

**Linear Distances In Brazilian Human Dry Skulls For Sex Estimation****Distâncias lineares em crânios secos humanos brasileiros para estimativa de sexo**

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**Carolina Lucena Veloso Gusmão**Mestre em Perícias Forenses pela Faculdade de Odontologia da Universidade de Pernambuco  
(FOP/UPE)

Faculdade de Odontologia da Universidade de Pernambuco (FOP/UPE)

R. Nevinha Gondin de Oliveira, n66. Bairro: Jardim Luna. Cidade: João Pessoa, Paraíba

E-mail: Carolinav42@gmail.com

**Maria Izabel Cardoso Bento**Mestre em Perícias Forenses pela Faculdade de Odontologia da Universidade de Pernambuco  
(FOP/UPE);

Faculdade de Odontologia da Universidade de São Paulo (FOUSP)

Endereço: Rua Carlos de Barros, no500, Residencial Ipanema, apto 604

E-mail: cardosobel@outlook.com

**Viviane Freire Lira**

Doutorado pela Universidade de Dundee – Escócia

Faculdade de Odontologia da Universidade de Pernambuco (FOP/UPE)

Av. General. Newton Cavalcanti, 1650 - Tabatinga, Camaragibe - PE, 54756-220

E-mail: vflira@gmail.com

**Larissa Chaves Cardoso Fernandes**Mestre em Perícias Forenses pela Faculdade de Odontologia da Universidade de Pernambuco  
(FOP/UPE)

Centro Universitário UNIESP

Avenida Presidente Epitácio Pessoa, 4050, Apt 1701, Miramar, João Pessoa/PB

Email: larissaccfernandes@gmail.com

**Evelyne Pessoa Soriano**

Pós-doutorado em Antropologia Forense pela Universidade de Coimbra/UC

Professora Associada. Livre-docente pela Universidade de Pernambuco

Av. General. Newton Cavalcanti, 1650 - Tabatinga, Camaragibe - PE, 54756-220

E-mail: Evelyne.soriano@upe.br

**Viviane Moura Leite**Mestre em Perícias Forenses pela Faculdade de Odontologia da Universidade de Pernambuco  
(FOP/UPE)

Polícia Civil do Estado do Amazonas (PCAM)

Av Rio Jutai, 1139 - Manaus - AM cep 69053-020

E-mail: mouravivi@hotmail.com

**Adriana Conrado de Almeida**

Doutorado em Saúde Materno Infantil pelo Instituto De Medicina Integral Professor Fernando Figueira

Docente do quadro permanente do Mestrado de Perícias Forenses da Faculdade de Odontologia/UPE

Av. General. Newton Cavalcanti, 1650 - Tabatinga, Camaragibe - PE, 54756-220

E-mail: adriana.almeida@upe.br

**ABSTRACT**

**Background:** In order to establish an identity under dispute, sex estimation is one of the main pieces of information to be investigated when dealing with unknown human remains. The aim of the study is investigate the applicability of linear quantitative methods in Brazilian skulls to estimate sex. **Methods and findings:** This is a blind, cross-sectional, quantitative study. The sample consisted of 427 adult dry human skulls belonging to the Forensic Anthropology Study Center (CEAF/FOP/UPE). Using a digital caliper, three linear measurements were made: from the right zygomatic orbital point to the left zygomatic orbital point (RZOP-LZOP); right infraorbital point to the left infraorbital point (RIOP-LIOP); and distance between the lower points of the mastoid processes, right and left (RPIM-LPIM). The collected data were analyzed using descriptive and inferential statistics using the IBM SPSS software. **Results:** The RZOP-LZOP and RPIM-LPIM distances presented a higher median for men (99.69 mm and 105.92 mm, respectively). The RIOP-LIOP distance had a higher median in women (58.57 mm). All measurements were statistically dimorphic for sex ( $p < 0.001$ ). **Conclusion:** The linear distances RZOP-LZOP, RIOP-LIOP and RPIM-LPIM are methodologies capable of estimating sex in this studied sample.

**Keywords:** Forensic anthropology, Skull, Craniometry, Sexual characters.**RESUMO**

**Contexto:** Para estabelecer uma identidade em disputa, a estimativa do sexo é uma das principais informações a serem investigadas ao lidar com restos humanos desconhecidos. O objetivo do estudo é investigar a aplicabilidade de métodos quantitativos lineares em crânios brasileiros para estimar o sexo. **Métodos e resultados:** trata-se de um estudo cego, transversal e quantitativo. A amostra foi composta por 427 crânios humanos adultos secos pertencentes ao Centro de Estudos de Antropologia Forense (CEAF / FOP / UPE). Utilizando um paquímetro digital, três medidas lineares foram feitas: do ponto orbital zigomático direito ao ponto orbital zigomático esquerdo (RZOP-LZOP); ponto infraorbital direito ao ponto infraorbital esquerdo (RIOP-LIOP); e distância entre os pontos inferiores dos processos mastóideos, direito e esquerdo (RPIM-LPIM). Os dados coletados foram analisados por meio de estatística descritiva e inferencial por meio do software IBM SPSS. **Resultados:** As distâncias RZOP-LZOP e RPIM-LPIM apresentaram mediana maior para os homens (99,69 mm e 105,92 mm, respectivamente). A distância RIOP-LIOP teve mediana maior nas mulheres (58,57 mm). Todas as medidas foram estatisticamente dimórficas para o sexo ( $p < 0,001$ ). **Conclusão:** As distâncias lineares RZOP-LZOP, RIOP-LIOP e RPIM-LPIM são metodologias capazes de estimar o sexo na amostra estudada.

**Palavras-chave:** Antropologia forense, Crânio, Craniometria, Personagens sexuais.

## 1 INTRODUCTION

Estimating sex is one of the main pillars in identification processes since by defining it, one can exclude approximately half of the population<sup>1</sup>. Thus, the adult human skeleton offers a multitude of information about who belonged to it by evidencing peculiar morphological (qualitative) and metric (quantitative) characteristics that allow a correct diagnosis. The pelvis is the bone structure with the greatest sexual dimorphism, followed by the skull, mandible, and femur. When the expert has a complete adult skeleton, the chances of an estimate of sex reach 98% by analyzing the isolated pelvis, 92% by assessing the cranial characteristics and, when analyzed together, the pelvis and skull provide an estimate higher than 99%, and this percentage decreases as fewer remnants are available.<sup>2-4</sup>

In general, female bones are more delicate, smaller, and lighter than the male one. In relation to the male skull, the female skull is morphologically smaller and more rounded, with less coarse and prominent muscle inserts and ridges. Furthermore, the superciliary arch is less evident, the frontonasal joint is more curved, and the nuchal line and the outer occipital protuberance are smaller and less rough. The frontal sinuses, orbital edges and glabella are less pronounced.<sup>4,5</sup>

In addition to morphological characteristics, the literature is clear regarding studies that report the effectiveness of using metric variables in skulls to distinguish sexes. Several authors have shown high levels of correctness for sexual dimorphism by using linear cranial measurements.<sup>2,6-15</sup>

The great dilemma in forensic anthropology is the morphological and metric variability that exists between different populations, i.e., whether these peculiarities arise from historical and social contexts, climatic factors and/or food habits.<sup>17</sup> Thus, it is necessary to expand research in different populations aiming to establish a standard that can be applied efficiently to the purpose of the investigation. Thus, the objective of this study is to investigate the use of craniometry through analysis of linear measurements for the estimation of sex in a Brazilian population.

## 2 MATERIAL AND METHODS

This study was approved by the Research Ethics Committee of the Hospital Universitário Oswaldo Cruz (HUOC/PROCAPE) under CAAE no. 04255518.3.0000.5192 in accordance with the Resolution no. 466/12 of the National Health Council, Ministry of Health, Brazil.

This is a blind study with a quantitative and transversal approach of the diagnostic type. The research universe consisted of 427 skeletons cataloged according to sex and age belonging to the osteological collection of the Center for the Study of Forensic Anthropology (CEAF), Faculty of Dentistry, University of Pernambuco (FOP/UPE), located in the Northeast Region of Brazil. This collection is described in greater detail in the article by Carvalho *et al.*<sup>17</sup>

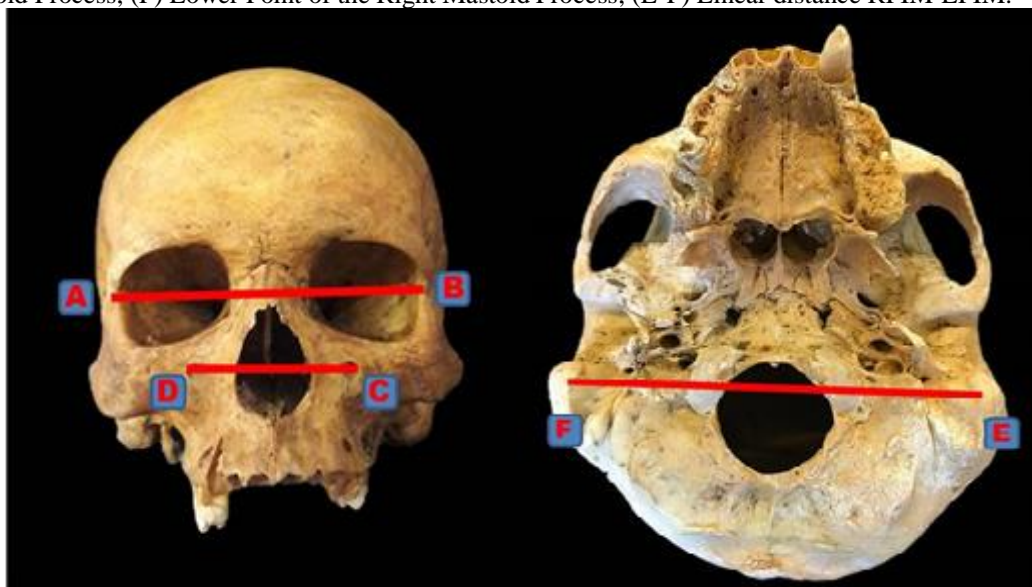
For sample selection, skeletons aged between 20 and 96 years with skulls were included. Those with bone pathologies, fractures, severe anomalies or malformations that compromised the anatomy were excluded as this made it impossible to locate the craniometric reference points (Table 1).

**Table 1.** Description of craniometric reference points for measurements.

Craniometric Point	Location	Measured Distance
Left Zygomatic Orbital Point (LZOP)	Most anterior point of the left frontal-zygomatic suture.	LZOP-RZOP
Right Zygomatic Orbital Point (PZOP)	Most anterior point of the right frontal-zygomatic suture.	
Left Infraorbital Point (LIOP)	Most external point of the lateral border of the left infraorbital foramen.	LIOP-RIOP
Right Infraorbital Point (RIOP)	Most external point of the lateral border of the right infraorbital foramen.	
Lower Pole of the Left Mastoid Process (LPIM)	Lower part of the Left Mastoid Process.	LPIM-RPIM
Lower Pole of the Right Mastoid Process (RPIM)	Lower part of the Right Mastoid Process.	

The measurements were taken in millimeters using a precision digital caliper (Stainless-Hardened® - 150 mm, Mauá, São Paulo, Brazil). The linear distances between the craniometric points are illustrated in Figure 1.

**Figure 1.** (A) Right Zygomatic Orbital Point; (B) Left Zygomatic Orbital Point; (A-B) RZOP-LZOP linear distance; (C) Left Infraorbital Point; (D) Right Infraorbital Point; (C-D) Linear distance (RIOP-LIOP); (E) Lower Point of the Left Mastoid Process; (F) Lower Point of the Right Mastoid Process; (E-F) Linear distance RPIM-LPIM.



To ensure intra-examiner reproducibility, a previous calibration was performed with 10% of the sample at an interval of eight days between two exams and the interclass correlation coefficient (ICC) was calculated. The results were classified as excellent (0.81-0.99). The collected data were analyzed using descriptive and inferential statistics in the IBM SPSS software, and univariate binary logistic regression was performed for each measurement.

### 3 RESULTS

Considering the inclusion and exclusion criteria of this study, the number of skulls per linear measurement varied as listed on table 2. The measurement taken within the Mastoid Process (RPIM-LPIM) was the most inclusive measurement, as included 283 skulls with an average age of 62.3 years. Followed by the measurement taken between the frontal-zygomatic sutures (RZOP-LZOP) with 277 skulls and an average age of 62.57 years. While the one between the infraorbital point (RIOP-LIOP) measured only 146 skulls with an average age of 55.79 years.

Considering the data was not normal, the values presented on table 2 are the median values for each measurement for males and females. All measurements showed statistically significant differences for sex ( $p < 0.001$ ). The distance RIOP-LIOP showed values for males higher than values for females, different from the other measurements, which presented higher values for males.

**Table 2.** Distribution of median values (p25; p75) for measurements made in different cranial regions between sexes. Center for Studies in Forensic Anthropology (CEAF) - Camaragibe/PE - Brazil, 2019.

Region	Sex	Measurements	p-value
Superior facial (n=277)	Male (n=160)	<b>RZOP-LZOP</b> 99.69 (96.83; 102.33)	<0.001*
	Female (n=117)	95.82 (93.80; 99.20)	
Inferior facial (n=146)	Male (n=93)	<b>RIOP-LIOP</b> 56.00 (53.26; 59.64)	<0.001*
	Female (n=53)	58.57 (55.79; 61.17)	
Base of the skull (n=283)	Male (n=163)	<b>LPIM-RPIM</b> 105.92 (101.52; 109.52)	<0.001*
	Female (n=120)	102.03 (98.46; 106.77)	

(\*): Significant difference of 5.0%.

p25: Referring to the value found between the first and second quartiles of the sample.

p75: Referring to the value found between the third and fourth quartiles of the sample.

As Table 3 shows, there was a statistically significant difference between sexes for all linear measurements ( $p < 0.001$ ) and the OR did not go through the confidence interval of 1. For the LZOP-RZOP measurement, at each 1-mm increase, the skulls were 1.13 times more likely to belong to the female sex; for LIOP-RIOP, the chance of individuals being female was 1.17 times likely to being male at every 1 mm; for LPIM-RPIM, skulls were 1.10 times more likely to be female (Table 3).

**Table 3.** Results for analyses by univariate binary logistic regression for cranial measurements by assessment area; with the gender sex as an outcome, the male sex was the reference category. Center for Studies in Forensic Anthropology (CEAF) - Camaragibe/PE - Brazil, 2019.

Variable	p-value	OR (95% CI)
LZOP-RZOP	<0.001	0.884 (0.835; 0.936)
LIOP-RIOP	<0.001	1.179 (1.071-1.299)
LPIM-RPIM	<0.001	0.903 (0.864-0.944)

OR = Odds Ratio.

CI95% = Confidence Interval at 95%

#### 4 DISCUSSION

The study of the characteristics of the skull offers, after the pelvis, a greater precision to distinguish sex in a skeleton<sup>4,14,18</sup>. However, Byres<sup>5</sup> emphasized that among ethnic groups, these characteristics may vary. On average, the female skull is smaller than the male skull. However, Asian men have the skull size closer to that of white women. In general, the forehead is higher in women than in men. However, in the Asian population, men express this characteristic to a greater extent<sup>4,14</sup>. Because of this, the need for specific studies for different populations is emphasized.<sup>4,14,19,20</sup>

Most research that seeks to study sexual dimorphism is based on qualitative differences. It is concerned with aspects of the bone surface of the skull, the glabella, the shape of the chin, the mastoid process, the coronoid processes, the fronto-nasal joint, and teeth.<sup>14</sup> Vanrell<sup>21</sup> stated that when using only morphological characteristics of the skull and jaw for sex estimation, there is an accuracy rate of around 77%. This value is lower than when using metric analyses, which reach an accuracy above 90%.

In turn, research using quantitative variables, since they are based on distances between craniometric reference points, is more accurate and reliable because it results in numerical data that can be worked out mathematically, providing safer results for the estimation of sex.<sup>12</sup> However, attention is necessary when using patterns of studies carried out with foreign populations, as these variables undergo changes between populations, especially in Brazil, which has unique characteristics due to ethnic miscegenation.<sup>20</sup>

There is a consensus in the literature on the need for investments in studies focusing on methodologies for estimating sex from bone fragments since in cases of more complex expertise reports (in which one does not have the complete bone for obtaining information, only skull fragments), the forensic professional may not be able to solve the case due to the lack of appropriate methods.<sup>4,22</sup> Because of this issue, researchers are investigating the applicability of linear measurements on the skull and highlighting the importance of associating more than one measurement to make the diagnosis of sex more accurate.<sup>11</sup>

In Lauro de Freitas, Bahia/Brazil, Lima, Silva and Almeida Júnior<sup>4</sup> used three linear measurements to distinguish the sex of 160 adult human dry skulls (80 male and 80 female) belonging to the Center for Study and Research in Forensic Medicine and Forensic Anthropology of the Metropolitan Union of Education and Culture. One of the analyses was the distance between the zygomatic orbital points, right and left. The results corroborated those found in this study, since male means (97.27 mm) were higher than female means (92.58 mm).

In 1999, Saliba<sup>8</sup> conducted a study on 198 adult skulls (96 men and 72 women) from the city of Lauro de Freitas, Bahia, and obtained good results in relation to the RZOP-LZOP distance. The male mean (94.74 mm) was higher than the female mean (91.34 mm). For sex estimation, 62.50% were correct answers, 37.5% were errors, and there was no indeterminacy. There is a small difference between the classification limits and the absence of values between both confidence limits, showing that the measurement is reliable for the studied population.

Almeida Jr. *et al.*<sup>11</sup>, in the municipality of Lauro de Freitas, Bahia, also carried out a metric study on skulls to assess sexual dimorphism in 200 skulls distributed equally between sexes and classified them according to sex and age. Among the measurements used was the linear distance between the right and left infraorbital foramina. As a result, the average female distance (58.255 mm) was similar as the present study's distance (female median = 58.57 mm). However, the data were divergent as to the male sex. While they found greater measurements for men (mean of 60.94 mm), in our study, the women presented higher values (56.00 mm).

Marinescu *et al.*<sup>12</sup> studied eleven linear measurements in 200 dry adult skulls (100 men and 100 women), with an average age of 39 years, belonging to the osteological collection of the Anthropology Institute of the University of Romania. Regarding the distance between the mastoid processes, men had a mean of 105.4 mm, in agreement with the current research (median of 105.92 mm). For females, the value was lower in both studies (mean 99.00 mm and median 102.03 mm, respectively). However, in the present Brazilian study, the value found is within the standard deviation observed in the Romanian study (98.46 mm and 106.77 mm).

Oliveira<sup>15</sup> also studied the distance between mastoid processes and found a statistical difference for the distinction of sex, corroborating the studies by Marinescu<sup>13</sup> and the present work. The means were higher for men (107.05 mm) and lower for women (103.75 mm). In this study, the percentage of correct answers was 63% for this isolated measurement, with a higher number of correct answers for females (70.0%). The sample used in this study consisted of 100 skulls distributed equally between sexes. They were aged over 22 years at the time of death. The skeletons were from the cemetery of São Gonçalo, Cuiabá-Mato Grosso/Brazil.

In forensic anthropology, the use of morphological and morphometric characteristics is of great value, especially when applied in skulls for sex estimation and human identification.<sup>18,19</sup> In our study, we conclude that the linear distances used have statistical value to be applied to the studied population in the Northeast Region of Brazil. However, in addition to having continental dimensions, Brazil experienced ethnic miscegenation between blacks, whites and indigenous people.<sup>14,20,22</sup> This emphasizes the need and the importance that, as our study, further studies be carried out to cover each specific region of Brazil.

## 5 CONCLUSION

We can conclude that for the studied population, the measurements RZOP-LZOP and RPIM-LPIM are longer in males and the dimension RIOP-LIOP is longer in females. These linear distances are statistically significant for estimating sex from human dry skulls and can be used as aids to experts in identification processes.

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