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Morphometric Study of Scapulae in Human Skeletons in Northeastern Brazil

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ABSTRACT

Introduction: Scapula is a flat triangular bone that situates at the posterior wall of the thorax and composes the shoulder joint. On its lateral angle, there is an opening called glenoid cavity which morphology varies between individuals, contributing to shoulder lesions, surgical access and the selection of prostheses.
Material and Methods: A total of 116 dried human adult scapulae localized in the Northeast of Brazil were analyzed. The shape of the glenoid cavity was evaluated, and linear measurements of the scapulas and glenoid cavity were taken to estimate the total size. Values of p≤0.05 were considered significant.
Results: The most frequent shape of glenoid cavity was inverted comma-shaped, with 63 scapulae (54.3%). The mean value of the SI diameter was 36.85±0.36 mm for the right side, and 36.32±0.34 mm for the left side. The mean value of the AP1 diameter was 26.00±0.33 mm for the right side and 26.64±0.32 mm for the left side. For the AP2 diameter, the values were 18.27±0.36 mm for the right side and 18.22±0.55 mm for the left side. The right and left glenoid cavity index were 0.48±0.008% and 0.47±0.01%, respectively. The value for MSL was 171.3±22.64 mm for the right side and 172.6±23.68 mm for the left side. While the value for MSB was 100.8±0.86 mm for the right side and 103.5±0.90 mm for the left side.
Conclusion: For the first time a study describing the scapular morphometry was developed on Northeastern Brazil. The findings contriutes for understanding the ethnicity role on scapular morphology variation.
Keywords: Anatomy. Brazil. Glenoid cavity. Scapula. Osteology.

Introduction

Scapula is a flat triangular bone that situates at the posterior wall of the thorax, having an intimate relation with a grand variety of muscles, and composes the shoulder joint. Its lateral angle is truncated and can also be described as the head of the scapula, where there is an concavity called glenoid cavity, which is the connection point of the humerus with the shoulder girdle named glenohumeral joint. The margin of the glenohumeral joint articular surface is covered by a fibrocartilaginous structure called glenoid labrum, which is responsible for deepening the shallow concavity of the joint.[1]

The morphology of this bone varies between individuals based on the presence of a notch on the anterosuperior rim of the glenoid cavity. Prescher and Klümpen (1997)[2] classified the scapulae as oval shaped, when the notch on the anterior margin is absent; as pear shaped, when this notch influences the silhouette of the bone structure; and as inverted comma shape, when this notch exists, but it is indistinct.[2]

Therefore, this variation contributes to the probability of occurring lesions on human shoulder joints. On his study, Prescher and Klümpen (1997)[2] concluded that the presence of this glenoid notch hinders the fixation of the glenoid labrum to the underlying bone structure, hence, individuals with a pear-shaped glenoid cavity are more propense of suffering Bankart lesions than who have an oval-shaped glenoid cavity.[2] This information has its special value because the shoulder joint is the most fragile and propense to deslocations joint of the human body.[1]

In addition to that, other studies prove that morphometric characteristics and dimensions of scapulae contributes on possible surgical access, like reverse shoulder arthroplasty, being of extreme importance that the surgeon masters this knowledge and the morphometric profile of the glenohumeral joint.[3–7]

The present study aimed to establish a morphometric profile of scapulae and its glenoid cavities, considering the Northeastern Brazilian territory.

Materials and methods

A total of 116 (62 right sided and 54 left sided) dried human adult scapulae of unknown ethnicity without any gross pathology or abnormality were analyzed. The scapulae were obtained from the Human Anatomy Laboratory of the Federal University of Ceará (UFC) and Federal University of Paraiba (UFPB), localized in the Northeast of Brazil.

Qualitatively, it was evaluated the shape of the

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glenoid cavity, which was classified into pear-shaped, inverted comma-shaped or oval shaped. For this task, it was important the use of drawings from the bone silhouette made by a lead pencil on a white paper (Figure 1).

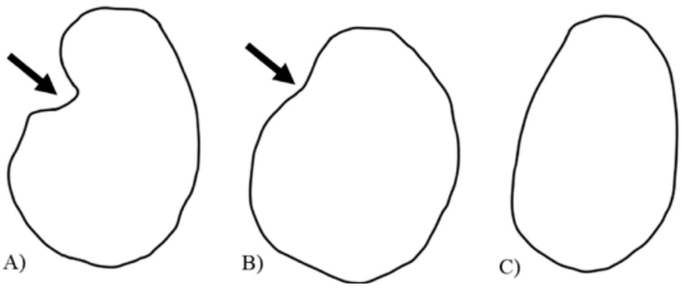

Figure 1. Classification of glenoid cavity's shapes by Prescher and Klümpen (1997)[2]. Lateral view. A- Pear shape; B- Inverted comma shape; C- Oval shape. (Collection Research)

Quantitatively, the following measurements were taken:

• Maximum scapular length (MSL)- line "A" that unites the superior angle to the inferior angle (Figure 2).

• Maximum scapular breadth (MSB)- line "B" which starts at the point where the spine of the scapula appears medially and goes to the posterior margin of glenoid cavity (Figure 2).

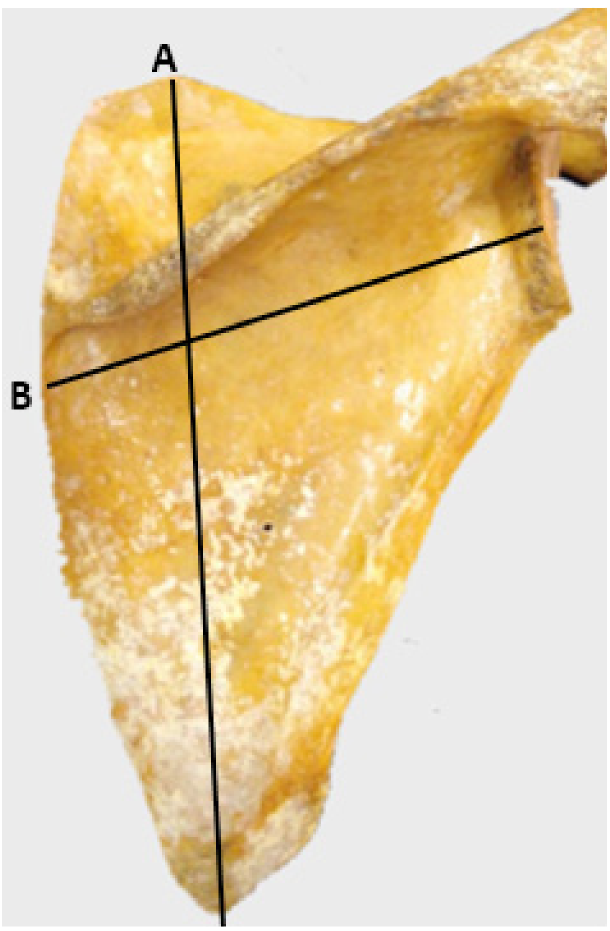

Figure 2. Measures of the scapula. Posterior view. A- Maximum length of scapula; B – Maximum breadth of scapula. (Collection Research)

• Supero inferior glenoid diameter (SI)- the line that leaves the most superior point of supraglenoidal tubercle and goes to the inferior point of the glenoid cavity (Figure 3).

• Antero posterior glenoid diameter 1 (AP1)- the line that represents the maximum breadth of the glenoid cavity, perpendicular to the SI line (Figure 3).

• Antero posterior glenoid diameter 2 (AP2)- Parallel to the AP1 line, corresponds to the anterior-posterior diameter of the superior half of the glenoid cavity (Figure 3).

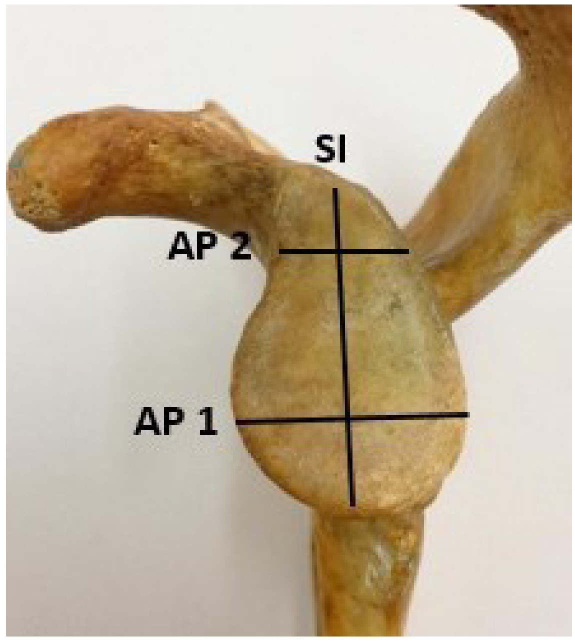

Figure 3. Measures of the glenoid cavity. Lateral view. SI- Supero inferior diameter; AP1- Antero posterior glenoid diameter 1; AP2- Antero posterior diameter 2. (Collection Research)

• Glenoid cavity index (GCI)- number that results from the mathematical expression below:

$$GCI = \frac{\text{Antero posterior glenoid diameter 1 X 100\%}}{\text{Superior inferior glenoid diameter}}$$

Measurements were made using digital caliper with an accuracy of 0.01 mm. Student's t-test was applied to evaluate differences between right and left antimeres using GraphPad Prism version 6.00 for Windows, GraphPad Software, USA. Values of $p \leq 0.05$ were considered significant.

Results

In the present study, the most frequent shape of glenoid cavity analyzed on all 116 scapulae was inverted comma-shaped, with 63 scapulae (35 right side and 28 left side), corresponding a more than half of all scapulae studied (54.3%). The less common shape was pear-shaped, with 19% (Table 1).

No statistical differences between the right and left sides were observed in all parameters analyzed ($p>0.05$), except the average value for maximum breadth was 100.8±0.86 mm for the right side and 103.5±0.90 mm for the left side (p=0.03), (Table 2).

Table 1. Glenoid cavity's shape percentage in both sides. N=116

Glenoid cavity Shape	Right side	Left side	Total
Pear	12 (22.3%)	10 (16.1%)	22 (19%)
Oval	14 (25.9%)	17 (27.4%)	31 (26.7%)
Inverted Comma	35 (56.5%)	28 (51.8%)	63 (54.3%)

Table 2. Mean ± SD values of scapula measurements of both sexes. N=116

Parameters	Right side	Left side	P value
SI diameter	36.85±0.36 mm	36.32±0.34 mm	0.29
AP1 diameter	26.0±0.33 mm	26.64±0.32 mm	0.20
AP2 diameter	18.27±0,36 mm	18.2 ±0,55 mm	0.93
Maximum scapular length (MSL)	171.3±22.64 mm	172.6±23.68 mm	0.96
Maximum scapular breadth (MSB)	100.8±0.86 mm	103.5±0.90 mm	0.03
GCI	48±0.8%	47±1%	0.37

Discussion

Considering the existence of an important variability of scapulae morphology, publications from around the globe contributed describing different populations and regions. The data was collected in a variety of ways, with some taking direct measurements from embalmed cadavers and dry bones, while others used radiographic measurements from cadavers or living patients. In the present study, 116 human dry scapulae were analyzed and some measurements were taken in order to establish an average profile of scapulae in Northeastern Brazil and to compare our findings with other studies made around the globe.

We found that 85 specimens (73.3%) had a glenoid notch which endorses Prescher and Klümpen (1997) conclusion on German population,[2] as well as Mamatha *et al*. (2011), Akhtar *et al*. (2016) and Tiwari *et al*. (2018) on Indian population.[8–10] However, despite the presence of the notch, the most common glenoid shape on 63 scapulae (54.3%) of the current study was inverted comma shape, differing from the findings of the previous authors. Prescher and Klümpen (1997) found that 55% of the sample had a pear shape and 45% had an oval shape.[2] Mamatha *et al*. (2011), Akhtar *et al*. (2016) and Tiwari *et al*. (2018) agreed on describing the pear shape as the most common shape followed by the inverted comma shape as the second most common type in the Indian population.[8–10] Nevertheless, observations of Coskun *et al*. (2006)[11] and El-Din and Ali (2015)[12] in Turkish and Egyptian population, respectively, established that oval-shaped glenoid was the most common shape and enhanced the role of ethnicity on glenoid shape morphology variety (Table 3).

It is well known that the presence of the glenoid notch hinders the fixation of the glenoid labrum to the underlying bone structure because the labrum is not fixed to the bony margin but bridges the notch itself and this fact could make the shoulder joint less resistant to dislocating forces.[2] This supposition is supported by the theory of failure of the anterior capsular ligament complex mentioned by O'Connell *et al*. (1990),[13] which asserts the detachment of the anterior capsule, including the labrum from the anterior glenoid could lead to recurrent anterior shoulder instability. The most convincing argument for the notch existence is proposed by Martin (1933), who cites the pressure made by the tendon of the subscapularis muscle on the anterior margin of glenoid cavity when the arm is carried upwards.[14]

Considering the quantitative parameters of the scapula, the results mean MSL of the right side was 171.3±22.64 mm, while the left side was 172.6±23.68 mm. These findings were much higher than those presented by Flower and Garson (1879), Von Schroeder *et al*. (2001), Coskun *et al*. (2006), Aigbogun *et al*. (2017), El-Din and Ali (2015) and Akhtar *et al*. (2016) for European, Canadian, Turkish, Nigerian, Egyptian and Indian population, respectively.[9,11,12,15–17] These differences may be due to population variation in which South American people appear to have longer scapulae compared to the rest of the world (Table 4).

Table 3. Comparative analysis of glenoid cavity's shape.

Population	Pear	Oval	Inverted comma	Total
Prescher and Klümpen (1997),[2] Germany	129 (55%)	107 (45%)	0 (0%)	236 (100%)
Coskun *et al*. (2006),[11] Turkey	26 (28%)	64 (72%)	0 (0%)	90 (100%)
Mamatha *et al*. (2011),[8] India	89 (44%)	44 (22%)	67 (33%)	202 (100%)
El-Din *et al*. (2015)[12], Egypt	50 (31.25%)	81 (50.63%)	29 (18.12%)	50 (100%)
Akhtar *et al*. (2016),[9] India	115 (50.44%)	31 (13.60%)	82 (35.96%)	126 (100%)
Tiwari *et al*. (2018),[10] India	103 (50%)	40 (19.42%)	63 (30.58%)	206 (100%)
Present study	31 (52.6%)	16 (27.1%)	12 (20.3%)	59 (100%)

For the MSB, we observed a mean value of 100.8±0.86 mm for the right side and a mean value of 103.5±0.90 mm for the left side. Although there was observed a significant difference between sides (p=0.03), it was isolated only for this parameter, hence it may be only a casual asymmetry. Again, it is possible to see differences from others authors work. Von Schroeder *et al*. (2001),[16] Flower and Garson (1879)[15] and El-Din and Ali (2015)[12] showed higher values for these measurements and, on Indian studies, these values were lower[9,18] (Table 4).

As for the glenoid cavity dimensions, the mean SI diameter was 36.85±0.36 mm for the right glenoid and 36.32±0.34 mm for the left glenoid. Von Schroeder *et al*. (2001) and Coskun *et al*. (2006) showed very similar values to ours.[11,16] Aigbogun *et al*. (2017)[17] and El-Din and Ali (2015)[12] presented higher results from African population whereas Mamatha *et al*. (2011), Akhtar *et al*. (2016) and Tiwari *et al*. (2018) showed lower values for the Indian population[8–10] (Table 5).

The mean AP1 diameter in the present study was 26.0±0.33 mm for the right side and 26.64±0.32 mm for the left side. Von Schroeder *et al*. (2001) presented higher values than ours,[16] whereas Coskun *et al*. (2006)[11] showed lower results. Aigbogun *et al*. (2017)[17] work revealed numbers similar to ours although his results showed significant difference between right and left antimeres. Mamatha *et al*. (2011), Akhtar *et al*. (2016) and Tiwari *et al*. (2018) also showed lower values in the Indian population[8–10] (Table 5).

The mean AP2 diameter found on our results was 18.27±0.36 mm for the right side and 18.22±0.55 mm for the left side. El-Din and Ali (2015) presented values

Table 4. Mean width (mm) ± Standard Deviation of the Maximum Length of Scapula and Maximum breadth of Scapula in different populations.

Population	Maximum Length of Scapula	Maximum breadth of Scapula
Flower and Garson (1879),[15] Europe	155.54	101.42
Von Schroeder *et al*. (2001),[16] Canada	155±16	106.9±9.7
El-Din *et al*. (2015),[12] Egypt	Right: 151.05±8.42	107.43±8.07
	Left: 151.20±9.47	107.01±9.00
Akhtar *et al*. (2016),[9] India	Right: 135.70±14.32	97.97±9.07
	Left: 134.29±14.14	97.02±0.30
Aigbogun *et al*. (2017),[17] Nigeria	Right: 144.54±11.84	-
	Left: 143.24±15.24	-
Present study	Right: 171.3±22.64	100.8±0.86
	Left: 172.6±23.68	103.5±0.90*

* This study showed statistically significant difference between sides

Table 5. Mean width (mm) ± Standard Deviation of the SI diameter and AP1 diameter.

Population	SI diameter	AP1 diameter
Von Schroeder *et al*. (2001),[16] Canada	36.4±3.6	28.6±3.3
Coskun *et al*. (2006),[11] Turkey	36.3±3	24.6±2.5
Mamatha *et al*. (2011),[8] India	Right: 33.67±2.82	23.35±2.04
	Left: 33.92±2.87	23.05±2.30
El-Din *et al*. (2015),[12] Egypt	Right: 38.88±2.63	21.33±2.06
	Left: 39.01±2.49	21.69±2.06
Akhtar *et al*. (2016,[9] India	Right: 36.03±3.15	23.367±2.53
	Left: 35.52±3.12	23.59±2.47
Aigbogun *et al*. (2017),[17] Nigeria	Right: 37.71±4.24 *	26.20±3.30 *
	Left: 36.22±3.58	24.35±3.64
Tiwari *et al*. (2018),[10] India	Right: 35.94±2.30	24.37±2.34
	Left: 35.68±2.14	24.20±2.28
Present study	Right: 36.85±0.36	26.0±0.33
	Left: 36.32±0.34	26.64±0.32

* This study showed statistically significant difference between sides

for AP2 diameter higher than those for AP1 diameter even though the latter one was supposed to be the maximum width of the glenoid cavity as described in his work.[12] Considering his mistake and assuming that the AP2 diameter values should be for AP1 diameter and vice versa, Egyptian population would have the largest glenoid cavity from the studies compared on Table 6. Moreover, Indian studies made by Mamatha *et al.* (2011)[8], Akhtar *et al.* (2016)[9] and Tiwari *et al.* (2018)[10] showed again lower values, which corroborates with Piponov *et al.* (2016) study that patients of Asian ethnicity exhibited smaller glenoid AP diameters than African-American patients.[19]

Table 6. Mean width (mm) ± Standard Deviation of the AP2 diameter.

Population	AP2 diameter
Mamatha *et al.* (2011),[8] India	Right: 16.27±2.01
	Left: 15.77±1.96
El-Din *et al.* (2015),[12] Egypt	Right: 28.31±2.38
	Left: 27.99±2.55
Akhtar *et al.* (2016),[9] India	Right: 16.30±2.16
	Left: 16±2.34
Tiwari *et al.* (2018),[10] India	Right: 16.62±2.82
	Left: 16.14±2.84
Present study	Right: 18.27±0.36
	Left: 18.22±0.55

Evaluation of the glenoid cavity size is extremely important in the context of shoulder joint surgeries as reverse shoulder arthroplasty (RSA). Important errors on selecting glenoid component can be prevented by understanding the glenoid anatomy[7] and the chance of occurring a malposition of the glenoid component is less likely if the surgeon is familiar with the glenoid morphology preoperatively.[5] Also, on some population, the baseplate used for fixation in those procedures may not fit appropriately which could culminate in a much more difficulty of inserting the component intra-operatively. Matsuki *et al.* (2019) concluded that even the smallest component available o RSA which has 25 mm of diameter is oversized for many Japanese females because the mean glenoid width is 24.4 mm.[20] Equivalently, Yang *et al.* (2018) reached that standard components are not adequate for RSA implantation in the Chinese population, especially in small female patients.[4]

Finally, the mean glenoid cavity index (GCI) found in the present study was 0.47±0.01 on the left side and 0.48±0.008 on the right side. Polguj *et al.* (2011) found higher values on Polish population[21] as well as Aigbogun *et al.* (2017) on Nigerian population.[17] Akhtar *et al.* (2016) and Tiwari *et al.* (2018) found lower values for the Indian population[9,10] (Table 7).

Table 7. Mean value of Glenoid Cavity Index (%) ± Standard Deviation.

Population	GCI (%)
Polguj *et al.* (2011),[21] Poland	72.35±5.55
Akhtar *et al.* (2016),[9] India	Right: 66.13±8.67
	Left: 66.73±7.47
Aigbogun *et al.* (2017),[17] Nigeria	Right: 69.59±5.52
	Left: 67.11±6.03
Tiwari *et al.* (2018),[10] India	Right: 66.94±6.46
	Left: 68.04±4.66
Present study	Right: 48±0.8
	Left: 47±1

Conclusion

For the first time a study describing the scapular morphometry was developed on NortheasternBrazil along with a result comparison with other similar studies around the globe.

As unique finding, the inverted comma-shaped glenoid cavity was the most frequent shape. This is important for the understanding the ethnicity role on scapular morphology variation and that Northeastern Brazillians are less propense to have shoulder lesions than people in countries like India and Germany.

Moreover, establishinga scapula quantitative measurements, especially of the glenoid cavity, may contribute tosuccessful surgical accesses, the selection of the most appropriate glenoid component, as well as the development of prostheses.

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