Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2024;42:10-14

Sexual Dimorphism by Morphometric Analysis of the Scapula In Humans: a Cross-Sectional Study

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Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT

Introduction: to evaluate sexual dimorphism in scapulae from a contemporary osteological collection belonging to Federal University of Pernambuco (UFPE - Brazil). Methods: A total of 87 scapulas of Brazilian origin were verified, 46 male and 41 female, from the Human Identification and Forensic Osteology Laboratory of UFPE, Vitória de Santo Antão Campus, aged between 17 and 103 years, representing contemporary Brazilian individuals (1919-2022). Measurements of height and width of the glenoid cavity (ACG and LCG), and length and width of the scapula (CE and LE) were taken using a digital caliper as a measuring instrument.

Results: the mean values (in millimeters) of the scapular measurements were significantly higher in the population of male individuals (M) than in the female population (F): LE – M 150.16 ± 11.58, LE – F 134.07 ± 10.47, CE – M 104.48 ± 6.61, CE – F 93.08 ± 6.89, LCG – M 37.61 ± 2.68, LCG – F 32.87 ± 2.19, ACG – M 27.05 ± 2.66 and ACG – F 23.19 ± 1.76.

Conclusion: the data presented in the present study reveal that the human scapula can be a bone used for the analysis of sexual dimorphism.

Keywords: Forensic anthropology; Sexual dimorphism; Scapula.

Introduction

Forensic anthropology assists with the identification (i.e., estimation of sex, age at death, stature, ancestry) of skeletal remains within a medico-legal context and mass disasters[1]. Identification of human remains is a prime issue in cases of mass disasters, explosions, and assault cases where the body is dismembered to conceal the identity of the victim. The estimation of sex is important in the forensic identification of human remains. Accurate sexing of the remains primarily narrows down the pool of possible victim matches[2].

Among the methods used to analyze sexual dimorphism through bones, morphometric evaluation of the skull and pelvis is widely used in forensic identification due to its high accuracy[3]. Furthermore, the literature has highlighted the relevance of studying bones belonging to the appendicular skeleton (upper and lower limbs) to analyze sexual dimorphism, as evidenced in recent research[4,5,6].

The scapula plays a critical role in the function of the shoulder complex, serving as a junction between the trunk and forelimb and providing attachment sites for the robust musculature spanning the thorax, humerus, and forearm[7]. It is a flat and triangular bone located posterolaterally in the thorax region, extending from the 2nd to the 7th rib. This bone forms the girdle of the upper limb and plays a fundamental role in the structure of the shoulder, providing support for the movements of the upper limb through the glenohumeral joint[8]. In addition, it serves as an attachment point for the thoracoappendicular muscles, connecting indirectly to the ribs through the functional scapulothoracic

DOI: 10.51929/jms.42.102025
ISSN 2177-0298

joint. The scapula has three margins: medial, lateral and superior. The medial margin is thinner compared to the lateral one, while the superior margin is the thinnest and shortest of the three. It also has three angles: superior, inferior and lateral, the latter being interrupted by the glenoid cavity. These angles serve as references for morphometric measurements. Its two faces are the anterior, also called costal; and the posterior, which contains the spine of the scapula. The glenoid cavity, located on the lateral margin, accommodates the head of the humerus and forms the glenohumeral joint, also known as the shoulder joint. This cavity is a shallow, concave fossa[9]. The bony features of the scapula allow the identification of sexual dimorphism through specific measurements.

Although several studies in the literature show sexual dimorphism in bones of the skull and pelvis, few studies show sexual dimorphism in bones of the axial skeleton. Therefore, the present study aimed to evaluate sexual dimorphism in scapulae from a contemporary osteological collection belonging to the Academic Center of Vitória de Santo Antão, Federal University of Pernambuco (CAV—UFPE).

Methods

This research utilized 87 individuals (46 males and 41 females) from the Federal University of Pernambuco skeletal collection housed at the Laboratory of Human Identification and Forensic Osteology, Academic Center of Vitória de Santo Antão - CAV/UFPE, between November 2024 and February 2025. The collection consists of 168 (89 males and 79 females) documented skeletons, i.e. sex, age at death, occupation, and cause of death. The individuals used for this project ranged in age from 17 to 103 years old. The collection consists of individuals who donated their bodies for research and teaching purposes. This collection represents a contemporary Brazilian population as all of the individuals lived the majority of their life during the twentieth century; all individuals used in this study were born between 1919 and 2002 and died between 2006 and 2023.

Two independent researchers followed the protocol of Peckmann, Meek, and Mahakkanukrauh (2017)[1] to measure the length (LE) and breadth (BE) of the left scapula and the protocol of Prescher and Klumpen (1995)[10] to measure the length (LGC) and breadth (BGC) of the left glenoid cavity as shown in Figures 1 and 2.

1- LE: Scapular Length (distance from the superior angle to the inferior angle);

2- BE: Scapular Breadth (measurement taken from the central point of the triangular region of the spine of the scapula to the margin of the glenoid cavity, at the height of the center of the scapula);

3- BGC: Glenoid Cavity Breadth (maximum distance between the most superior and the most inferior point of the glenoid cavity);

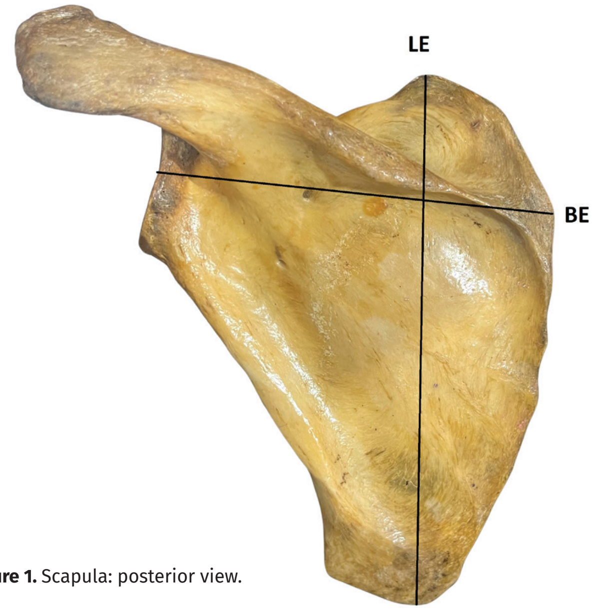

Figure 1. Scapula: posterior view.

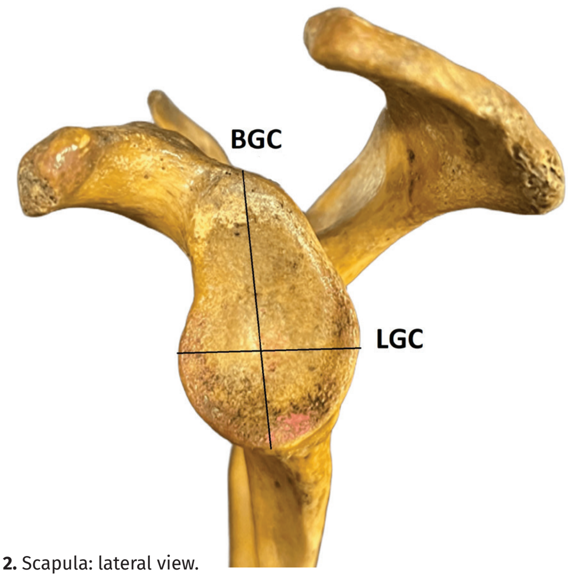

Figure 2. Scapula: lateral view.

4- LGC: Glenoid Cavity Length (maximum distance in the anteroposterior direction of the glenoid cavity).

Measurements were recorded using a digital caliper (Eccofer®) with a capacity of 150 mm and an accuracy of up to 0.02 mm. Therefore, only the left scapula was measured. In cases where the left scapula exhibited trauma, damage, pathological changes, or was absent, measurements were taken from the right scapula instead.

The statistical software RStudio (version 2024.12.0+467) was used to calculate the intraclass correlation coefficient (ICC) to assess the reliability of measurements performed by the two evaluators. The ICC ranges from 0 to 1, indicating poor reliability when below 0.5. When the ICC value falls between 0.5 and 0.75, reliability is considered moderate. An ICC between 0.75 and 0.90 indicates good reliability, while a value above 0.90 denotes excellent reliability[11]. For the comparison of male and female scapular measurements, the normality of the variables' data distribution was confirmed by the Shapiro-Wilk test. Given the parametric data, the t-test was used to identify potential differences in the evaluated morphometric parameters. Furthermore, using the confidence interval calculator provided by the PEDro Database, the mean difference (along with its corresponding 95% confidence interval – 95% CI) was calculated for each measurement between male and female scapulae to quantify the observed differences.

Results

Considering a total of 356 morphometric measurements conducted by the two researchers, the ICC was 0.98. Regarding the analyzed morphometric parameters, all exhibited sex differences (Table 1). The scapular measurement values were significantly higher in the male population, as indicated in Table 2.

Discussion

The present study revealed a statistically significant difference in the results between the sexes, indicating that the male scapula has larger measurements than the female scapula in the analyzed population. More specifically, men have an LE approximately 16.09 mm greater than that of women (95% CI: 11.36 to 20.82) and a CE approximately 11.4 mm greater (95% CI: 8.52 to 14.28). LGC and BGC were also significantly larger in men compared to women, with LGC being approximately 4.74 mm greater (95% CI: 3.69 to 5.79) and BGC approximately 3.86 mm greater (95% CI: 2.89 to 4.83). Differences between the sexes in growth and development patterns result in variations in the size and shape of male and female bones. On average, men possess larger bones than women and bone features tend to be more pronounced and noticeable in males than females. These anatomical characteristics are more delicate and less prominent in women, with smaller joint ends and less pronounced muscle insertions[3].

Our results align with previous studies that examined the scapula as a potential indicator of sexual dimorphism in various populations using similar morphometric evaluations. Through an archaeological investigation, Özer, Sağir, and Güleç (2006)[12] studied sexual dimorphism in scapulas from an excavation site in Anatolia, Turkey, using the same variables utilized in the current study. The analysis achieved an accuracy score of 95% indicating that these variables are effective for discriminative purposes.

The Hamann-Todd collection (USA) was first utilized in a study by Dwight (1894)[13], a pioneer in researching sexual dimorphism in the scapula. Dabbs (2010)[14] examined 724 left scapulas from this collection, which included 194 black males, 169 black females, 302 white males, and 139 white females, aged between 19 and 93 years, who lived during the late 19th and early 20th centuries. When assessing 23 variables, the model based on five variables was found to be the most accurate, achieving an average accuracy rate of 95.7% across all groups. The five variables examined were the maximum length of the scapular spine, maximum scapular length, height of the glenoid prominence, lateral curvature, and thickness of the lateral border. Among these variables, our findings support their data, revealing significant differences between the sexes in the measurements of the scapula's maximum length and the height of the glenoid cavity.

Koukiasa, Eliopoulos, and Manolis (2017)[15] investigated the metric patterns of the scapula and clavicle in a modern osteological collection from a Greek population. However, the authors noted that

Table 1. Statistical analysis of sexual dimorphism.

Measurement	n	Test	p-value*
BE male x BE female	46/41	*t*-test	<0.01
LE male x LE female	46/41	*t*-test	<0.01
LGC male x LGC female	46/41	*t*-test	<0.01
BGC male x BGC female	46/41	*t*-test	<0.01

*p>0.05

Table 2. Descriptive statistics of the population analyzed.

Variable	n	Mean (mm)	Standard Deviation (SD)	Minimum (mm)	Maximum (mm)	Mean Difference (IC95%)
BE						
Male	46	150.16	11.58	124.01	176.5	16.09
Female	41	134.07	10.47	116.1	153.1	(11.36 to 20.82)
LE						
Male	46	104.48	6.61	87.5	118.01	11.4
Female	41	93.08	6.89	86.1	104.5	(8.52 to 14.28)
LGC						
Male	46	37.61	2.68	31.5	43.5	4.74
Female	41	32.87	2.19	28.1	37.0	(3.69 to 5.79)
BGC						
Male	46	27.05	2.66	21.5	33.5	3.86
Female	41	23.19	1.76	20.0	28.1	(2.89 to 4.83)

certain scapula regions, such as the glenoid cavity, are typically found intact, even in archaeological remains. A total of 197 bones were analyzed—107 male and 90 female—from which seven measurements were taken: maximum scapular height, maximum scapular width, glenoid cavity height, glenoid cavity width, maximum clavicle length, anterior clavicular diameter, and superior clavicular diameter. The results revealed significant differences between sexes, with accuracy ranging from 84.9% to 91.4%, and the highest accuracy rate was achieved using measurements from the left scapula. Although no clear difference was observed between left and right bones regarding sexual dimorphism, left bones demonstrated considerably higher scores in correct sex estimation than right bones in this study. Our measurements indicated that left scapulae are reliable indicators of sexual dimorphism in the analyzed population.

Other evaluation methods were explored, such as in the study by Zhang *et al.* (2016)[16], which conducted a study in China using computed tomography for 3D analysis of 414 individuals (190 women and 224 men aged between 24 and 74). Bilateral scapular parameters were analyzed: morphological width, morphological length, longitudinal length, maximum longitudinal length, transverse length and axillary margin length. The results showed that there was an accuracy of 85.5% to 86.87% in predicting sex using the analyzed parameters.

In southern Spain, Rosales-Rosales *et al.* (2019)[17] performed a bilateral evaluation of the size of the glenoid cavity, considering its height and width. They analyzed 154 individuals using computed tomography (CT) and 3D imaging too, consisting of 106 women and 48 men. The results showed statistically significant differences between the sexes. The mean length of the glenoid cavity was 30.78±2.96 mm for men and 27.87±2.10 mm for women. Likewise, the mean width varied significantly, measuring 22.31±2.32 mm in men and 19.34±1.91 mm in women.

Lee, Lawrence, and Rainbow (2024)[7] conducted a study in the USA to investigate sexual dimorphism in scapular shape and examine the role of static allometry in the relationship between size and shape according to sex. The results indicated that scapular size increases proportionally to body height in both males and females. However, males tend to have larger scapulas for bodies of the same height. In addition, large female scapulas tend to be shorter in the superoinferior direction and broader in the mediolateral direction, with smaller glenoid cavities and flatter acromions, resulting in a reduced subacromial space. On the other hand, the average male scapula had greater superoinferior height, a larger and more retroverted glenoid, and a wider acromion and supraspinatus fossa compared to the average female scapula.

The present study supports previous research indicating that male averages were greater than those of females according to Table 2. Scapular measurements were also greater in the male group compared to the female group. Ülkir *et al.* (2023)[18] concluded that the mean values for scapular width and maximum scapular length were higher in men (106.79±6.26 | 159.13±12.20) than in women (96.38±6.28 | 141.71±9.43), which aligns with the findings of the present study (Male LE: 150.16±11.58, CE: 104.48±6.61 | Female LE: 134.07±10.47, CE: 93.08±6.89). When comparing this study's results with previous studies, it is evident that there are differences in the means across various populations.

Given that miscegenation in Brazil is prevalent, the country does not exhibit well-defined ethnic and racial patterns. Therefore, the morphometric patterns of European populations, for instance, do not apply to identifying individuals within the Brazilian population. This underscores the necessity of developing a specific standard tailored to the characteristics of this population, as demonstrated in our study. In Brazil, Costa *et al.* (2016)[19] analyzed eight scapular parameters through morphometric evaluation and concluded that the average measurements obtained were significantly higher in the male population. Similar to our study, among the eight parameters used, the measurements of the width and length of the scapula presented values very close to our study.

Some studies have also suggested creating formulas based on the variations observed to achieve accuracy rates in specific populations, including those reported by, Papaioannou *et al.* (2012)[20], Giurazza (2013)[21], Kharuhadetch *et al.* (2022)[22], and Hudson and Langdon (2023)[23]. Constructing these formulas as well as the bone morphometric analysis itself is vital to ensure reliability in forensic analysis; however, it is essential to highlight that, on average, bone turnover occurs at a rate of 10% per year. As a result, most skeletons of adult humans are typically no older than 10 years[24]. Therefore, in Forensic Anthropology, it should be recognized that the analysis of skeletons primarily reflects conditions from the past decade, except for traumatic and pathological cases.

Limitations

Some limitations were noted in this study, such as the small number of available scapulas and the inability to establish a linear regression capable of predicting sex from these measurements of human scapulas.

Conclusion

The data presented in this study reveal that the human scapula can be a bone used for analyses of sexual dimorphism. Corroborating previous data from the scientific literature, the analyses performed on male scapulas showed higher morphometric measurements than those of female scapulas.

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Received: March 10, 20245
Accepted: April 4, 2025

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