Measurement of Clavicular Symmetry in Healthy Subjects Using Tomographic Database of Public Hospitals*

Mensuração de simetria clavicular em indivíduos saudáveis utilizando-se de banco de dados tomográficos de hospitais públicos

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Abstract

Objective This study aimed to perform an imaging evaluation to prove the existence or not of symmetry between the clavicles of healthy subjects from Curitiba, Paraná, Brazil, and identify potential factors influencing the clavicular length.

Method The study analyzed chest computed tomography (CT) scans of 211 patients with no clavicular fracture or malformations (100 women and 111 men). We measured the greatest clavicular diagonal on both sides, and the software automatically generated the maximum distance in millimeters. Relative and absolute frequencies described qualitative variables and mean values; quantitative variables used a 95% confidence interval. Value comparisons employed the student's t-test, and correlations determinations used Pearson's correlation coefficient. The significance level adopted was 5%.

Results There was a significant difference between the clavicular length (right clavicle, 143.58 mm; left clavicle, 145.72 mm; $p = 0.037$), indicating asymmetry. On average, the left clavicle was 3.71 mm larger. Asymmetry was significant for both men

Keywords
- anatomy, regional
- anthropometry
- clavicle
- tomography

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and women ($p < 0.001$). The average difference was 4.13 mm for men and 3.23 mm for women. Seventy-three percent of the sample had < 5 mm of asymmetry, 23.7% had 5 to 10 mm, and 3.3% had > 10 mm of asymmetry.

Conclusion The studied population did not present clavicular symmetry. On average, the left clavicle was longer than the right clavicle, with differences of 3.71 mm in the general sample, 3.23 mm in women, and 4.13 mm in men. The only significant factor was gender since men presented longer clavicles and higher differences than women.

Resumo

Objetivo Realizar avaliação imagiológica com intuito de comprovar a existência ou não de simetria entre as clavículas de indivíduos saudáveis da cidade de Curitiba/PR, aliada à identificação de possíveis fatores de influência no comprimento clavicular.

Método Foram analisadas tomografias computadorizadas de tórax de 211 pacientes sem fratura ou malformações na clavícula (100 mulheres e 111 homens). A maior diagonal clavicular foi medida em ambos os lados e o software gerou automaticamente a máxima distância em milímetros. Foram utilizadas frequências relativas e absolutas para descrever variáveis qualitativas e a média e intervalo de 95% de confiança para as quantitativas. As comparações foram feitas com o teste t de Student e correlações calculadas pelo coeficiente de correlação de Pearson. O nível de significância adotado foi de 5%.

Resultados Verificou-se diferença significativa entre o comprimento das clavículas (direita 143.58mm e esquerda 145.72mm, $p = 0.037$), indicando assimetria. Em média, o lado esquerdo é 3.71mm maior. A assimetria foi significativa tanto para homens quanto para mulheres ($p < 0.001$). A diferença média foi de 4.13mm para homens e 3.23mm para mulheres. 73% da amostra apresentou <5mm de diferença, enquanto 23.7% apresentaram 5-10mm e 3.3% apresentou >10mm de assimetria.

Conclusão Não foi possível encontrar simetria nas clavículas da população de Curitiba/PR. Em média, a clavícula esquerda é maior que a direita, com diferenças de 3.71mm na amostra geral, 3.23mm para mulheres e 4.13mm para homens. O único fator significativo foi o sexo, com homens tendo maiores comprimentos claviculares e maiores diferenças em comparação às mulheres.

Palavras-chave
- anatomia regional
- antropometria
- clavícula
- tomografia

Introduction

The clavicle is the only horizontally oriented long bone in the human body. Researchers have been analyzing clavicular morphology due to a paradigm shift regarding its treatment. The surgical approach is the gold standard in fractures with diastasis that hinder consolidation or deviations that compromise function. In a 2005 meta-analysis with a systematic review of 2,144 fractures, Zlowodziki et al.[1] showed an 86% reduction in the relative risk of pseudarthrosis after primary fixation compared with conservative treatment. A clavicle fracture is a common injury, affecting mainly young, active adults. It accounts for approximately 2.6% of all fractures. The middle third of the clavicle is the most affected region in up to 85% of cases. The current literature does not present absolute indications for surgical treatment, and relative criteria include fragment deviation or shortening higher than 2 cm, comminution, and imminent bone exposure.[2]

Concerning the significance of 'bone shortening' for injury treatment and prognosis, a measurement method for this deviation has not yet been standardized. The two methods most used today are the 'overlapping fragments' method, based on the injured clavicle,[3,4] and the 'length difference' method, based on the length difference to the contralateral clavicle.[5] Thorsmark et al.[6] compared these methods in 2017 and showed that the most reliable technique is 'length difference.' However, these authors also reported an increase in the final length of the injured bone as a postoperative complication. They inferred that the main issue resides in the clavicular length symmetry concept in the same subject, indicating potential methodological errors in both approaches.

In light of the above, we propose to evaluate the validity of the allegations from Thorsmark et al.[6] by performing an imaging assessment to confirm the existence or not of clavicular symmetry in healthy subjects from the city of Curitiba, Paraná, Brazil, and identify potential factors influencing the clavicular length.

Methodology

The study received ethical approval from Plataforma Brasil (CAAE 60958022.8.0000.0103) and the Ethics Committee of Hospital Universitário Evangélico Mackenzie per the

attributions defined in the Brazilian National Health Council (CNS, for its acronym in Portuguese) Resolution n° 466 of 2012 and its complements (opinion n° 5.601.178).

This study used chest computed tomography (CT) scans from a computerized image visualization system for public hospitals. File retrieval occurred from January to December 2020. We downloaded DICOM files for clavicular measurement and allocated them to a database adopting a data anonymization protocol. The inclusion criterion for the collection process was all scans completely covering the clavicles, showing both the lateral and medial joint surfaces. The exclusion criterion was the presence of any evidence of malformation, fractures, or previous surgical procedures in this topography. As such, we included 250 subjects. Next, we reviewed all scans to find collection errors, resulting in a final sample of 211 people, including 111 males and 100 females.

Measurements occurred at the image visualization software DICOM Arya/PACS Aurora (©Pixeon, 2022), version 20.11.0. Using the 3D Ruler tool, an examiner determined the largest diagonal of the clavicle of each subject by demarcating pre-established points, such as the midpoint of the articular surface of the clavicle to the acromioclavicular joint (1) and the midpoint of the joint surface of the clavicle to the sternoclavicular joint (2) on each both sides of axial chest CT scans. The software processed these points and automatically generated the bilateral distance in millimeters (mm) (►**Fig. 1**).

The length difference (LD) between clavicles corresponded to the right clavicle (RC) length minus the left clavicle (LC) length, per the formula LD = RC – LC.

According to this formula, a length difference greater than zero (positive) demonstrates clavicular asymmetry because the right clavicle is longer than the left one; in contrast, a

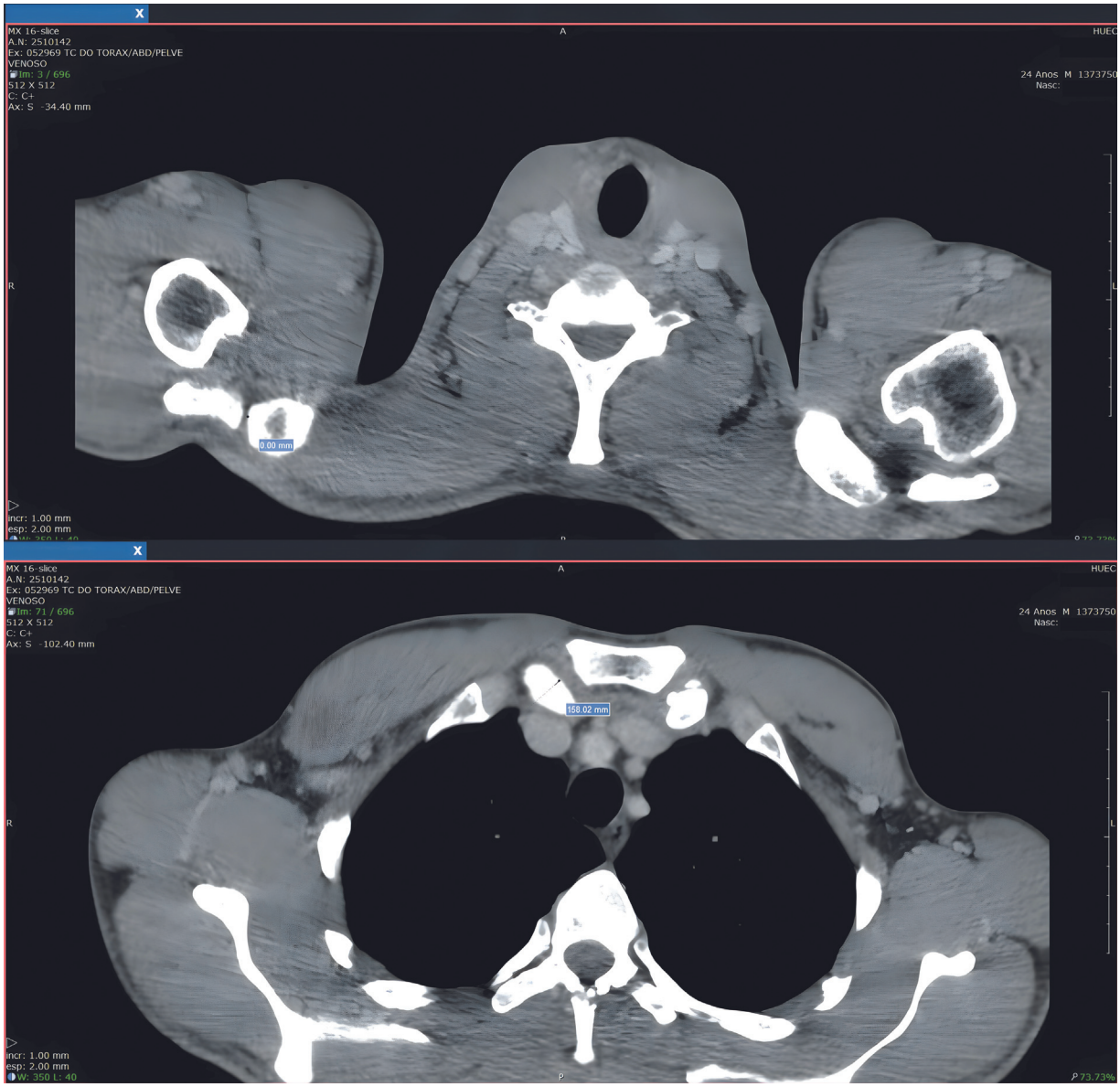

Fig. 1 Demonstration of the DICOM Arya/PACS Aurora software (©Pixeon, 2022) and the method for clavicular length measuring with the '3D Ruler' tool. The upper panel identifies the midpoint of the joint face of the clavicle to the acromioclavicular joint (Point 1). The lower panel shows the midpoint of the joint face of the clavicle to the sternoclavicular joint (Point 2).

difference smaller than zero (negative) indicates the opposite. The variable considering positive/negative values was called the 'normal difference'. It helped to determine the laterality of the asymmetry, if any. To assess the actual asymmetry, we created a quantitative variable called 'absolute difference', which does not consider the positivity/negativity of the number, only its value.

The R software (©The R Foundation, 2022) performed the following analysis. Qualitative variables (gender) analysis employed relative and absolute frequencies. Quantitative variables (age, clavicle measurement, measurements differences, and absolute differences between measurements) analysis used mean values and 95% confidence intervals. Quantitative variables comparisons employed Student's t-tests. Age correlation determinations used Pearson's correlation coefficient.

All analyses considered a 5% significance level.

A Student's t-test for paired samples compared measurements from both sides within the same subject. A Student's t-test for independent samples compared measurements between genders.

Model adjustments considered age and gender as explanatory variables for clavicle measurement. In addition, we created an identifier to indicate if the values referred to the left or right clavicle.

Results

Descriptive and Comparative Analysis

Our data indicate that, regardless of gender, our sample presented an average length of 143.58 mm for the right clavicle and 145.72 mm for the left clavicle. The mean length difference was statistically significant ($p < 0.001$).

A 'normal' difference lower than zero (-2.15) indicates that, on average, the left clavicle was longer than the right clavicle. The 'absolute' difference showed an average distance between clavicles of 3.71 mm in healthy subjects, regardless of gender.

Considering gender differences, both females and males had negative 'normal' differences between the clavicles (females = -1.63 / males = -2.61). These differences indicated that the left clavicle is longer than the right clavicle in both genders. The mean 'absolute' difference was 3.23 mm for women and 4.13 mm for men ($p < 0.001$).

Lastly, when grouping the subjects per the amount (in mm) of absolute difference between clavicles, most (73%) present less than 5 mm of difference between these bones. However, it is worth noting that 27% of the sample had an absolute difference above 5 mm, and 3.3% had a difference greater than 10 mm (►**Table 1**).

Correlations

We calculated the Pearson's correlation coefficients between age and left and right clavicle measurements separately for both genders and disregarding the separation between them. There was no significance for the calculated correlation values, indicating the lack of association between patient age and clavicle measurements (►**Table 2**).

Model Analysis and Adjustment

The descriptive analysis reveals a difference between the measures of the left and right clavicle; the left clavicle tends

Table 1 Summary of the descriptive and comparative analysis of the study

Variables			Observations	Proportion	Mean value (95% CI)	p-value
Gender	Female		100	47.4%	–	–
	Male		111	52.6%	–	–
Age			211	100.0%	54 (17; 91)	–
Clavicle measurement	Right		211	50.0%	143.58 (123.40; 163.76)	**0.037**
	Left			50.0%	145.72 (124.59; 166.86)	
	Female gender	Right	100	50.0%	136.77 (122.62; 150.93)	0.116
		Left		50.0%	138.40 (124.03; 152.77)	
	Male	Right	111	50.0%	149.71 (132.69; 166.73)	**0.029**
		Left		50.0%	152.32 (134.70; 169.95)	
Difference between clavicle measurements		General	211	100.0%	-2.15(-2.54; -1.75)	<**0.001**
		Female gender		47.4%	-1.63(-2.15; -1.10)	**0.013**
		Male gender		52.6%	-2.61(-3.20; -2.03)	
Absolute difference between clavicle measurements		General	211	100.0%	3.71 (3.44; 3.97)	<**0.001**
		Female gender		47.4%	3.23 (2.89; 3.58)	<**0.001**
		Male gender		52.6%	4.13 (3.74; 4.53)	
Grouping of the absolute difference between clavicle measurements		< 5 mm	154	73.0%		
		5 mm to 10 mm	50	23.7%		
		> 10 mm	7	3.3%		

CI 95%, 95% confidence interval

Table 2 Pearson's correlation coefficients between age and clavicle measurements in general and per gender

	Measurement (right clavicle)	Measurement (left clavicle)
Age	-0.009 (p = 0.895)	-0.019 (p = 0.787)
Age (female gender)	-0.119 (p = 0.239)	-0.058 (p = 0.567)
Age (male gender)	0.024 (p = 0.800)	0.017 (p = 0.863)

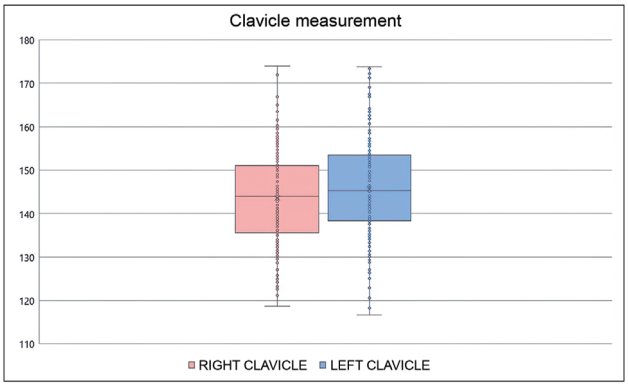

Fig. 2 Boxplot demonstrating the variation of clavicular measurements regarding the right or left side, indicating a greater length of the left clavicle compared with the contralateral one.

to be longer. In addition, the extreme values from the left side can be higher compared with the right side (►**Fig. 2**).

Regarding gender, male subjects had higher absolute length measurements than their female counterparts (►**Fig. 3**).

Moreover, there was a value dispersion between the left and right clavicle measurements in subjects from all age groups, with no indication of an association between variables (►**Fig. 4**).

As for model adjustment, given the laterality effect, we estimated a 2.15-mm increase in the mean size of the left clavicle compared with the right clavicle. Regarding gender, we inferred an increment of 13.43 mm in the average clavicle length in males compared with females (►**Table 3**).

The estimated age effect showed that a mean length difference of −0.1 mm (0.1 mm decrease) per year but with no statistical significance.

Next, we noticed the behavior of the values predicted by the model, which we adjusted per the observed covariates and the clavicle measurements. The behavior without large deviations from the main diagonal indicates a good model adjustment (►**Fig. 5**).

Discussion

Clavicle shortening is one of the most significant surgical criteria for fractures; the size of the contralateral clavicle is often used to plan the approach.[2] In an article published in 2006, Lazarides e Zafiropoulos[5] stated that, after evaluating 132 patients undergoing conservative treatment for clavicle fracture, shortening resulting from the union without

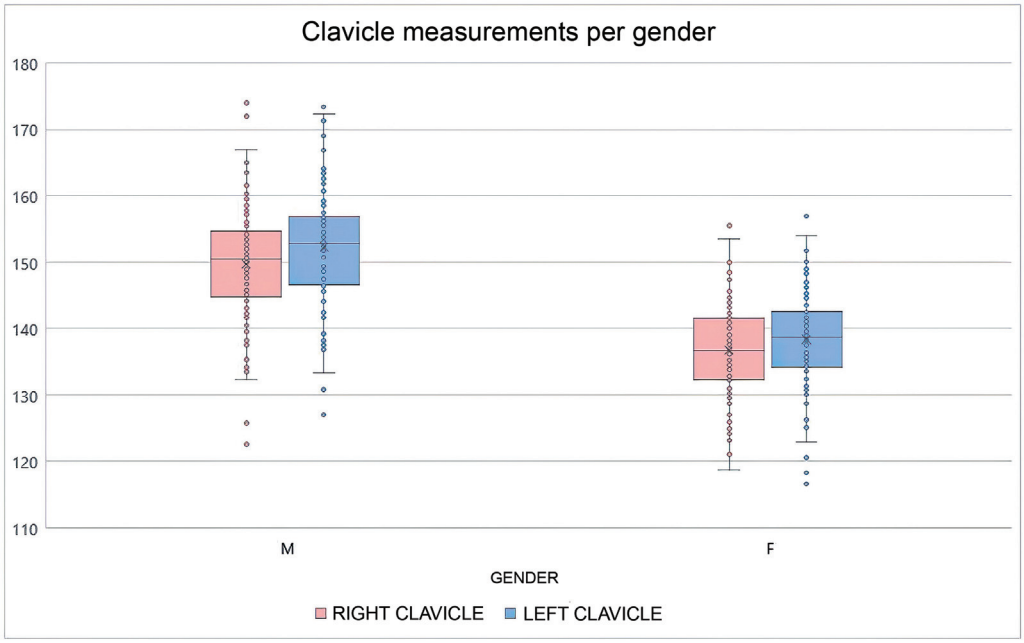

Fig. 3 Boxplot showing the range of clavicular measurements per gender, indicating longer clavicles in males than females and a longer left clavicle compared with the right clavicle.

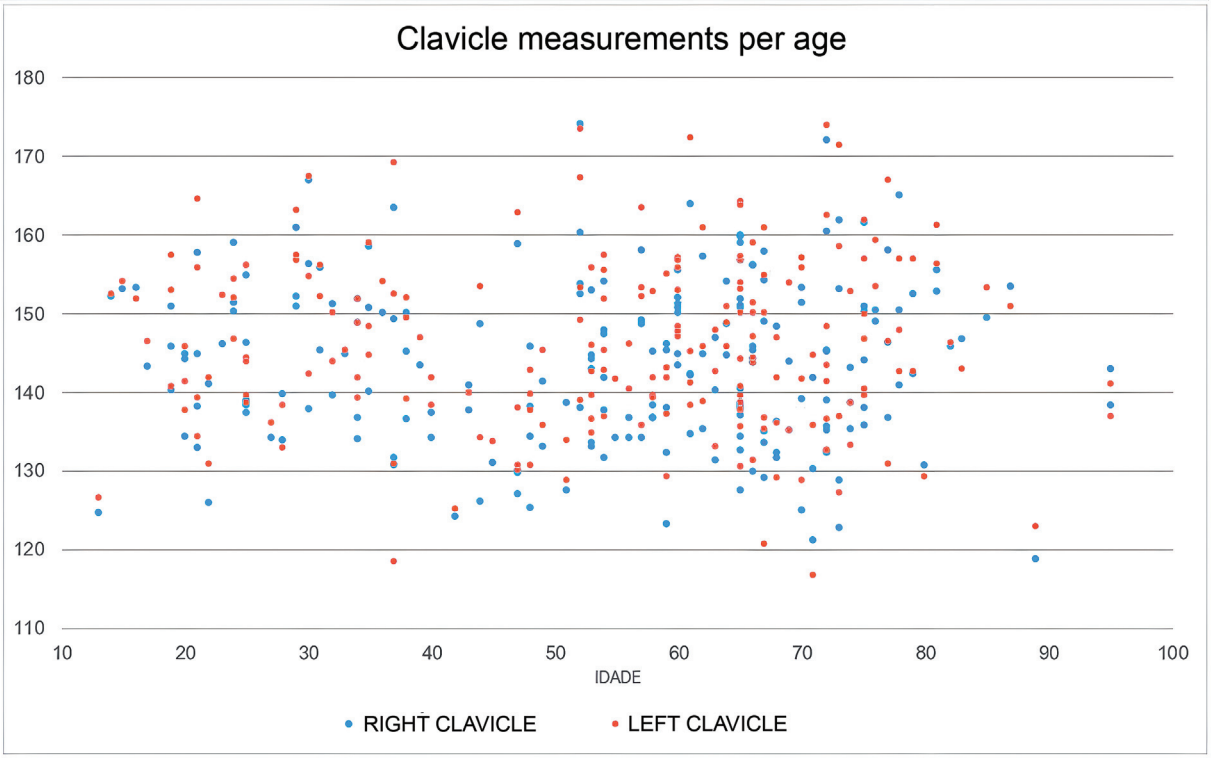

Fig. 4 The scatterplot shows data dispersion indicating the lack of association between age and clavicular length.

Table 3 Summary of the fixed effects and their statistical significances

Fixed effects	Parameters	Coefficients	95% CI	p-value
	Intercept	137.049	(133.616;140.482)	<0.001
	(Left) clavicle	2.145	(1.585;2.706)	<**0.001**
	Age	-0.100	(-0.066;0.046)	0.730
	Gender (male)	13.432	(11.288;15.756)	<**0.001**

CI 95%, 95% confidence interval

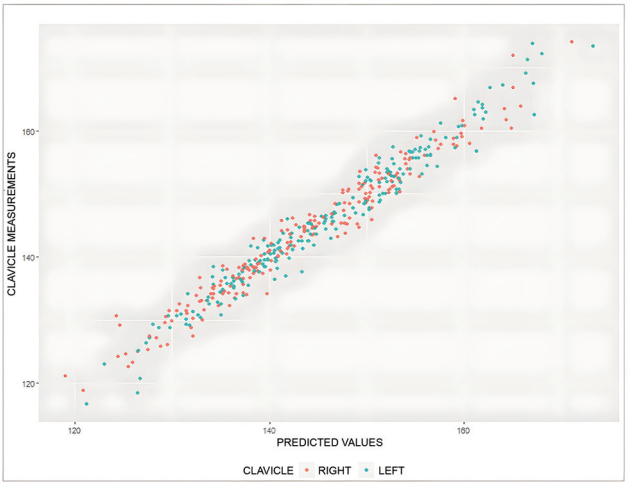

Fig. 5 The distribution of observed and predicted values reveals a good model adjustment.

intervention above 14 mm for women and 18 mm for men led to unfavorable evolution and dissatisfaction with the outcome.

These findings emphasize the critical role of applying a method to maximize satisfactory outcomes for clavicle fractures. Therefore, it is crucial to infer the presence or absence of clavicular symmetry in healthy subjects, allowing the safe use of these data to define the proposed treatment.

Hoogervorst et al.[7] used a methodology equivalent to ours to infer the existence of clavicular symmetry. Their study assessed 100 subjects (42% males and 58% females), revealing a significant difference between clavicle sizes and a mean length difference of 0.88 mm (-2.47 mm – +4.48 mm). The authors selected patients with a mean age of 55.5 years, founding that the right clavicle was, on average, 1.79 mm smaller than the contralateral one and that the mean absolute length difference was 3.74 mm. Thirty percent of the evaluated sample presented at least 5 mm in the absolute

difference between the clavicles (28% between 5 and 10 mm and 2% > 10 mm). In addition, they reported that gender is a determinant factor for the absolute size of the clavicles, with men having longer bones.

In 2013, another similar study by Cunningham et al.[8] evaluated 102 subjects (39.2% males and 60.8% females) with a mean age of 53.6 years old.

This study also showed similar results, with a mean length difference of 4.25 ± 3.8 mm. The authors reported that the discrepancy was < 5 mm in 71.5% of the evaluated subjects, from 5 to 10 mm in 21.5%, and > 10 mm in 7% of the sample. As such, 28.5% of the subjects presented a length variation > 5 mm.

In contrast to the previous study and observations in the Brazilian population, Cunningham et al.[8] did not find a statistically significant relationship between the patient's gender and clavicular length.

In parallel with our data, there is a statistical equivalence when comparing Brazilian findings and the reported studies, showing that results remain similar even when doubling the sample size (100 vs. 102 vs. 211). This similarity indicates that such equivalence persists even when comparing populations from different continents (Americas x Europe), corroborating the findings. Here, we emphasize the crucial role of the heterogeneity of the Brazilian population. In addition, it is necessary to expand this type of evaluation to other regions to assess the existence of morphological differences resulting from populational characteristics and confirm the maintenance of this similarity.

The analysis of the literature data and their comparison with ours highlights the evidence of clavicular asymmetry in the Brazilian population as in other samples; the mean difference between clavicular dimensions ranged from 0.88 to 4.25 mm, with the right clavicle comparatively smaller than the left clavicle in two out of the three studies. Cunningham et al.[8] reported a significant correlation between the patient's dominant side and a shorter clavicular length, but this information requires further studies for corroboration.

In 2016, Sehrawat and Pathak[9] highlighted the importance of this topic in the forensic literature, considering the clavicular anthropometric evaluation as a robust tool to infer gender in unidentifiable remains and listing several papers on clavicular length assessment presenting the same asymmetry pointed out by the orthopedic literature. The authors stated that the determinism of this asymmetry is multifactorial and due to genetic factors, intrauterine development, hormonal influences, socioenvironmental factors, and physical activity. However, they said that the asymmetry resulting from dominance did not constitute a factor for reliable determination in post-mortem forensic analysis.

Thus, we observed that the lack of information about the dominance of the evaluated patients is a limitation in our study. We recommend introducing this data in future studies with the Brazilian population to better structure the potential influence of this variable.

Our data may indicate a potential methodological error in the decision-making algorithm regarding conservative versus surgical treatment based on clavicular symmetry and using length difference as a reference. This error could be even more significant in the male population, which presented the highest mean values of comparative difference. This makes it even more difficult to assess the 'symmetry' factor as decisive in the orthopedic management of clavicle fractures.

This study aimed to form a database for developments regarding clavicular symmetry assessment, either using larger samples to corroborate our findings or evaluating additional data that may influence the asymmetry (such as the assessment of the dominant limb performed by Hoogervorst et al.[7])

By bringing these results to the debate, we expect to discuss the methods used to measure symmetry and clavicular shortening and the usefulness and practical effectiveness of algorithms for patient treatment. With this, we wish to enable better decision-making so that the expected outcome of clavicle fractures is as satisfactory as possible.

Conclusion

Our findings show that it is not possible to infer the anatomical symmetry between the bone structures of the clavicles within a single subject in the population from Curitiba, Paraná, Brazil. The average clavicle length difference was 3.71 mm in the general sample, 3.23 mm in females, and 4.13 mm in males. Furthermore, the discrepancy was at least 5 mm in 27% and greater than 10 mm in 3.3% of the subjects.

The only factor with a statistically significant influence contributing to this disparity was gender since males presented the highest absolute values of clavicular length and higher length differences than females.

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Conflict of Interests
The authors declare no conflict of interests.

References

1 Zlowodzki M, Zelle BA, Cole PA, Jeray K, McKee MDEvidence-Based Orthopaedic Trauma Working Group. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of the Evidence-Based Orthopaedic Trauma Working Group. J Orthop Trauma 2005;19(07):504–507
2 Court-Brown CM, Heckman JD, McQueen MM, Ricci WM, Tornetta P III, McKee MD. Rockwood and Green's fractures in adults. 8th ed. Philadelphia: Wolters Kluwer; 2015
3 Hill JM, McGuire MH, Crosby LA. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg Br 1997;79(04):537–539
4 Silva SR, Fox J, Speers M, et al. Reliability of measurements of clavicle shaft fracture shortening in adolescents. J Pediatr Orthop 2013;33(03):e19–e22

5 Lazarides S, Zafiropoulos G. Conservative treatment of fractures at the middle third of the clavicle: the relevance of shortening and clinical outcome. J Shoulder Elbow Surg 2006;15(02):191–194
6 Thorsmark AH, Muhareb Udby P, Ban I, Frich LH. Bone shortening of clavicular fractures: comparison of measurement methods. BMC Musculoskelet Disord 2017;18(01):537
7 Hoogervorst P, Appalsamy A, Franken S, van Kampen A, Hannink G. Quantifying shortening of the fractured clavicle assuming clavicular symmetry is unreliable. Arch Orthop Trauma Surg 2018;138(06):803–807
8 Cunningham BP, McLaren A, Richardson M, McLemore R. Clavicular length: the assumption of symmetry. Orthopedics 2013;36 (03):e343–e347
9 Sehrawat JS, Pathak RK. Variability in anatomical features of human clavicle: Its forensic anthropological and clinical significance. Transl Res Anat 2016;3-4:5–14