

Original article

Morphometric Study of Anatomical Variations of the Acromion Process in Libyan Adults in Benghazi using CT scans, and their Clinical Implications

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Abstract

The acromion process of the scapula extends anterolaterally and passes over the glenohumeral joint, creating the subacromial space between the acromion and the humeral head. Important functional structures (bursa, ligaments, tendons) pass through this space, risking impingement or injury. Subacromial impingement syndrome (SIS) is a common musculoskeletal issue faced worldwide; thus, studying acromion morphology is of great importance for its clinical implications in acromioplasty - the recommended intervention for SIS. Prevailing theories of SIS include the acromion's morphology and angle as anatomical factors. This retrospective study aims to determine the anatomical variations of acromion processes among adults in Benghazi, Libya. Computed tomography (CT) scans obtained from Al-Jala Teaching Hospital from January 2024 to December 2024 were used in this study. CT scans were all of patients aged 18 and over, and the female-to-male ratio was 1.18:1. In addition to parameter measurements, each acromion was classified using Bigliani et al.'s (1986) acromion classification. This study found that type II (curved) was the most frequent acromion shape among Libyan adults. No statistical significance was observed in terms of correlating acromion shapes to sex (score = 0.709 > p-value = 0.05), nor was it significant in terms of left versus right scapulae (score = 0.650 > p-value = 0.05). Acromion process morphology and parameters vary among Libyan adults. Clinical implications for surgeons and radiologists include surgical intervention for musculoskeletal injury, which is discussed, and thus highlights the need for preoperative imaging of the acromion.

Keywords: Acromion Process, Subacromial Impingement Syndrome, Anatomical Variations

Introduction

The scapula is a flat bone located posterior to the ribcage. It is part of the pectoral girdle, which is responsible for shoulder joint movement and stability. Its flat, triangular shape and processes extend from thoracic vertebrae T2 to T7, and it bears three margins: superior, medial, and lateral. The lateral margin is the thickest, strongest, and is especially significant, as it houses the glenoid cavity, responsible for articulation with the humerus [1,2].

The coracoid, spine, and acromion are the three processes of the scapula. The acromion process is a continuation of the scapular spine that extends anterolaterally. Its only articulation is with the clavicle, forming the synovial acromioclavicular joint; and is connected to the coracoid process through the coracoacromial ligament, forming the coracoacromial arch.

The acromion process itself passes over the glenohumeral joint, leaving a small emptiness named the subacromial space. The subacromial space is bound superiorly by the coracoacromial arch, inferiorly by the rotator cuff, and posteriorly by the subacromial bursa [3]. Structures passing through, or lying in the subacromial space include the subacromial bursa, biceps long tendon, and rotator cuff tendons [4]. This allows for potential impingement or injury of structures between the acromion

process and the head of the humerus [5].

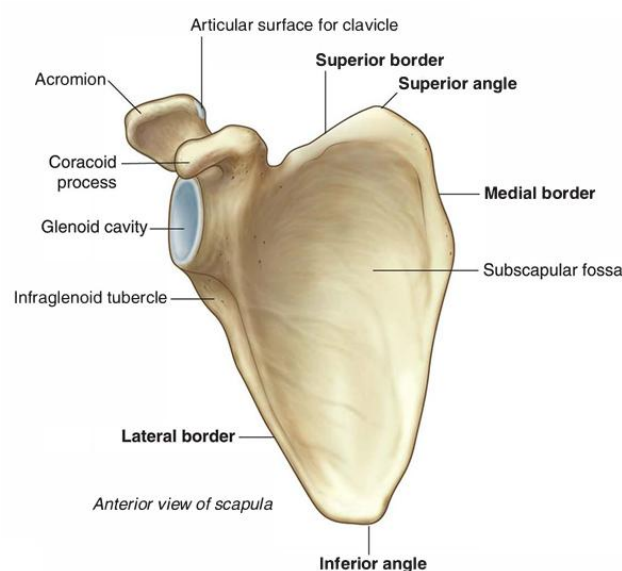


Figure 1: The acromion process (Anterior view of costal surface) [6]

SIS is a common, clinically challenging disorder that causes shoulder joint pain, degenerative changes, inflammation, and limited range of motion. SIS is often

due to the impingement of the subacromial bursa, or rotator cuff tendons that lie within the subacromial space[5]. The acromion process and coracoacromial arch press against these structures, thus the potential for compression and impingement. The prevailing theory about rotator cuff impingements categorizes the underlying causes as both functional and anatomical. Anatomical factors include the acromion process's morphology and angle[7]. The three anatomical types of acromion processes recognized in literature are based on Bilgani et al. (1986) classification: Type I (flat), Type II (curved), and Type III (Hooked). Other studies demonstrate the comparatively high incidence of rotator cuff injuries among those with Type III (hooked) acromion - supporting the predominant theory, and how anatomical variations contribute to pathologies of the shoulder [7]. Another anatomical factor is the coracoacromial distance - which with the acromio-glenoid distance, are related to the size of the subacromial space. Thus, the likelihood of SIS increases as subacromial space decreases [3]. A substantial percentage of the global population is influenced by frequent musculoskeletal issues such as shoulder pain and SIS. Thus, studying the acromion-cricoid distance and thickening is of great importance for its clinical implication in acromioplasty which is the recommended intervention for SIS [5].

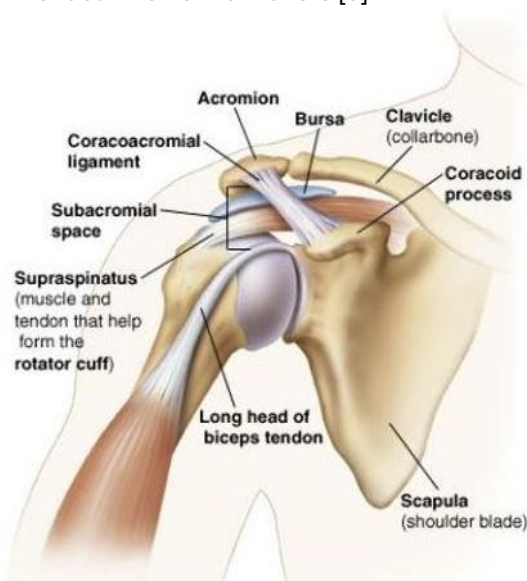


Figure 2: The subacromial space and related structures.[8]

It has been reported by Ahmidan et. al's (2022) study on 100 Libyan participants, 50 males and 50 females were included. The mean standard deviation of the maximum acromion height in males was 4.06 ± 0.63 , and 3.64 ± 0.61 among females [9].

A morphometric study was conducted in (2015) by Wael Amin Nasr El-Din et al. on the Egyptian population to assess acromion-type variations and glenoid cavity of scapula. Type II (curved) was the most frequent type at 61.25%. The second-most common type was Type I (flat), at 25%, and the least common was Type III (hooked) being

13.75%. The study mentions that Type I acromion are the least likely to cause compression of the rotator cuff muscles, while curved is often recognized. However, the most vulnerable type to undergo compression of the rotator cuff muscles is type III [10].

A cross-sectional study by Akhtar et al. (2023) sought to examine the morphology and the morphometry of the acromion and its implication in SIS among Northern Indians [5]. They found that Type II (53.34%) had the highest prevalence, Type I (28.33%) was the second-most prevalent type, while Type III (18.33%) was the least frequent. Moreover, this study correlates that studying acromion variations and other parameters helps surgeons in acromioplasty, specifically in knowing how much to shave off the acromion. SIS and rotator cuff injuries can be better understood and treated by knowing the acromion parameters and variations. The study was limited by the lack of knowledge regarding the age and sex of the specimens [5].

Chaimongkhon, Thawanthorn et al. (2020) descriptive study on the morphometry of the acromion and the risk of SIS used 392 dry scapulae of the Thai population [11]. This study found that the most frequent type was curved (78.8 %,) the least common type was flat (9.2%.), while the second-most frequent was hooked (12%). As the sample was grouped according to their age, the results changed. They found that flat was the most prevalent type among participants aged 31-40 years old. The mean standard deviation of acromion length was 43.55 ± 4.93 , 46.66 ± 4.8 in males, and 43.55 ± 4.93 in females [12].

Evidently, there is a significant lack of studies among the Libyan population concerning clinical ramifications of anatomical variations - especially regarding the acromion process and its specific clinical and surgical implications. This study provides Libyan surgeons and radiologists with important anatomical data relevant to the population they are treating, while contributing information about the Libyan population to international medical literature.

This retrospective study aims to determine the anatomical variations of acromion processes among Libyan adults, including morphology, length, breadth, thickness, acromio-coracoid distance, and acromion-glenoid distance, utilizing 534 randomly selected computed tomography (CT) scans containing at least one of the acromion obtained from Al-Jala Teaching Hospital from January 2024 to December 2024.

Materials and Methods

This retrospective was conducted using CT scans of acromion processes in Libyan adults in Benghazi. the exclusion criteria were set to be: i) Cases with fractures and other pathologies of the scapula. ii) Ages below 18 and, iii) suboptimal imaging quality. RadiAnt DICOM viewer 2021 software was used to examine the previously mentioned targeted parameters. a total of 1068 acromion CT scans were reviewed. From which 582 were excluded, mainly due to suboptimal imaging quality in which the

acromion and its relevant parameters were completely or partially invisible and/or unmeasurable. Descriptive statistical analysis, independent t-tests, and chi-square tests were performed using SPSS version 26 (IBM, Armonk, NY). This study and its use of participants' data have obtained ethical approval from the Libyan International Medical University's Research Ethics Committee and are in compliance with the Helsinki Declaration. All members of this research are aware of data protection and data dissemination concerning this paper. The original data collected was only available to the authors and supervisors, who bear the responsibility of securing the hard copies of said data safely. Access to the data was restricted to the authors and supervisors of this study. Personal information was not revealed to the authors or supervisors. The descriptive analysis of continuous variables was demonstrated through their means, standard deviations, and ranges, while categorical variables such as the acromion shapes were demonstrated through their frequencies and percentages

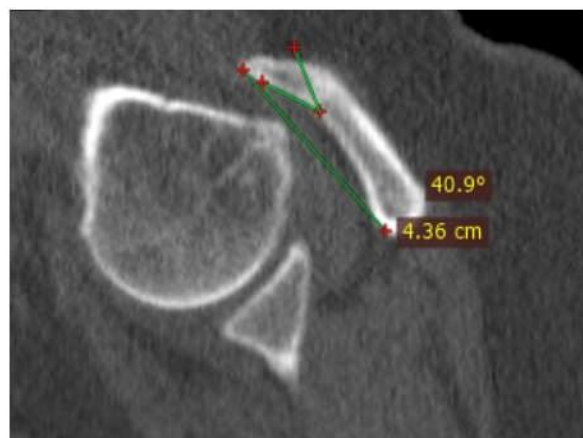


Figure 3: Example of measurement of an acromion process' terminal angle. An angle of 40° puts this acromion into the classification of Type III (hooked).

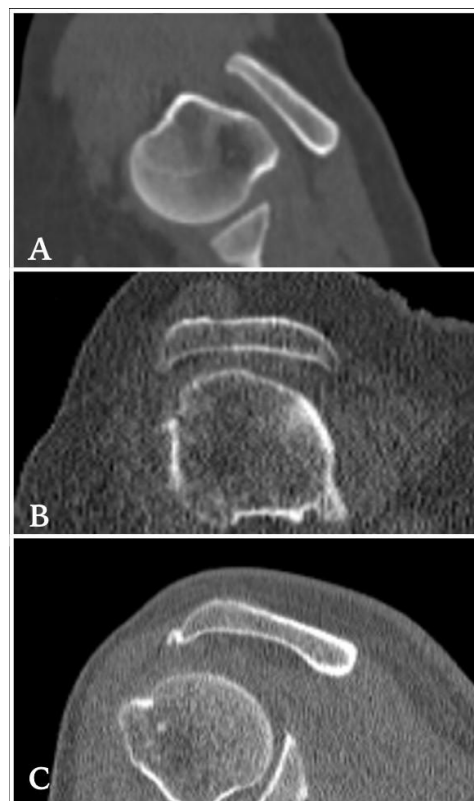


Figure 4: Examples from this study's data of the three types of acromion process morphology (A) Type I Flat, (B) Type II Curved, (C) Type III Hooked

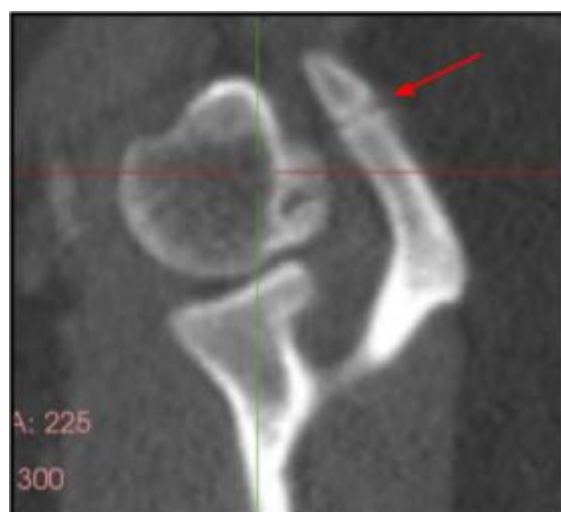


Figure 5: Example from the data of a Type B (meso-acromial) Os Acromiale (red arrow). This acromion happens to be Type I (Flat).

Results

The mean acromion thickness is 7.59 ± 1.47 mm, ranging from 1.25 mm to 13.30 mm. The mean acromion length 43.5 ± 8.6 mm, ranging from 20.30 mm to 65.61 mm. The mean coraco-acromial distance is 32.7 ± 5.5 mm, ranging from 17 mm to 52 mm. The mean acromion-glenoid distance is 21.5 ± 3.93 mm, ranging from 12.30 mm to 37 mm. (Table 1)

The most common type is curved, with a percentage of 50%, observed in 244 acromions. The second-most

common type is flat, found in 199 acromions, with a percentage of 40.9%. The least common type is hooked, observed in 43 acromions, with a percentage of 8.8%. (Table 2)

The most common type, accounting for 50.2% (n = 244), was Type II (curved); 48.3% (n = 114) of left acromion, and 52.0% (n = 130) of right acromion. Type I (flat) was the

second-most common type, accounting for 40.9% (n = 199); 41.9% (n = 99) of left acromion, and 40% (n = 100) of right. The least common type was Type III (hooked) observed at 8.8% (n = 43); accounting for 9.7 % (n = 23) of the left acromion, and 8% (n = 20) of the right acromion. (Table 3)

Table 1: Descriptive analysis of the four parameters

Descriptive Statistics					
	N	Minimum (mm)	Maximum (mm)	Mean (mm)	Std. Deviation
Acromion Thickness	486	1.25	13.30	7.5948	1.47634
Acromion Length	486	20.30	65.61	43.7163	8.66820
Coraco-Acromial Distance	486	17.00	52.00	32.72	5.518
Acromion-Glenoid Distance	486	12.30	37.10	21.5675	3.93720
Valid N	486				

Table 2: Percentage prevalence of each acromion type

Acromion Shapes				
	Frequency	Percent	Valid Percent	Cumulative Percent
Flat (Type 1)	199	40.9	40.9	40.9
Curved (Type 2)	244	50.2	50.2	91.2
Hooked (Type 3)	43	8.8	8.8	100.0
TOTAL	486	100.0	100.0	100.0

Table 3: Chi square of prevalence of each acromion type of left and right acromion

Acromion Types Cross Tabulation						
			Acromion Type			
			Flat	Curved	Hooked	Total
Side	L	Count	99	114	23	236
		Expected Count	96.6	118.5	20.9	236.0
		% within side	41.9%	48.3%	9.7%	100.0%
	R	Count	100	130	20	250
		Expected Count	102.4	125.5	22.1	250.0
		% within side	40.0%	52.0%	8.0%	100.0%
Total		Count	199	244	43	486
		Expected Count	199.0	244.0	43.0	486.0
		% of total	40.9%	50.2%	8.8%	100.0%

There is no statistical significance (p-value ≥ 0.05) between the left or right acromion and the incidence of specific acromion types as shown in Table 4.

Table 4: Chi-square of prevalence of each acromion type of left and right acromion

Chi-Square Test		
	Value	P-value
Pearson Chi-Square	0.861 ^a	0.650
Likelihood Ratio	0.861	0.650
N of Valid Cases	486	

The distribution of the data was determined using histograms and Kolmogorov-Smirnov tests performed separately for both the left and right-side acromion. Excluding the right acromion thickness, all of the parameters were normally distributed. Figure 3 below shows that the right acromion thickness is not normally distributed. Independent t-tests were performed on the normally-distributed parameters.

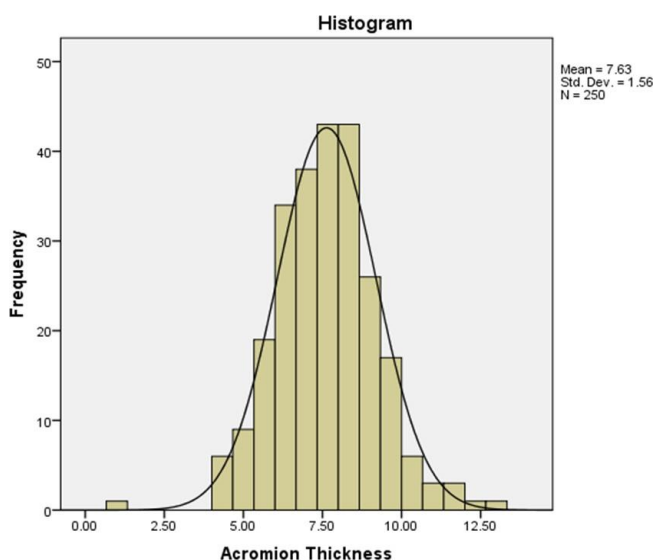


Figure 6: Histogram of right-side acromion thickness data distribution.

The average right acromion length on the right side is 43.9 ± 8.68 mm, and on left side is 43.44 ± 8.65 mm. There is no significant difference between the acromion length on both the right and left sides (p -value ≥ 0.05). The average coraco-acromial distance on the right is 32.73 ± 5.49 mm, and on the left is 32.69 ± 5.54 mm. The difference between the coraco-acromial distance on the right and left sides is not statistically significant (p -value ≥ 0.05). The average acromion-glenoid distance on right is 21.66 ± 4.26 mm, and on the left 21.37 ± 3.78 mm. There is no statistical significance between the acromion-glenoid distance on both sides (p -value $\geq$

0.05). (Table 5)

Table 5: Independent t-test for the normally-distributed parameters for left and right acromion. All measurements are in millimeters (mm)

Parameters	Right Acromion Mean $\pm$ SD	Left Acromion (Mean $\pm$ SD)	P-Value
Acromion Length	43.9 ± 8.68	43.44 ± 8.65	0.506
Coraco-Acromial Distance	32.73 ± 5.49	32.69 ± 5.54	0.935
Acromion-Glenoid Distance	21.66 ± 4.26	21.37 ± 3.78	0.420

Mann-Whitney U tests were performed on the acromion thickness, which was not normally distributed (p -value ≥ 0.05), and showed no statistical significance. (Table 6)

Table 6: Mann-Whitney U test Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Acromion Thickness is the same across categories of side.	Independent-Samples Mann-Whitney U Test	.576	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

There is a moderate correlation (0.328) between the acromion length and the coraco-acromial distance. (Table 7)

Table 7: Pearson correlation for both acromion length and the coraco-acromial distance

Correlation Test			
		Acromion Length	Coraco-Acromial Distance
Acromion Length	Pearson Correlation	1	0.328**
	Sig. (2-tailed)		0.000
	N	486	486
Coraco-Acromial Distance	Pearson Correlation	0.328**	1
	Sig. (2-tailed)	0.000	
	N	486	486

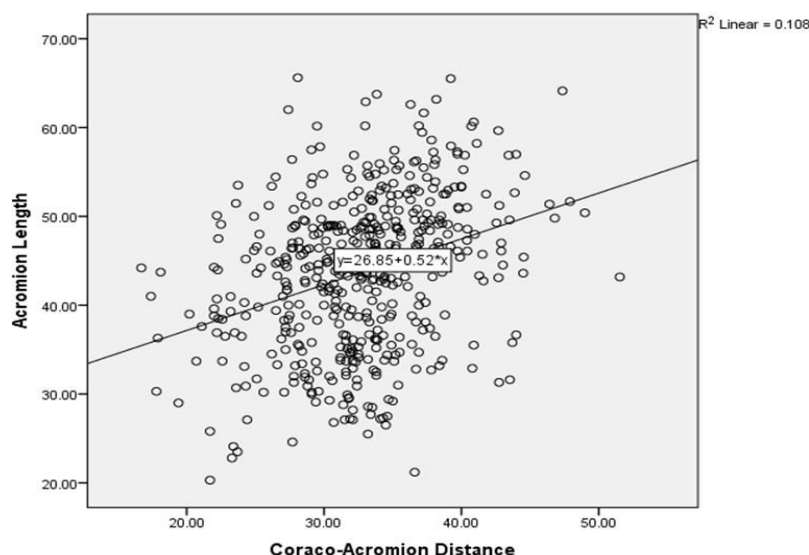


Figure 7: Pearson correlation test between acromion length and coraco-acromial distance.

There is a linear relationship between the acromion length and the coraco-acromial distance, as shown in figure 7. A weakly positive correlation of (0.224) between acromion length and the acromion-glenoid distance is shown in Table 8.

Table 8: Pearson correlation for both acromion length and acromion-glenoid distance.

Correlation Test			
		Acromion Length	Acromion-Glenoid Distance
Acromion Length	Pearson Correlation	1	0.224**
	Sig. (2-tailed)		0.000
	N	486	486
Acromion-Glenoid Distance	Pearson Correlation	0.224**	1
	Sig. (2-tailed)	0.000	
	N	486	486

A weak linear relationship between acromion length and the acromion-glenoid distance is shown in figure 8.

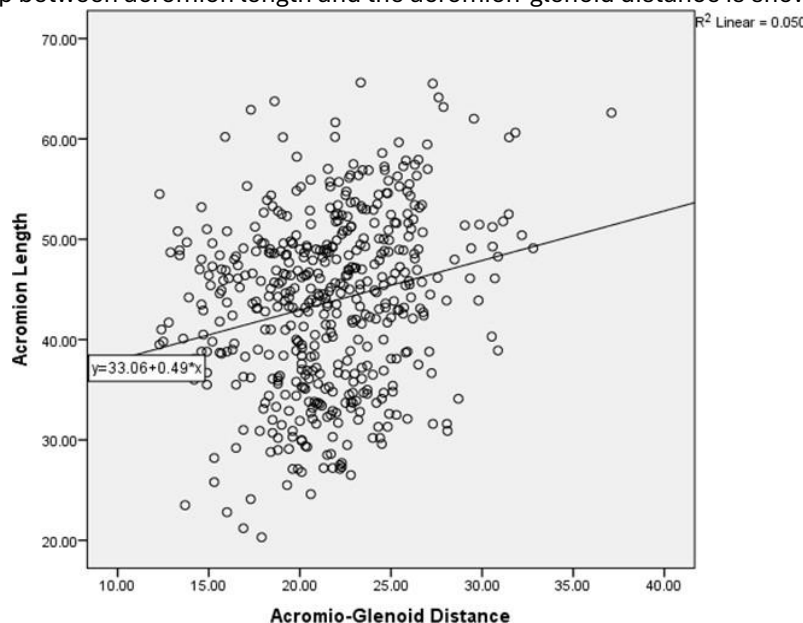


Figure 8: Pearson correlation test between acromion length and acromion-glenoid distance.

ANOVA test which demonstrates a significant difference between the means of acromion-glenoid distance and the three acromion types (flat, curved and hooked). (Table 9)

Table 9: one way ANOVA of acromion-glenoid distance among the acromion types

ANOVA - Acromion-Glenoid Distance			
	Sum of Squares	Mean Square	Sig.
Between Groups	265.325	132.662	0.000
Within Groups	7252.918	15.016	
TOTAL	7518.243		

Post-Hoc analysis using Bonferroni shows a statistically significant difference between the means of the flat and curved types (p-value less than 0.05) and the acromion-glenoid distance. However, there is no statistical significance between the acromion-glenoid distance and hooked type (p-value $\geq$ 0.05).

(Table 10)

Table 10: Post-Hoc analysis of acromion-glenoid distance between different acromion shapes and types

Multiple Comparisons						
Dependent Variable: Acromion-Glenoid Distance						
Acromion Type	Acromion Type	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
flat	curved	-1.49846*	.37014	.000	-2.3877-	-.6093-
	hooked	-.12518-	.65167	1.000	-1.6907-	1.4404
curved	flat	1.49846*	.37014	.000	.6093	2.3877
	hooked	1.37328	.64091	.098	-.1664-	2.9130
hooked	flat	.12518	.65167	1.000	-1.4404-	1.6907
	curved	-1.37328-	.64091	.098	-2.9130-	.1664

ANOVA test shows no statistically significant difference between the means of coraco-acromial distance and the three acromion types (p-value $\geq$ 0.05). (Table 11)

Table 11: one way ANOVA of coraco-acromial distance among the acromion types

ANOVA			
Coraco-Acromial Distance			
	Sum of Squares	Mean Square	Sig.
Between Groups	84.022	42.011	0.252
Within Groups	14683.473	30.401	
TOTAL	14767.495		

Discussion

Morphological evaluation of the acromion is critical for understanding acromion-related pathologies and their surgical interventions; however, the precise relationship between acromion morphology, morphometry, and SIS remains complex and multifactorial [5]. Bigliani et al. (1986) classified acromial shapes into three primary types: flat (Type I), curved (Type II), and hooked (Type III) [5]. Their findings indicated that Type III acromion were most-strongly associated with rotator cuff injuries. In this study of the Libyan population in Benghazi, the distribution of these types was 40.94% (flat), 50.20% (curved), and 8.84% (hooked), (See Appendix) making the curved type the most common, and the hooked type, which is the most linked to SIS, the least common. This corroborates the idea that SIS is multifactorial - including genetic predispositions to tendon degeneration, or occupational factors such as repetitive strain. This study's data distribution aligns with findings from other studies

conducted on similar racial populations [13,14,19]. Whereas other studies conducted on South Indian and Thai populations produced contradicting results [15,20]. Additionally, since acromion type distribution did not differ significantly between left and right acromion ($\chi^2 = 0.650$, $p \geq 0.05$), the results suggest no laterality-based variation in acromial morphology. The near-symmetrical prevalence (48% / 52% curved bilaterally) further supports morphological symmetry, rejecting any side-specific anatomical predisposition for acromion-related pathologies [25].

Acromion thickness represents a critical anatomical factor in the surgical management of SIS, particularly during acromioplasty [9]. The morphometric parameters evaluated in this study hold substantial clinical relevance, given that acromioplasty remains the gold-standard surgical intervention for SIS. This study's findings demonstrate mean acromial thickness at 7.62 ± 1.55 mm (right) and 7.55 ± 1.38 mm (left), aligning closely with

Paraskevas et al. (2008) [14] and Akhtar et al. (2023) [5]. This study measured right and left acromial lengths at 43.92 ± 8.68 mm and 43.44 ± 8.65 mm respectively, indicating comparable dimensions between sides, and thus no statistical significance. The morphometric analysis revealed the mean coraco-acromial distance to be 32.73 ± 5.49 mm (right) and 32.69 ± 5.54 mm (left); these observations are similar to the ones conducted by Koca et al. (2022) [12]. These dimensions directly reflect the functional length of the coracoacromial ligament, an important structure in shoulder biomechanics. The consistency between left and right suggests bilateral symmetry in this parameter, which may inform surgical planning for procedures involving coracoacromial ligament excision - a recognized intervention for SIS [20]. The Acromion-Glenoid distance in this study was 21.75 ± 4.07 mm (right), and 21.37 ± 3.78 mm (left), which is significantly higher than observations conducted by Paraskevas et al. (2008) [14], yet lower than findings by El-Din et al. (2015) [17].

The identified moderately-positive association between acromion length and coraco-acromial distance ($r = 0.328$, $p < 0.001$) suggests that longer acromions may elevate the coracoacromial arch, potentially reducing cuff compression—a paradoxical protective effect. While longer acromions are generally considered a risk factor for SIS [15], the data indicates that they might have a protective effect by increasing the coracoacromial space and reducing tendon compression.

Statistical analysis demonstrated no significance between the acromion-glenoid nor the coracoacromial distances within the side of the acromion process, in opposition to Akhtar et al. (2023) [5] which highlighted statistical significance between left and right acromion. Statistical analysis revealed a significant, but weak, positive correlation between acromion length and Acromion-Glenoid distance ($r = 0.207$, $p < 0.001$), indicating that increased acromion length significantly associates with marginally greater Acromion-Glenoid distance. While this anatomical relationship may contribute to superior humeral head displacement patterns in rotator cuff-deficient shoulders, the limited association strength suggests that additional biomechanical factors such as history of shoulder trauma likely exert more substantial influences on glenohumeral stability.

An analysis of variance test (ANOVA) was conducted to compare the difference in means between coraco-acromial distance and acromion-glenoid distance to the type of acromion as seen on table 10. The test demonstrated no statistical significance between any of the three shapes to the coraco-acromial distance ($p \geq 0.05$). However, the acromion-glenoid distances demonstrated a positive statistical significance to acromion type, indicating that longer acromion extending laterally may preserve or slightly increase the Acromion-Glenoid distance as opposed to acromion that curve anteriorly.

The flat-curved acromion type relation shows a highly significant p value of 0.000 and a mean difference of -1.49 mm. These results suggest that flat-type acromion have a smaller acromion-glenoid distance than curved-type acromion. Smaller acromion-glenoid distances are at increased risk of SIS [22]. Both the curved-hooked and flat-hooked acromion type relations showed non-significant p values, 0.098 and 1.000 respectively, indicating no statistical significance between the acromion-glenoid distance of flat or hooked-type acromion.

Acromion-glenoid distance is associated with SIS [26]. flat-type acromion may contribute to narrower spaces compared to curved-type ones. Flat-type acromion having shorter acromion-glenoid distances contributes to vertical compression that increases risk of chronic bursitis and diffuse tendon wear due to repetitive vertical loading. This may explain why some patients with minimal anterior curvature still develop SIS symptoms. However, hooked-type acromion, which are often linked to SIS, did not demonstrate a correlation to significant acromion-glenoid distance reduction. This is due to the fact that hooked-type acromion may curve downward without reducing Acromion-Glenoid distance.

This study is limited in terms of assessing functional impingement since it was conducted via CT scans rather than MRIs and ultrasound. Although this study demonstrated a non-significant value for the curved-hooked acromion type relation to acromion-glenoid distance, it was almost statistically significant, suggesting the need to conduct the same investigation on a larger data sample. Future studies should aim for a much larger data sample that also includes other regions of Libya.

Conclusion

In conclusion, the dominance of the curved type and the relatively low frequency of the hooked type may point towards population-specific anatomical characteristics that affect the occurrence and manifestation of shoulder conditions, such as SIS. The results support the theory that SIS is complex, involving occupational aspects and functional factors that are partially determined by anatomical structure. The validity of utilizing one side as a reference in clinical evaluation is supported by the bilateral symmetry in acromion measurements observed in this study. Crucially, even without the conventionally implicated hooked type, the correlation between Type 1 (flat) acromion and their shorter acromion-glenoid lengths suggests a previously underestimated risk factor for SIS. This highlights the clinical need for a customized evaluation based on the acromion's shape and structural relations. When evaluating shoulder pain, orthopedic surgeons and clinicians should use acromial morphometric examination, particularly for flat acromion. These measurements serve as a guide for surgical interventions, preventing overtreatment or undertreatment. When reporting CT scans for probable shoulder impingement or rotator cuff pathology,

radiologists should include the acromion type and parameter measurements. To validate results and enhance the anatomical database of Libyans, future studies should evaluate bigger, more geographically varied populations. Real-time biomechanical impact assessments are advised using functional imaging methods such as dynamic ultrasound or magnetic resonance imaging (MRI). By comparing clinical results with morphometric data, shoulder pathology prediction patterns may be established.

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