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Original Article

Sex dimorphism according to the nasozygomatic triangle

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Sex is one of the first features to be diagnosed in human identification, composing, with age, ancestry and stature, the so called "big four". **Aim:** The present study aimed to metrically analyze the sexual dimorphism in skulls of known age and sex from Rio Grande do Sul – Brazil. **Methods:** This was a cross-sectional study of metrical analysis, which used a sample comprised of 209 human skulls (106 male and 103 female) older than 22 years old at the time of death, undamaged and without signs of trauma or abnormalities. The point nasion and the most superior points on the zygomaticotemporal sutures from each side were connected forming a triangle. This area was calculated using Heron's formula, and the results were submitted for statistical analysis. **Results:** All measurements showed significant values for sexual dimorphism. Through the area of the triangle, it was possible to determine sex with an accuracy of 83.97% for males and 83.50% for females. **Conclusion:** This simple method requires only a caliper, and still can be reliable for forensic human identification. It must be diffused and tested on other samples, and can be used as a good and inexpensive tool for experts in day-to-day practice.

Keywords: Forensic anthropology. Sex determination by skeleton. Sex characteristics. Skull.

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Introduction

Historically, human identification is one of the biggest challenges faced by forensic science. The existence of sexual dimorphism in human skeletons and its importance in investigative methods has long been recognized. Krogman and Íscan[1] asserted that sex assessment was possible, with levels of reliability of 100% when the entire skeleton is present, 92% using the skull alone, and 98% when combining pelvis and skull. Together with pelvic bones, the skull remains among the most dimorphic segments of the skeleton, although this determination has its reliability totally established only after puberty[2,3].

Morphological analysis, being an even faster process, brings a high degree of subjectivity, decreasing its reliability. For this reason, metric techniques, being intrinsically more objective, can offer a better data achievement, with less variability between experts[1,4,5].

Craniofacial structures have the advantage of being composed largely of hard tissue with a higher resistance to decomposition[6], allowing their analysis even after mass disasters, or other forms of violence. Krogman and Iscan[1] and Meindl et al.[7] have stressed that anatomical variations are population-dependent, and any method for human identification should be tested and validated in the target population, prior to being used.

Patil and Mody[8] claim that large and robust skulls tend to be male, and delicate skulls tend to be female. To Kranioti et al. [9], the males are statistically larger in all their dimensions in relation to females. Several authors concluded in their research, among different craniometric points analyzed, that the bizygomatic distance exhibited a high degree of sexual dimorphism[9-11]. The purpose of this study was to evaluate the accuracy of a new sexing method using the area of the triangle formed from the measurements of three craniometrics points in the upper face of skulls.

Materials and Methods

This research was conducted in the city of Porto Alegre, Rio Grande do Sul - Brazil, after being approved by the Ethics Committee of the Faculty of Dentistry of Piracicaba, UNICAMP, São Paulo – Brazil, approval number 138/2010. The sample consisted of 209 skulls (106 males and 103 females) selected by convenience during six months of data collection, according to the routine exhumations of the cemetery. Individuals from 22 years of age or older at time of death were included, to ensure full development of the skull and end of facial growth. Exclusion criteria were any kind of trauma, visible anomalies, or post-mortem damage, like bone breaking or cracking during exumation, that could interfere with the measurements taken. The possibility of edentulism was not an exclusion criterion, since the presence or absence of teeth does not influence the used measures. Sex verification was ensured by the burial records and codified to allow a blind analysis.

The metric analysis of the skulls was performed by a single examiner previously calibrated after measuring 50 skulls, with a digital caliper (Mitutoyo, São Paulo – Brazil), and registered in an Excel sheet. The data consisted of the measurements between nasion (point N) and the most superior point of the zygomatic-temporal suture on both sides – which was called, for this study, zygomatic-temporal point (point ZT). Table 1 shows the measurement abbreviations and definitions, and Figure 1 shows their representations on the skull.

Table 1. Abbreviation and definition of the measures taken

Measure	Definition
N – ZT.R	From nasion to the most superior point of the zygomatic-temporal suture on the right side
N – ZT.L	From nasion to the most superior point of the zygomatic-temporal suture on the left side
ZT.R – ZT.L	Between the most superior point of the zygomatic-temporal suture from right to left sides

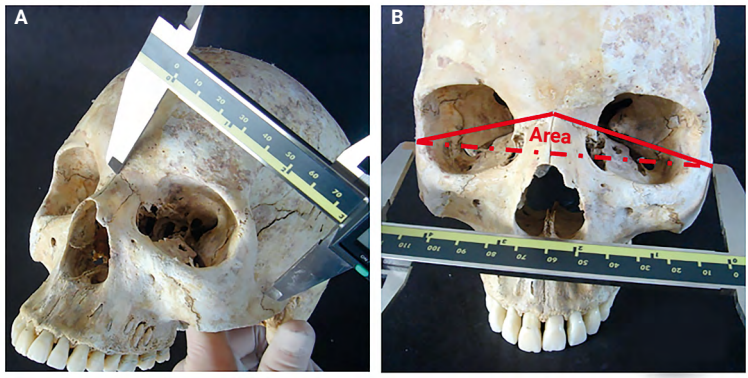

Figure 1. Measure taken from nasion to point ZT.L (A); and graphic representation of the triangle formed by the three points (B).

After the three measurements had been taken, the triangle formed by their connection (Figure 1) had its area calculated by Heron´s formula[12]. This is used in plane geometry to determine the area of a triangle when only the length of the sides a, b and c are known, as shown below:

$$\textit{Triangle area} = \sqrt{s\,(s-a)(s-b)(s-c)}, \text{ in which } s = \frac{a+b+c}{2}$$

The area of the proposed nasozygomatic triangle can only be calculated by this formula, since the triangle has its base backwards from its apex, making it an angled figure relative to the anatomic coronal plane.

The measurements taken were subjected to Student t-test ($p < 0.001$) for assessment of sexual dimorphism. In order to test for intra-examiner error, the skulls of 20% of the sample were randomly selected, including both sexes, and were analyzed twice, within a two week interval. The two sets of values for these individuals were compared by means of a paired Students´t-test, showing non statistically significant difference ($p > 0.05$).

Results

For the three measurements taken from the sample (209 skulls), and the triangle area calculated by their connection, sexual dimorphism was statistically significant ($p<0.001$) in all values, as shown in Table 2. On analyzing the ratio between the male and female average of the measurements and triangle area, the male average was always higher than the female, thereby showing relevant sexual dimorphism of this anatomic triangle, as shown in Table 3.

Table 2. Student t-test with average male and female and their minimum and maximum limits

	Male			Female			
	mean (SD)	min	max	mean (SD)	min	max	p
N – ZT.R (mm)	76.67 (4.207)	75.866	77.487	71.546 (2.896)	70.988	72.104	<0.001*
N – ZT.L (mm)	76.857 (4.395)	76.011	77.704	71.606 (2.861)	71.054	72.157	<0.001*
ZT.R – ZT.L (mm)	117.998 (5.368)	116.964	119.031	111.117 (4.344)	110.280	111.954	<0.001*
Area (mm^2)	2,896.006 (338.470)	2,830.821	2,961.191	2,503.607 (200.644)	2,464.952	2,542.262	<0.001*

* all significant at $p<0.001$

Table 3. Quotient between male and female average

	Quotient	%	Interpretation
N – ZT.R	1.072	7.20	average male 7.2% higher than female
N – ZT.L	1.073	7.30	average male 7.3% higher than female
ZT.R – ZT.L	1.062	6.20	average male 6.2% higher than female
Triangle area	1.157	15.7	average male 15.7% higher than female

Figure 2 shows a diagram with the range of the triangle area for males and females. To obtain it, the average area of the triangle for each sex and their respective standard deviation was used. From that, it can be said that if the triangle area value is lower than 2,558mm^2, the skull is female; if the value is greater than 2,703mm^2, it is male. However, if the value is between 2,558mm^2 and 2,703mm^2, the method does not contribute to sex diagnosis, since this range was found to be doubtful. Skulls with nasozygomatic triangle area greater than 3,234mm^2 were considered hypermales, and those with area below 2,303mm^2 were considered hyperfemales, as can be seen in Figure 2.

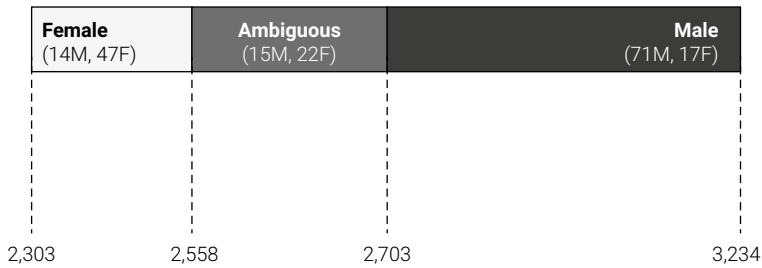

Figure 2. Sex diagnosis according to the nasozigomatic triangle area (in mm^2)

For skulls with this triangle area higher than 2,703mm^2, or lower than 2,558mm^2, this sexing method has a reliability of 83.97% for males and 83.50% for females, respectively, as shown in Table 4. Intra-observer error showed non-significant values between the two groups of measures (p=0.773 for N – ZT.R; p=0.100 for N – ZT.L; and p=0.266 for ZT.R – ZT.L).

Table 4. Sex determination accuracy and area values for male and female

Area (mm^2)	Sex	Accuracy
> 2,703	Male	83.97%
<2,558	female	83.50%

Discussion

Forensic anthropologists are continually challenged by the human identification issue, and develop new methods or improve the accuracy of existing ones, applied on various parts of the skeleton so that the method can be admissible in court[10,13,14].

It is known that anthropological research is more susceptible to errors when purely morphological criteria are considered, due to phenotypic variations, pathological signs and even according to the observer, making the analysis undesirably subjective. Thus, a quantitative method, for its objectivity and reproducibility by any researcher and expert, can join to the group of procedures for human identification, with accuracy and reliability[5,8].

In a forensic anthropological analysis of a skeleton, with identification as its primary aim, sex is one of the first and most important piece of information to be obtained, being part of the so called "big four", together with age, stature, and ancestry[15-17]. Human bones have low sexual dimorphism, if compared with other primates[18]; still, the most dimorphic parts of the skeleton is the pelvis, followed by the skull. Therefore, whenever the pelvis is not available, sexing methods must be based on cranial anatomy[1,5]. The percentage of correct answers regarding sex diagnose based exclusively on skull features range from 70.56% to 92%[7,19]. Results obtained in this study, using the area of the proposed nasozygomatic triangle (in mm^2) reached a reliability of 83.97% for males and 83.50% for females.

Before puberty, sexual characteristics are not very pronounced; it is only after this period, under hormonal influence, environment and muscles, that the human skeleton begins to show sexual dimorphism. Due to this, in this study, as inclusion criteria, only skulls of individuals aged from 22 years old and up at time of death were analyzed.

Mainly due to the variation between groups of different ancestries, the methods of identification in forensic anthropology must be regionalized and validated for specific populations. This is the reason why previous studies should test and find the reliability of a given method in their respective target population, so that it can be used for human identification[5,7]. Craniometric traits show a level of regional differentiation comparable to genetic markers, with high levels of variation within populations as

well as a correlation between phenotypic expression and geographic distance, which allows high levels of classification reliability when comparing skulls from different parts of the world[20].

The Brazilian population has a high degree of biological variation. This is due to the hybridization of the Amerindians as first settlers with European and Sub-Saharan groups, after colonization occurred in the 16th century, which was studied by Ross et al.[21], and stressed by Urbanová et al.[22]. This showed higher misclassification of sex and ancestry for the Afro-Brazilian sample, according to software tools. It also must be noted that genetic marker studies[23,24], showed a regional variation according to the mtDNA lineages, with high European influence in the Southern region, where this study was performed. The use of craniometric methodology published in tables and indexes from studies of foreign authors or other regions of Brazil must be cautious, and craniometric variations for any method should be validated, for forensic purposes.

Large and robust skulls tend to be male, and delicate skulls tend to be female[8]. As known from anthropological studies, males skulls are statistically higher in all their dimensions in relation to females[9]. This study also observed the preponderance of all measures in males. The average area of the nasozygomatic triangle in males was 15.7% higher than females.

Among the measurements, bizygomatic width was classified as the most dimorphic measure for sex diagnosis[9,10]. After this, measurements of the upper portion of the facial skull have also been shown as sexually dimorphic[11]. This study used craniometric measurements of the upper face in search of this dimorphism reported in literature, and applied a new method to examine an old issue in forensic anthropology: sexual diagnosing by use of the skull. The use of techniques such as computerized tomography[25], 3D graphics[26], and morphometric geometry[27] can be very helpful, but if a simple method that requests only a caliper and can still be reliable for forensic human identification, it must be diffused and tested on other samples. The accuracy of the cutoff points showed that the method can be used as a good and inexpensive tool for experts in day-to-day practice, dealing with unidentified individuals.

However, the predictive values (sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratio) were not calculated, and can be investigated by future researchers. In skulls that show results between 2,558mm^2 and 2,703mm^2 the method does not contribute to sexual diagnosis, which was considered as a limitation, as well as skulls younger than 22 years old, not included in the sample. Future projects should also consider the possibility of adapting the method for children and young adults.

To conclude, the proposed method uses points which are easily identifiable and of rapid measurement, with which experts can diagnose sex when only the skull is available. If the value found of the nasozygomatic triangle area is within the doubtful range, nothing can be said about sex by the proposed technique; however, if this value is not between 2,558mm^2 and 2,703mm^2, sex information can be achieved with a reliability of 83.97% for males and 83.50% for females.

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