

# Osteometric and Osteomorphological Sex Estimation from the Os Coxa in an Archaeological Population Related to the 1755 Earthquake of Lisbon \*

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## Abstract

**Introduction:** The ability to determine sex from unknown skeletal remains vital, and methods to do it on various bones of the human skeleton have been researched extensively. The present work consists in the analysis of coxal bones belonging to the victims of the 1755 Lisbon's Earthquake. **Aims:** This project aims the characterization of the population whose skeletal remains were found in the Cloister's South Wing of Academia das Ciências de Lisboa in 2004. **Materials and Methods:** In order to achieve the final objective, six measurements were taken, in anatomic position, and seven indices were calculated. Furthermore, morphological characteristics were observed through four different methods. These procedures were applied to a total number of 129 coxal bones. **Results:** From measurements and indices, the best results found were 16 females and 5 males, but the overall results were not reliable, since there was no consensus between the different measurements and so the majority of the coxal bone were classified as ambiguous. However, the Phenice's Method in the study of the coxal morphology showed to be very specific – through this procedure 18 females and 9 males were estimated. **Conclusions:** It was noticed that the measurements and the calculation of indices are less reliable than the morphological observations. Moreover, Phenice's Method seemed to be the most precise, once it evaluates three parameters simultaneously, instead of just one, allowing to obtain more accurate results for sexual discrimination.

**Keywords:** sex estimation; coxal bone; measurements and indices; morphological characteristics

## Introduction

The present investigation is related to the characterization of the population whose skeletal remains were recovered in the archaeological research carried out in 2004, in the Southern Cloister of Academia das Ciências de Lisboa, concerning the 1755 Earthquake, a disaster that affected Lisbon on the morning of November 1st. The earthquake struck the city and destroyed a large part of it causing the death of countless people, who were left under the rubble or later buried in mass graves (1). This event was followed by a tsunami and several fires (2).

As it presents a great sexual dimorphism, the coxal bone allows the characterization of disarticulated skeletal populations like this (Figure 1), using metric and morphological parameters based on a normal bone development. Pasuk Mahakkanukrauh (3) studied 200 coxal bones from a Thai population in order to obtain a quantitative method for estimating sex. In the other way, Phenice's study (4) allows sexual discrimination through the observation of the subpubic region. Following this line, P. Walker (5) defined a method with the same goal, through the analysis of the morphology of the greater sciatic notch.

The main objective is to characterize, from a paleodemographic point of view, the mentioned population, regarding the generic factor sex, through quantitative discriminating methods and morphological characteristics, applied to the coxal bone.

## Materials and methods

In order to achieve the final objective, measurements were taken, and morphological characteristics were observed. These measurements, indices and morphological characteristics were applied to a total number of 129 coxal bones, which were previously weighed. Concerning the measurements, six were taken – total height of the os coxa (TH) (Figure 2), maximum width of the ilium (MW), pubis length (PL), ischium length (IL), acetabulum diameter (AcetD) (Figure 3) and pubic tubercle-acetabulum length (PTAD) –, in anatomic position, and seven indices were calculated from these six measurements – ischio-pubic index (IP), pubis length-total height index (PL-TH), acetabular diameter-maximum width index (AcetD-MW), maximum width-total height index (MW-TH), acetabulum diameter-pubic tubercle-acetabulum index (AcetD-PTAD), pubic tubercle-acetabulum-ischium length index (PTAD-IL) and ischium length-total height index (IL-TH). Both total height of the coxal bone (TH) and maximum width of the ilium (MW) were taken using a Vernier Caliper ©, Mitutoyo, with a nominal resolution of 0,01mm and an associated error of  $\pm 0,15\text{mm}$ , and the other measurements using a digital caliper (Absolute Digimatic Caliper ©, Mitutoyo), with a nominal resolution of 0,01mm and associated error of  $\pm 0,02\text{mm}$ .

The measurements and indices taken are listed in Table 1, presented by Pasuk Mahakkanukrauh (3). Four of them (IL, PL, TH and MW) are

referenced by Buikstra and Ubelaker (6), six (PL, IL, PTAD, TH, MW and AcetD) by Steyn and Íscan (7), who presented the PTAD measurement as having low sexual dimorphism, and five (PL, IL, TH, MW and AcetD) by Steyn and Patriquin (8), with the PL measurement being considered non-discriminating.

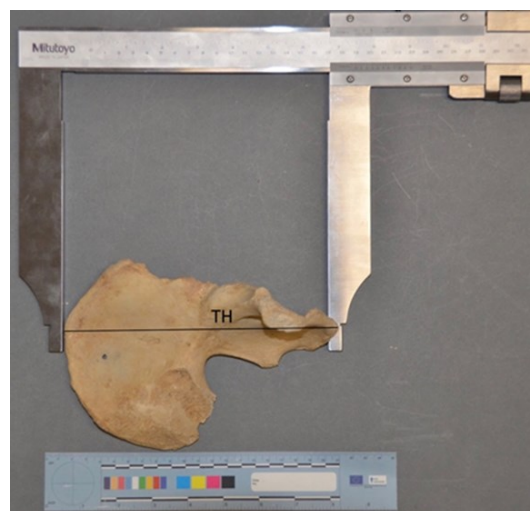


**Figure 1** Ossuary after excavations (photo obtained during the 2004 excavations of Cloister's South Wing of Academia das Ciências de Lisboa, provided by Professor João Luís Cardoso).

Regarding to the morphologic evaluation, primarily the subpubic region – ventral arc, subpubic concavity and ischiopubic ramus ridge – was analyzed according to Phenice's Method (4), the greater sciatic notch was evaluated according to P. Walker (5) (after Buikstra and Uberlaker (4)) and the preauricular sulcus was observed using Buikstra and Ubelaker (6). Finally, the pubic symphysis was studied using the Suchey-Brooks' Method (9) for topographic alterations of this structure. In Table 2 methods and respective classifications are showed. The minimum number of individuals (MNI) was calculated and all measurements were performed twice by different observers so that it was possible to assess the interclass correlation

coefficients which were after categorized with a Fleiss Scale of Agreement (10).

The Statistical Package for the Social Sciences (SPSS) software (version 26; IBM Corporation Armonk, NY, USA) was used for the statistical analysis.



**Figure 2** Measuring the total height of the os coxa with a Mitutoyo Vernier caliper.



**Figure 3** Measuring the acetabulum diameter with a digital caliper.

## Results

A minimum number of individuals (MNI) equal to 23 was obtained using the right complete hip bone and the right ischium.

Concerning to the indices, only five of the seven evaluated were used, since after the interobserver evaluation it was found that

AcetD\_MW and IL\_TH indices had an ICC below of what is considered adequate. For all eleven measurements, interclass correlation coefficients were obtained, resulting minimum values of 0.671 and maximum of 0.967, being considered between good and excellent (10). After the statistical treatment, it was found that with just one measurement, 16 females and 5 males were obtained; two measurements resulted in 7 females and 1 male classified by both, with 7 individuals being considered male and female; with three measurements, 2 individuals were considered female, 6 individuals were considered men and female simultaneously by the different measurements; it was not possible to obtain sex estimation results with more than three cross-measurements.

The minimum, maximum and mean obtained with measurements and indices are listed in Table 3. For the morphological evaluation, the values of ICC varied between 0,587 and 0,894 and it was possible to study a partial number of 84 coxal bones, of which the subpubic region characteristics were observed in 63, the greater sciatic notch in 60, the preauricular sulcus in 62 and pubic symphysis in 30 coxal bones.

Of the 63 bones where it was possible to observe the subpubic region, only 41 allowed the use of three Phenice's measurements (4), resulting 18 females and 9 males, with the rest presenting at least one ambiguous classification. In Figure 4 are listed the results to Phenice's Method (4).

When applying P.Walker's Method (5), 11 subjects were considered female, 8 probably female, 8 probably male, 3 male and 6 ambiguous.

Regarding to Buikstra and Ubelaker's Method (6), 31 females and 13 males were obtained, illustrated by Figure 5.

Lastly, the bones were analyzed with Suchey-Brooks' Method (9), resulting 19 females and 11 males.

## Discussion

Comparing morphological characteristics and linear measurements, it's possible to affirm that the results are very different for the same bones, with the morphological evaluation obtaining better results discriminating by sex that linear measurements and indices, which resulted mostly in ambiguous outcomes.

Morphological features also present a higher number of coxal bones able to be analyzed – 84 versus 57 in the application of the measurements. This is the result of the objectivity underlying the linear measurements that doesn't

allow results if one end of the measure is slightly damaged.

The values obtained for the interclass correlation coefficient (ICC) regarding the evaluation with measurements and indices were good and excellent (10). However, it was not possible to discriminate the sex of this population of coxal bones through the measures used. Most of the coxal bones were considered ambiguous and it's not observed consensus between the different measurements. Although Pasuk Mahakkanukrauh (3) has very high correlation factors for all linear measurements and indices, in a population where sex is not known, it is not possible to use these measurements and indices for discrimination according to sex. Furthermore, all the measurements considered dimorphic by Buikstra and Ubelaker (6), Steyn and Íscan (7) and Steyn and Patriquin (8) do not have discriminating characteristics in the present study.

Comparing the different morphologic methods (Figure 6), we can see how some may be better than others.

The Phenice's Method (4) estimates through the categorization of the different parts of the subpubic region, becoming way more discriminatory, since it doesn't use only one part to conclude regarding the estimation of the sex. This method also proved to be one of the best to estimate the sex because it didn't get any conflicting results.

P. Walker's Method (5) compared the greater sciatic notch of the coxal bone with a scheme that had the different forms of the structure and their correspondence with male or female. This method proved not to be the best, since it had conflicting results with other methods.

Buikstra and Ubelaker (6) analyzed the preauricular sulcus characteristics. This method had more results since the preauricular sulcus was intact in several coxal bones, which allowed us to analyze it. Even though we have more results with this method, some of them are conflicting with other methods that analyze other parts of the coxal bone.

Suchey-Brooks' Method (9) compared pubic symphysis with the available plates, which distinguished development stages and sex. Some of the results are conflicting with other methods used, which makes this method not the best for sex estimation. Also, this method isn't the most viable considering that the available plates (Figure 7) aren't always identical to the pubic symphysis of the coxal bone.



Thereby, with Phenice's Method (4) it was possible to discriminate using its 3 morphological characteristics, being this method the most reliable, since with other methods the ambiguous classification was higher.

In 1969, Phenice developed the Phenice's Method (4) supporting it was a new way of sexing the os pubis, counting with a total of 275 coxal bones, of which 95 were female and 180 were male. The percentage of correct sex estimation was 96%, proving the Phenice's Method (4) was viable.

Other previous studies also applied the Phenice's Method (4) to estimate the sex of coxal bones. In 2002, Ubelaker (11) tested this method in 198 os coxae. The sex estimation was correct in 175 bones, 79 female and 96 males. In this study 88,45% of the estimations were correct.

In 1989, Lovell (12) also tested the Phenice's Method (4) in 50 hip bones, but he also tested what would happen when this method was used by observers with different levels of experience. Of the 50 bones, it was possible to estimate the sex in 36, of which 13 were male and 23 females. The estimations were 83%  $\pm$  7% correct.

### Conclusion

Due to the discrepant results obtained in the application of different measurements on individuals of the catastrophic population of the 1755 Lisbon Earthquake, the sexual classifications obtained through these indices are not considered reliable.

As for the morphological characteristics, the Phenice's Method (4) is the one that allows to obtain more accurate results for sexual discrimination, since it evaluates three parameters simultaneously.

According to the results achieved, the methods based on the morphology of the coxal bone are more conclusive in estimating sex and, therefore, contributed more to the characterization of this population.

### Acknowledgments

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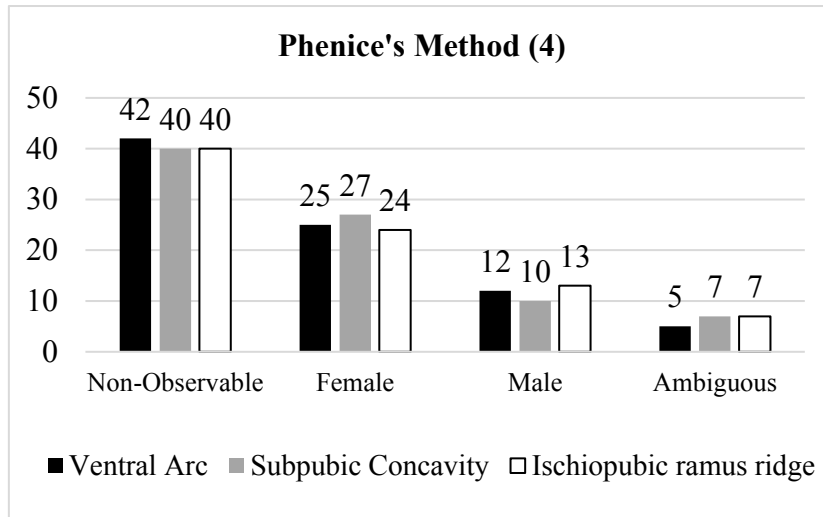


Figure 4 Results from the application of the 3 Phenice's characteristics to the 41 bones.

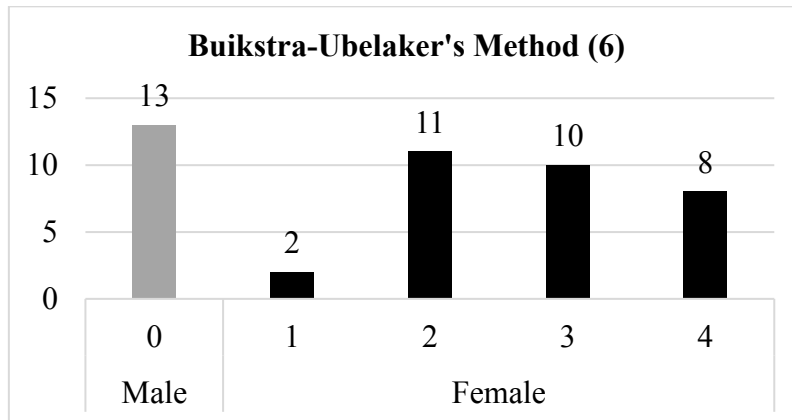


Figure 5 Results obtained with the Buikstra-Ubelaker's Method. The morphological characteristics are as follows: 0 – Male: not present; 1 – Female: Large and deep sulcus; 2 – Female: Large and shallow sulcus; 3 – Female: Narrow and well defined sulcus; 4 – Female: Sulcus is a depression of smooth walls, narrow.

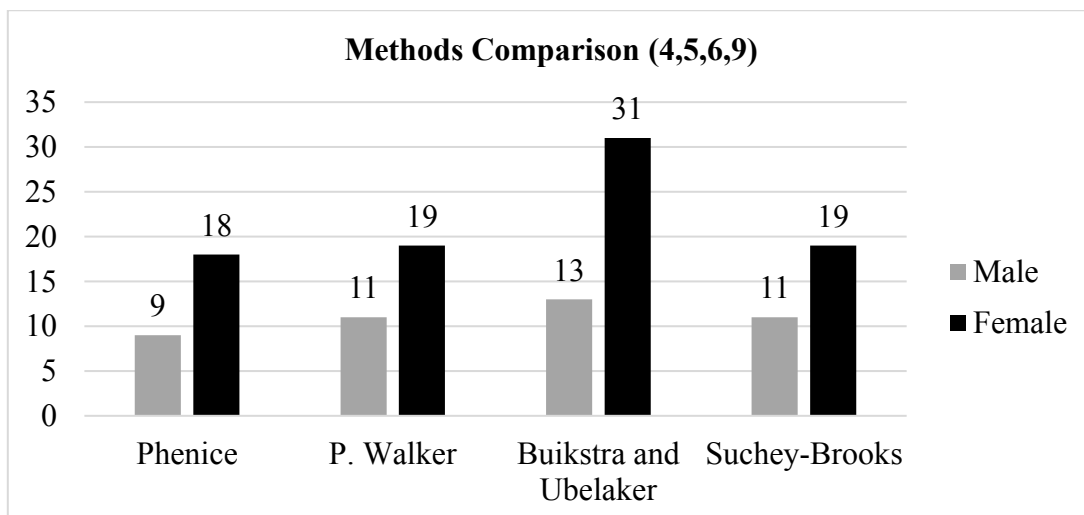


Figure 6 Comparison of the results obtained with the different methods.



Figure 7 Comparison of pubic symphysis with plate IV-2 from Suchey-Brooks' Method.

Table 1 The 7 measurements and the 6 indices (calculated from the measurements) that were applied to the coxal bone, with the respective description. Measurements and indices applied to the coxal bone.

Measurement and Index	Description	Citation
1. TH	Total height of the <i>os coxa</i> : the distance from the most superior point on the iliac crest to the most inferior point on the ischial tuberosity.	[6,7,8]
2. MW	Maximum width of the ilium: the distance from the anterior-superior iliac spine to the posterior-superior iliac spine.	[6,7,8]
3. PL	Pubis length: the distance from the point at the center of the acetabulum to the upper end of the pubic symphysis.	[6,7,8]
4. IL	Ischium length: the distance from the point at the center of the acetabulum to the point at which the axis of the ischium crosses the ischial tuberosity.	[6,7,8]
5. AcetD	Acetabulum diameter: the maximum vertical diameter of the acetabulum.	[7,8]
6. PTAD	Pubic tubercle-acetabulum length: the most superior point on the pubic tubercle to the nearest point on the acetabular rim.	[7]
7. IP	Ischio-pubic index: calculated by dividing ischium length by pubis length and then multiplying by 100.	[3]
8. PL-TH	Pubis length-total height index: calculated by dividing pubis length by total height and then multiplying by 100.	[3]
9. AcetD-MW	Acetabular diameter-maximum width index: calculated by dividing acetabulum diameter by maximum width and then multiplying by 100.	[3]
10. MW-TH	Maximum width-total height index: calculated by dividing maximum width by total height and the multiplying by 100.	[3]
11. AcetD-PTAD	Acetabulum diameter-pubic tubercle-acetabulum index: calculated by dividing acetabulum diameter by pubic tubercle-acetabulum length and then multiplying by 100.	[3]
12. PTAD-IL	Pubic tubercle-acetabular-ischium length index: calculated by dividing pubic tubercle-acetabulum length by ischium length and then multiplying by 100.	[3]
13. IL-TH	Ischium length-total height index: calculated by dividing ischium length by total height and then multiplying by 100.	[3]

Table 2 Methods, with the individual description and the respective classifications to evaluate the morphologic characteristics of the coxal bone. Methods and respective classifications to evaluate the morphologic characteristics.

Method	Description
Phenice <sup>[4]</sup>	Categorization of the subpubic region, through the analysis of the ventral arc, subpubic concavity and ischiopubic ramus ridge. 0 – Non observable; 1 – Female; 2 – Male; 3 – Ambiguous.
P. Walker <sup>[5]</sup>	Comparison between the greater sciatic notch with a scheme. For this, the bone is placed 15 cm from the diagram, aligned with the drawings. 1,2 – Female; 3 – Ambiguous; 4,5 – Male.
Buikstra and Ubelaker <sup>[6]</sup>	Analysis of the preauricular sulcus and classification according to the characteristics described: 0 – Male; 1-4 – Female.
Suchey-Brooks <sup>[9]</sup>	Comparison between the pubic symphysis and the available plates. These not only distinguish development stages, but also the sex.

Table 3 Minimum, maximum and mean obtained with linear measurements and indices (in Table 1), taken in the coxal bone, in cm regarding to measurements. Minimum, maximum and mean obtained with linear measurements and indices.

Measurements and Indices	Minimum	Maximum	Mean
TH	17,27	21,40	19,40
MW	13,04	17,54	15,08
PL	5,70	8,56	7,51
IL	5,73	7,82	6,59
AcetD	4,70	6,15	5,27
PTAD	4,34	7,23	5,41
IP	74,91	103,52	87,42
PL-TH	29,61	41,57	36,72
AcetD-MW	33,29	38,19	35,71
MW-TH	70,99	82,51	76,02
AcetD-PTAD	69,80	129,75	102,52
PTAD-IL	60,61	114,47	80,58
IL-TH	30,69	35,44	33,03