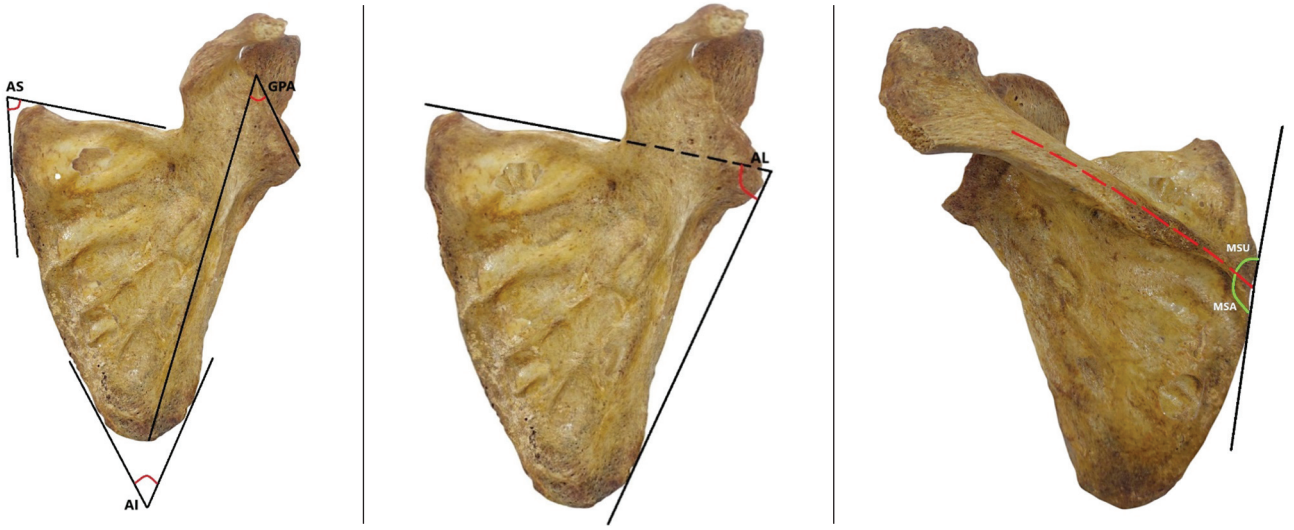

Figure 1. Illustration of scapular measurements on dry scapula. **AI:** The angle formed between the medial and lateral borders; **AS:** the angle formed between the extended lines of the medial and superior borders; **AL:** the angle formed between the lateral and superior borders; **MSA:** the angle between the portion of the medial border below the scapular spine and the spine itself; **MSU**: the angle between the portion of the medial border above the scapular spine and the spine itself; **GPA:** the angle between the axis passing through the supraglenoid and infraglenoid tubercules, and the axis drawn from the apex of the supraglenoid tubercle to the most caudal point of the scapular body.

Table 1
Comparison of angular measurements between right and left scapula.

		n	Mean±SD	95% confidence interval for mean		Min	Max	p-value
				Lower bound	Upper bound			
AI	Left	7	68.57±13.30	56.27	80.87	48	87	0.393
	Right	13	63.46±6.42	59.58	67.34	50	72	
AS	Left	7	78.29±6.73	72.07	84.51	68	85	0.485
	Right	13	76.38±5.72	72.93	79.84	69	88	
AL	Left	7	81.43±3.50	78.19	84.67	76	87	**0.046**
	Right	13	76.38±5.12	73.29	79.48	69	85	
MSU	Left	7	67.86±8.97	59.56	76.15	57	82	0.211
	Right	13	62.54±8.48	57.41	67.66	53	84	
MSA	Left	7	107.86±6.84	101.53	114.18	97	117	0.643
	Right	13	106.77±7.79	102.06	111.48	94	125	
GPA	Left	7	38.00±3.65	34.62	41.38	32	43	0.097
	Right	13	34.23±4.95	31.24	37.22	27	44	

AI: The angle formed between the medial and lateral borders; **AS:** the angle formed between the extended lines of the medial and superior borders; **AL:** the angle formed between the lateral and superior borders; **max:** maximum; **min:** minimum; **MSA:** the angle between the portion of the medial border below the scapular spine and the spine itself; **MSU:** the angle between the portion of the medial border above the scapular spine and the spine itself; **GPA:** the angle between the axis passing through the supraglenoid and infraglenoid tubercules, and the axis drawn from the apex of the supraglenoid tubercle to the most caudal point of the scapular body.

the left side ($p<0.05$). However, no significant differences were observed between the right and left sides for the remaining five angular parameters, indicating a high degree of symmetry in these measurements.

Discussion

The scapula, a key structure of the pectoral girdle, is characterized by its triangular shape, three borders, and three angles formed by the intersection of these borders.[1] The spine of the scapula divides the dorsal surface into the supraspinous and infraspinous fossae, which serve as attachment sites for several muscles. Functionally, the scapula articulates with the clavicle and humerus, facilitating shoulder girdle movements, and is therefore of critical clinical importance.[2] In this study, six angular parameters of the scapula were measured, and their symmetry between the right and left sides was evaluated. Among these parameters, only the AL exhibited a statistically significant difference between the two sides ($p=0.033$). The mean values for the parameters were as follows: AS:

Table 2
Summary of average angular measurements for right and left scapula.

		n	Mean±SD	95% confidence interval for mean		Min	Max
				Lower bound	Upper bound		
General	AI	20	65.25±9.39	60.85	69.65	48	87
	AS	20	77.05±5.99	74.25	79.85	68	88
	AL	20	78.15±5.15	75.74	80.56	69	87
	MSU	20	64.40±8.81	60.28	68.52	53	84
	MSA	20	107.15±7.31	103.73	110.57	94	125
	GPA	20	35.55±4.81	33.30	37.80	27	44

AI: The angle formed between the medial and lateral borders; **AS:** the angle formed between the extended lines of the medial and superior borders; **AL:** the angle formed between the lateral and superior borders; **max:** maximum; **min:** minimum; **MSA:** the angle between the portion of the medial border below the scapular spine and the spine itself; **MSU:** the angle between the portion of the medial border above the scapular spine and the spine itself; **GPA:** the angle between the axis passing through the supraglenoid and infraglenoid tubercules, and the axis drawn from the apex of the supraglenoid tubercle to the most caudal point of the scapular body.

77.05°±6, AI: 65.25°±9.4, AL: 78.15°±5.15, MSU: 64.4°±8.81, MSA: 107.15°±7.31, and GPA: 35.55°±4.81. These findings provide insights into scapular morphology and its implications for clinical and surgical applications.

Measurements of the superior angle have been studied in various populations, highlighting notable differences. Piyawinijwong et al.,[11] in their research on the Thai population, reported a mean value of 84.29°±9.43. Similarly, Sanga[12] determined the superior angle to be 89.57°±10.47 in the Indian population, while Zhang et al.[13] calculated an average value of 88.72° in their analysis of three superior angle types within the Chinese population. In a study of the Turkish population, Boyan et al.[14] identified a mean value of 95.5°, categorizing the scapula into six types based on the structure of the suprascapular notch. Notably, the value measured in our study (77.05°±6) is considerably lower than these findings.

Regarding the inferior angle, our study measured a mean value of 65.25°±9.4, which closely aligns with the findings of Boyan et al.[14] However, lower values were observed in other studies, with Piyawinijwong et al.[11] reporting 40.88°±5.29 and Sanga[12] noting 44.85°±8.14. The lateral angle in our study showed a statistically significant difference between the right and left sides (left: 81.43°±3.505, right: 76.38°±5.12). This is notably higher compared to the findings of Sanga,[12] who reported a lateral angle of 62.38°±10.05. The GPA a critical parameter for evaluating the glenoid slope relative to the scapular body, typically ranges between 36° and 43° in healthy individuals.[4] It is clinically significant, with values between 20° and 22° often indicating the need for surgical intervention to prevent long-term complications such as pain, weakness, and impaired daily function.[5–7]

Bestard et al.[8] first established the standard glenopolar angle (GPA) as ranging from 30° to 45°, highlighting values outside this range as critical indicators of dysplasia in scapular neck fractures Pazarcı et al.[15] compared GPA values between patients with anterior shoulder dislocation (Group 1) and a control group (Group 2), found averages of 32.34°±1.96 and 34.50°±2.32, respectively, noting a statistically significant difference but no gender-based variation. Similarly, Cini et al.[16] calculated a GPA of 38.6°±4.54 and proposed a regression formula for its estimation Sanga[12] reported a GPA of 38.65º±5.66º in dry scapula.

Kumari et al.[17] conducted a morphological analysis of GPA in the Indian population and found an average GPA of 42.6° for all scapula, with no significant differences between sides. They also demonstrated variance among measurement techniques: 42.6° from dry scapula, 39.8° from AP radiological images, and 42.3° from Neer I view radiographs. Pace et al.[18] found a GPA of 39° (ranging from 26° to 50°) in AP radiographs of 9 patients. Tuček et al.[19] further demonstrated method-dependent variation in GPA values: 42.3°±1.6 in 100 dry scapula, 37.1°±4.9 in 50 AP chest radiographs, 35.9° in 50 AP shoulder radiographs, and 43.0°±1.4 in 3D CT reconstructions. In our study, the mean GPA was 35.55°±4.81, aligning with lower values reported in studies involving radiological imaging. The discrepancies between measurements obtained from radiological images and dry bones emphasize the impact of measurement techniques on GPA outcomes.[9,16,18,19] Additionally, variations in GPA may be influenced by anatomical structures like the supraglenoid and infraglenoid tubercles, which serve as attachment points for the biceps brachii and triceps brachii muscles.[20]

Our findings provide valuable data on scapular morphometry in the Turkish population. The results suggest that angular characteristics of the scapula are generally symmetrical between the right and left sides, except for the lateral angle, which showed a statistically significant difference. These findings underscore the importance of further research, particularly on lateral angle variation. Limitations of our study include a small sample size and the absence of gender-specific data, which restrict the generalizability of our results. Future studies with larger, demographically diverse samples and comparisons across measurement techniques, including radiological imaging and 3D modeling, are anticipated to significantly enrich the literature.

Conclusion

This study offers valuable insights into the morphometric characteristics of the scapula in the Turkish population. While the scapula generally exhibits a symmetrical structure between the right and left sides, the observed differences in the lateral angle underscore the need for further research in this area. The GPA measurements, in particular, demonstrate clinical utility for applications such as fracture management and assessing dysplasia. However, the study's limitations—including a small sample size and the absence of gender-specific analysis—restrict the broader applicability of the findings. Future research involving larger and more demographically balanced sample groups is essential to enhance the robustness of the results. Additionally, comparing different measurement techniques, such as radiological imaging and 3D modeling, is anticipated to yield significant contributions to the literature, providing a more comprehensive understanding of scapular anatomy and its clinical implications.

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Conflict of Interest

There is no conflict of interest among the authors regarding the publication of this manuscript.

Author Contributions

SSM: project development, literature review, manuscript writing, critical revision of the text, design and planning of the method; HA: data analysis, manuscript editing, critical revision of the text, design and planning of the method; BÇ: data collection, literature review, manuscript writing, editing of the text.

Ethics Approval

Ethical approval was received from Bolu Abant İzzet Baysal University, Non-Interventional Clinical Researches Ethics Committee Approval for the present study with decision number: 2024/339.

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ORCID ID:
S. Sertel Meyvacı 0000-0002-9450-145X;
H. Ankaralı 0000-0002-3613-0523;
B. Çelik 0000-0003-4401-8678

Correspondence to: Beyza Çelik, PhD
Department of Anatomy, Faculty of Medicine,
Bolu Abant İzzet Baysal University, Bolu, Türkiye
Phone: +90 374 253 46 56
e-mail: beyzayilmazcelik1@gmail.com

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