ANATOMICAL STUDY OF SEPTAL APERTURE IN HUMAN HUMERUS IN A POPULATION FROM SOUTHWEST REGION OF BRAZIL

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ABSTRACT

Aim: To evaluate the influence of septal aperture (SA) according to sex and side of human skeletons in a sample of the Brazilian population. **Methodology:** 103 dried human humeri of both sexes (65 male and 24 female) were used, aged between 18 and 80 years. The morphometry of the SA dimensions was carried out, including the measurement of horizontal diameter and vertical diameter, using a digital caliper. Statistical analysis was performed, considering a significance level of 5%. The ANOVA test (unpaired) was performed to verify whether there was a difference between the sexes (male and female) on each side (right and left). For multiple comparisons, the Tukey test was used. When a normal distribution of data was not found, the Kruskal-Wallis test was performed to evaluate whether there was a difference between the sexes (male and female) on each side (right and left). In this case, for multiple comparisons, the Dunn test was used. **Results:** From 103 bones, the SA appeared in 18 bones, regardless of sex and side, resulting in a total incidence of 17.4%. In the general sample, the incidence of SA was 12.6% for males and 4.85% for females. When considering the side, the left side had a higher incidence than the right side, presenting 9.7% and 7.7% respectively. The most common morphological aspect was Oval on both sides and in both sexes. There were no statistical differences regarding morphometry, considering sex and side. **Conclusion:** SA is more common in males, on the left side and with an oval morphology in a population from southeastern Brazil.

Keywords: anatomy; septal aperture; morphology; clinical practice.

1. INTRODUCTION

The human humerus has at its distal end two depressions in the elbow joint, the coronoid fossa (anteriorly) and the olecranon fossa (posteriorly). Such depressions characterize the attachment sites of the coronoid process and the olecranon, both bony projections of the ulna [1]. Due to the proximity of the fossae, the region is characterized by forming a thin bone septum. The bone septum formed by the two fossae may be perforated, resulting in an anatomical variation called septal aperture (SA) [2,3], also known as supratrochlear foramen [1,4].

The first description of SA was done by Meckel et al. [5] and based on this description other studies were carried out to describe this structure in different animals [6]. Studies applied to the understanding of SA, thus, sparked a discussion both from an anthropological [7] and medical point of view [8-10].

Although the SA has been associated with a common condition in different populations [4], its etiology is not fully defined. Different factors have been related to the emergence of SA, such as hereditary factors or diseases such as osteoarthritis and osteoporosis. Furthermore, some authors have identified genes as factors in the formation of SA, such as T-box genes, which control the synthesis of crucial proteins for limb development. Disturbances in calcium metabolism and bone development have also been suggested as possible additional genetically based factors in the formation of SA [10].

Myszka et al. [2] suggests that SA can be caused by mechanical factors. In this context, the SA would be result of muscle and/or ligament laxity, that is, weaker muscles lead to greater joint laxity and impact of the ulnar processes on the humeral plate. If this explanation is correct, it may be possible to predict that individuals with weaker muscles and less pronounced muscle markers have a greater chance of developing SA.According to these same authors [2], among the muscle groups responsible for flexion and extension of the forearm, two (brachialis muscle and triceps brachii) seem to be the most important. The brachialis is the general flexor and the triceps brachii is the primary elbow extensor. If the mechanical theory is proven, it can be suggested that the muscles are weaker and, consequently, there is a less developed tuberosity of the ulna, a structure to which part of the brachialis is attached. A similar mechanism should also be observed in the olecranon of the ulna, which is the insertion site of the triceps brachii. Furthermore, given the dominance of the right hand, it can be expected that the dominant arm, with more developed muscles, is less prone to SA formation.On the other hand, a robusticity hypothesis was described, considering that the appearance of AS should be higher in females and on the left side (considered a non-dominant side) [11]. This idea was suggested based on associations between the presence of SA and robusticity measures [12].

Considering the variability in the incidence of SA between populations, the hypothesis of the present study is that the incidence of SA varies according to sex and side in a sample from southwest region of Brazilian population.

The aim of the present study was to evaluate the incidence of SA according to sex and side of human skeletons in a sample of the Brazilian population.

2. METHODOLOGY

2.1 Study design

This is a descriptive and cross-sectional observational study.

2.2 Sample

The sample consisted of 54 dry human bones, aged between 18 and 80 years, with the number of humerus bones in each bone corresponding to 50 bones on the right side and 53 bones on the left side, making up a total of 103 dry human humerus bones. Furthermore, the sample was composed according to sex, comprising a total of 65 male bones and 24 female bones. The bones that were evaluated belong to the Biobank “Bones, teeth and human cadavers” at the “Faculdade de Odontologia de Piracicaba (FOP)” at the “UniversidadeEstadual de Campinas (UNICAMP)”.The humerus bones belong to skeletons from individuals who died between 2008 and 2010, that were exhumed between 2013 and 2014. and were identified by death certificates.

2.3 Inclusion and exclusion criteria

The inclusion criteria wereused intact human humeri, and which did not present macroscopic deformities, fractures or any other pathological or surgical alterations.

The exclusion criteria were excluded human humeri from syndromic individuals or those with any anatomical abnormalities in the region of interest, as well as individuals with implants, plates and screws or any other metallic artifact close to the region.

2.4 Qualitative analysis of humeral septal aperture

The qualitative analysis was evaluated by the percentage of presence of SA in the total sample, in relation to sex and in relation to side (Figure 1). Furthermore, the presence was evaluated according to the morphological aspect, being classified as: Circular, Oval or Irregular.

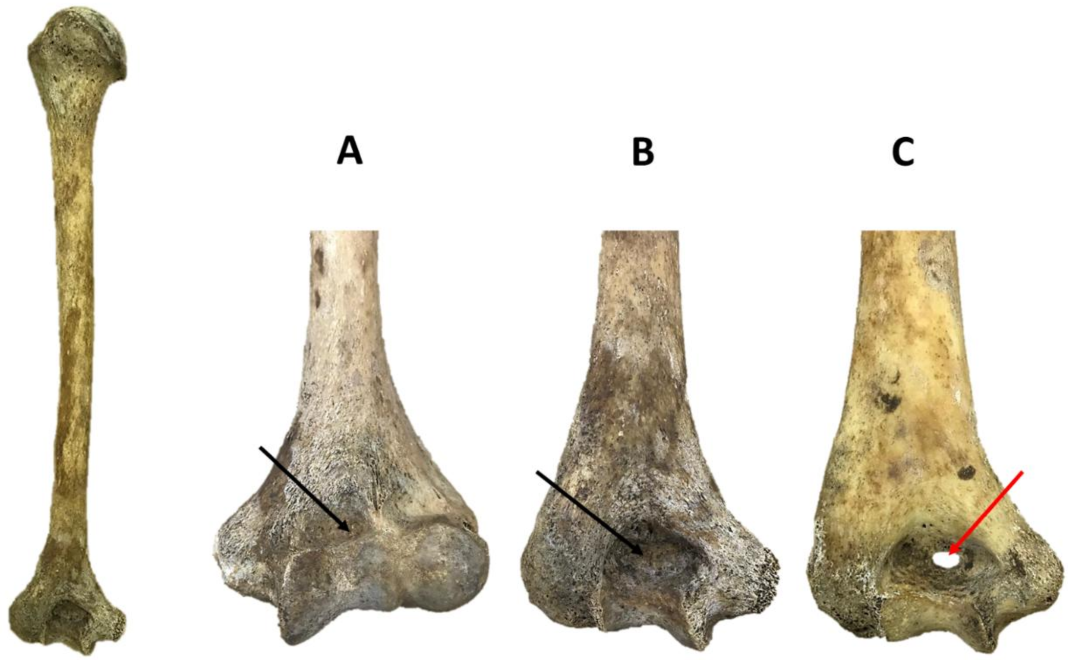

Fig 1. Dry human humerus bone highlighting the distal epiphysis in anterior view (A) and posterior view (B). In A, the black arrow indicates the coronoid fossa. In B, the black arrow indicates the olecranon fossa. In C, the presence of the SA indicated by the red arrow, can be seen in a posterior view of the distal epiphysis of the humerus.

2.5 Quantitative analysis of humeral SA

SA were measured by morphometric analysis using a Mitutoyo® digital caliper (Mitutoyo Sul Americana Ltda, Suzano, Brazil) in the following dimensions:

- Horizontal diameter (medio-lateral distance);

- Vertical diameter (proximo-distal distance).

The values obtained in this analysis were tabulated and statistically analyzed.

2.6 Statistical analysis

The incidence analysis (in percentage - %) of all data obtained was carried out. Descriptive statistical analysis was performed. For the measurements obtained, both vertically and horizontally, the distribution of the data was checked (normality test). When a normal distribution of data was found, the unpaired ANOVA test was performed to check whether there was a difference between the sexes (male and female) on each side (right and left). For multiple comparisons, the Tukey test was used. When a normal distribution of data was not found, the unpaired Kruskal-Wallis test was performed to check whether there was a difference between the sexes (male and female) on each side (right and left). In this case, for multiple comparisons, the Dunn test was used. The significance level was considered $P< .05$. All data were analyzed using GraphPAD Prism v.8 software (San Diego, CA, USA).

3. RESULTS

3.1 Incidence of SA

According to the general sample, in 103 bones evaluated, 18 bones presented SA (Figure 3), regardless of sex and side, resulting in a total incidence of 17.4%. In the general sample, the incidence of SA for males was 12.6% and for females it was 4.8%. When considering the side, the left side had a higher incidence than the right side, being 9.7% and 7.7% respectively.

The incidences of SA types were obtained in relation to side (Figure 2) and in relation to sex (Figure 3), separately, and the incidence was analyzed in relation to both sex and side (Figure 4).

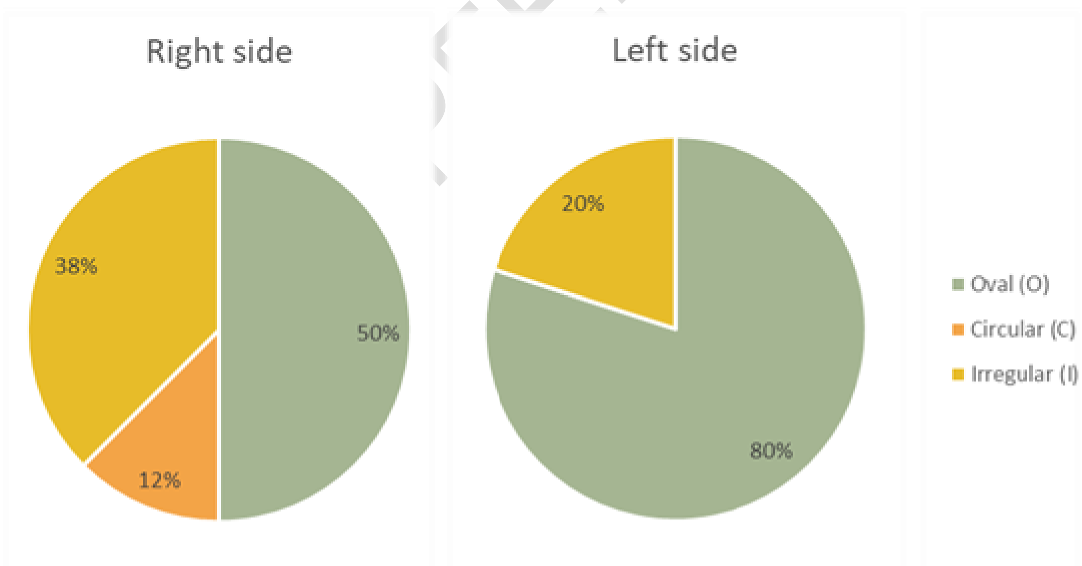

Fig 2. Incidence (in %) of types of SA on each side. There was no circular type incidence (C) on the left side. O: oval type, C: circular type, I: irregular type.

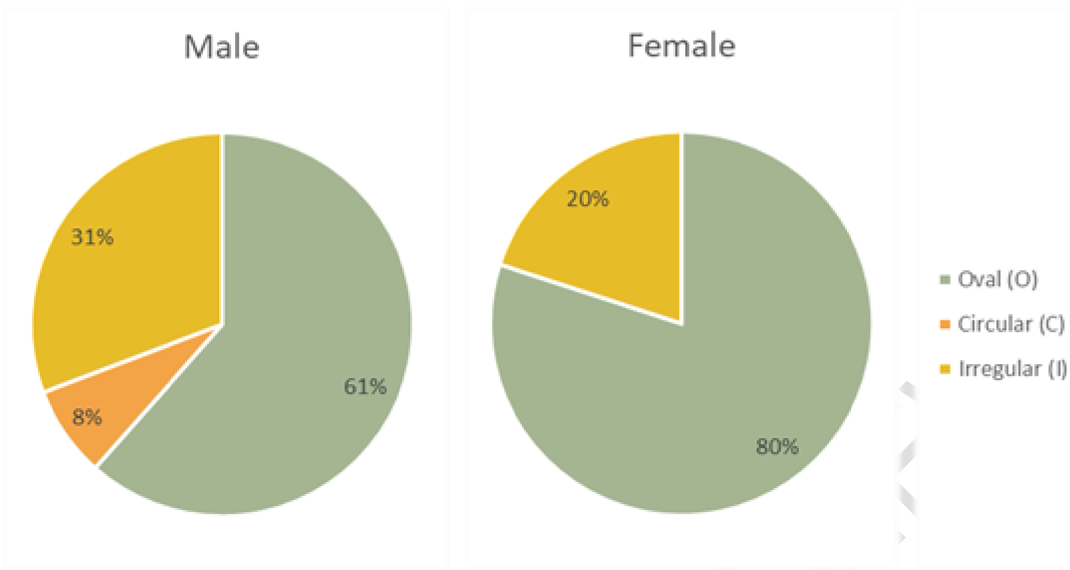

Fig 3. Incidence (%) of types of SA in each sex. There was no incidence of the circular type (C) in females. O: oval type, C: circular type, I: irregular type.

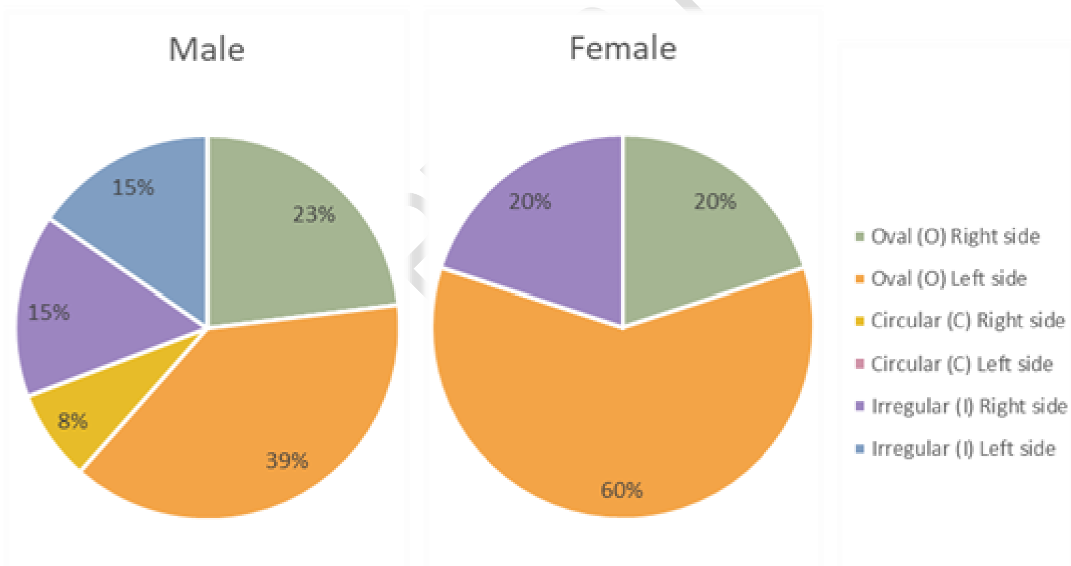

Fig 4. Incidence of types of SA in each sex and on each side. There was no incidence of the circular type (C) in females and on the left side of males and of the irregular type (I) in females on the left side. O: oval type, C: circular type, I: irregular type.

After measuring the vertical and horizontal length on both sides, the morphology of each SA was analyzed and classified according to the geometric shape it resembles (Oval, Circular and Irregular).

3.2 Vertical diameter

For the analyzed vertical diameter data, the normality test (Shapiro-Wilk test with alpha=0.05) showed normal distribution (Left Female: *P* = .4506; Right Female: *P* =.5928; Left Male: *P* =.5266; Male Right: *P* = .6983).

In female sex, the mean vertical diameter was 4.153mm (SD: 1.048) on the left side and 1.270mm (SD: 0.08185) on the right side. In males, the mean vertical diameter was 3.544mm (SD: 1.820) on the left side and 3.9530mm (SD: 1.677) on the right side (Table 1).

When comparing the sexes and sides of each sex, the unpaired ANOVA test did not detect a statistically significant difference (*P* = .1053). For multiple comparisons using the Tukey test, there were no statistically significant differences between the sexes on the same side (Left Female vs. Left Male: *P* =.9408; Right Female vs. Right Male: *P* = .0995), nor between the sexes on different sides (Right Female vs. Left Male: *P* =.1913; Left Female vs. Right Male: *P* = .9976), nor between the sides of the same sex (Left Female vs. Right Female: *P* = .1487; Left Male vs. Right Male: *P* = .9602) (Figure 5).

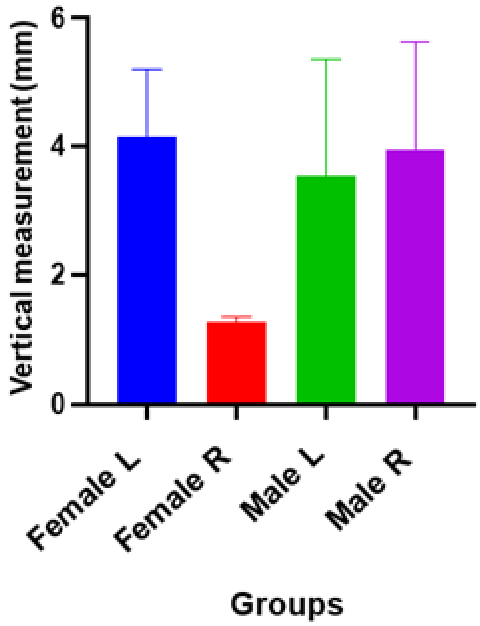

Fig 5. Vertical measurement (vertical diameter) when comparing sexes and sides (L: left side; R: right side).

3.3 Horizontal diameter

For the analyzed horizontal diameter data, the normality test (Shapiro-Wilk test with alpha=0.05) showed normal distribution only for some groups (Left Female: *P* = 0.7242; Right Female: *P*> .9999; Male Left: *P* = .3109). For one of the groups, the distribution was not normal (Right Male: *P* = .0078).

In female sex, the mean horizontal diameter was 4.737mm (SD: 2.688) on the left side and 0.9000mm (SD: 0.05000) on the right side. In males, the mean horizontal diameter was 4.965mm (SD: 2.079) on the left side and 4.523mm (SD: 2.453) on the right side (Table 1).

When comparing the sexes and sides of each sex, the Kruskal-Wallis test detected a statistically significant difference (*P* =.0494). For multiple comparisons using Dunn's test, there were no statistically significant differences between the sexes on the same side (Left Female vs. Left Male: *P* > .9999; Right Female vs. Right Male: *P* =.1460), and not between the sexes on different sides (Right Female vs. Left Male: *P* = .0711; Left Female vs. Right Male: *P* >.9999), and not between the sides on the same sex (Left Female vs. Female Right: *P* =.2337; Male Left vs. Male Right: *P* > .9999) (Figure 6).

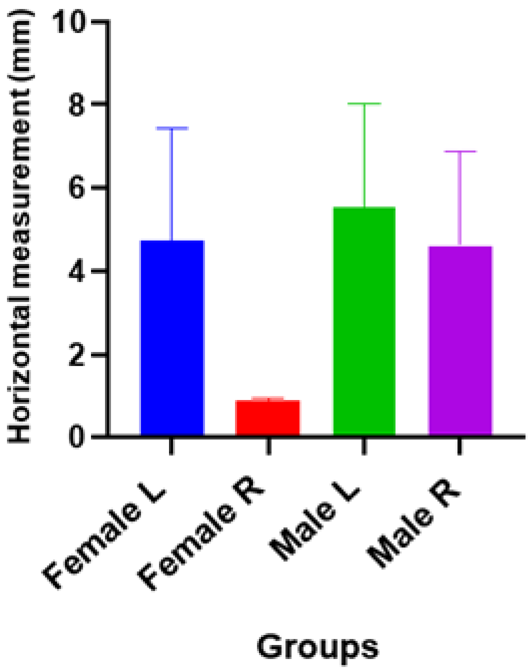

Fig 6. Horizontal measurement (horizontal diameter) when comparing sexes and sides (L: left side; R: right side).

Table 1. Mean, standard deviation (SD), median, percentiles of measurements obtained (mm) for each sex and side (R = right; L = left).

Measurement	Mean R side (SD)	Mean L side (SD)	Median R side	Median L side	Percentil (25%) R side	Percentil (25%) L side	Percentil (75%) R side	Percentil (75%) L side
Vertical								
Female	1.270 (0.08185)	4.153 (1.048)	1.250	3.810	1.200	3.320	1.360	5.330
Male	3.9530 (1.677)	3.544 (1.820)	4.000	2.930	2.010	1.670	5.320	5.140
Horizontal								
Female	0.9000 (0.05000)	4.737 (2.688)	0.9000	4.290	0.8500	2.300	0.9500	7.620
Male	4.523 (2.453)	4.965 (2.079)	5.930	4.335	1.410	3.225	6.220	7.330

4. DISCUSSION

The appearance of SA has been the subject of studies in which the approach involved different populations [3]. The incidences are variable, which proposes the idea that there may be different theories for the appearance of this anatomical variation. One of them is genetic, associated with the development of the elbow joint [13] and the other is biomechanical, associated with effort on the joint [2, 14].

From a genetic point of view, there is an association between the appearance of the septal aperture with a gene from the TBX family, which plays a role in the production of T-box proteins, which are fundamental in the development of limbs [13]. Furthermore, surgical experiences reporting the presence of a septal aperture have been associated with a medullary cavity with less space in the joint [9]. In this way, one can associate the idea that a variation in the development of the joint can result in the appearance of septal aperture.

The biomechanical theory is related to kinesiological characteristics, associated with greater effort in elbow joint movements [14]. Recently, Myszka et al. [2] carried out a morphometric study that correlated the anatomical characteristics of the septal aperture with structures where muscle insertions occur. In this study, the relationship between the presence of septal aperture and the morphological aspect of the olecranon, related to the triceps brachii muscle, and the radial tuberosity, related to the brachialis muscle, was evaluated. These authors concluded that hyperextension of the elbow associated with weakness of the triceps brachii muscle results in the appearance of septal aperture. The same does not occur when relating to the brachialis muscle, since the data correlating the morphological characteristics of the ulna tuberosity with the septal aperture were not statistically significant.

The total incidence in different populations is variable. There are populations with higher incidences, as in studies by Macalister [15], who found an incidence of 57.2% in a Libyan population; Hrdlička [11], who found a 46.5% incidence in an Australian population; and in the study by Myszka et al., [2], which found an incidence of 44% in the Polish population. The studies by Macalister, Hrdlička and Myszka et al. obtained their results from a sample of 682,13 and 180 humerus bones, respectively. Other studies showed lower incidences, such as the studies by Papaloucas et al., [16], Benfer and McKern [12] and Glanville [14], which observed, respectively, incidences of 0.304%, 6.9% and 6.1 % in Greek, American (USA) and Dutch populations. Such studies evaluated a total number of 656 [16], 63 [12] and 170 [14]. In Brazil, the previous study by Chagas et al., [3] found an incidence of 22.5% in 330 humerus bones in a population from Rio de Janeiro. The present study analyzed 103 bones, finding an incidence of 17.47%. The differences found may be associated with the quantity of bones in the sample, however, the studies make it possible to demonstrate that populations present differences in the onset of septal aperture. These studies argue that the appearance of septal aperture is associated with different theories already proposed, such as genetic changes, bone and joint pathologies such as osteoporosis and rheumatoid arthritis. However, the mechanical theory seems to be the one that best explains the appearance of septal aperture [16]. In fact, studies have presented samples from populations from older times, such as the study by Myszka et al. [2], which evaluated bones from the 11th to 12th centuries and Glanville [14] who evaluated bones from the medieval era, whose periods suggest greater mechanical strain compared to modern populations. This idea was proposed by Hirsh [17] who states that adaptations for more modern populations suggest changes in the habitual movements of the joint.

The results in the present study show that there is a higher incidence of septal aperture on the left side and this data corroborates with other studies [3, 4, 9, 14, 16, 18]. However, some studies have shown a higher incidence on the right side [8] or similar incidences between sides [6, 19]. The literature is not clear when considering the incidence of individuals who have the right or left limb as dominant side. However, studies suggest the left side as the normally non-dominant side since the bones of the right upper limb have more robust structures, which indicates a frequentright limb use [17]. Recently, the study by Myszka et al. [2] evaluated the morphological characteristics of the olecranon and the ulna tuberosity, areas of insertion of the triceps brachii and brachii muscles, respectively, and presented results that, even with a smaller difference, the structures are more robust on the right side. Additionally, the recent study by Baker et al., [3] presented in its data a novel assessment of AS associated with limb dominance. The authors found significant differences such as a high percentage of unilateral incidence on the non-dominant side. This novel assessment was important to favor the robusticity hypothesis over the mechanical hypothesis and brings a new tool to the debate on the presence of SA. In this present study, which used a sample from Brazil, the sample does not have information about limb dominance, therefore future studies are necessary using this novel assessment.

In relation to sex, this present study found a higher incidence in males, the result of which is not in line with what is presented in the literature. Studies that evaluated gender showed that septal aperture is more common in females [2, 9, 20]. This difference may be associated with the quantity of bones in the sample, since these studies evaluated more balanced samples in relation to the quantity of bones for each sex. In the present study, the sample had a greater number of male individuals. The association of a higher incidence of septal aperture in females may be associated with a higher incidence of bone pathologies such as osteoporosis and joint pathologies such as rheumatoid arthritis as one of the theories for the appearance of septal aperture.

The SA morphometry showed different mean values when comparing the vertical diameter with the horizontal diameter. This characteristic occurs on both the right and left sides, as well as in males and females. Variations in measurements between diameters explain the higher incidence of oval-shaped septal aperture, regardless of side and sex. Other shapes were observed, with the irregular shape having a higher incidence in relation to the circular shape. The circular shape was not found in females. The study by Mathew et al., [4] also found the oval shape to have a higher incidence compared to other shapes. These authors reported the circular shape as the second most frequent. However, these authors did not include the irregular shape, but rather other shapes such as triangular, rectangular, among others. If the different forms considered by these authors are added together, considering irregular forms, this morphology appears as the second highest incidence, thus corroborating the present study. The shape of the septal aperture may be associated with the shape of the apex of the olecranon, a structure which exerts greater pressure on the septum formed by the bottom of the olecranon fossa and the coronoid fossa, altering the blood flow in this region [17].

Medical imaging assessments in the ulnar region can generate interpretation problems, such as false positives for cysts and other lesions in the bone structure [21]. Furthermore, based on biomechanical theories associated with the appearance of septal aperture, this idea is of interest to physiotherapists, since the influence on kinesiological characteristics related to elbow mobility can generate new ideas in clinical practice and research.

5. CONCLUSION

This study concludes that the incidence of SA is low in a population from southeastern Braziland, following the hypothesis of the study, the incidence of SA varies according to the side and sex. The SA is more frequent on the left side, in males, and presenting, for the most part, in an oval shape. The dimensions of the septal aperture were not influenced by side or sex.

The knowledge of the morphological characteristics of SA is fundamental for clinical approaches involving medical professionals working in the diagnosis and treatment of joint problems.

ETHICAL APPROVAL

The present study was previously approved by the Research Ethics Committee of FaculdadesIntegradas Einstein de Limeira, registered on the National Research Council (CONEP) platform under CAAE process number 69535723.0.0000.5424.

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