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Research Paper

Sex determination in a Spanish population based on sacrum

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ABSTRACT

Sex determination is one of the essential steps when it comes to establishing an individual's biological profile. It is important in both archaeology and forensic studies. The sacrum is not generally conserved, but in cases where it is, it can be used for determination of the sex of skeletal remains. Furthermore, the sacrum is not a commonly studied bone and has not been studied in a Spanish population. For this study, measurements of 170 sacra of individuals from the contemporary osteological collection of San José from Granada including only the adults were taken. Measurements based on the anatomical regions of the sacra were established in order to obtain some regression formulas to determine sex. Our results show that the Superior Transverse Line and Right Lateral Sacral Crest are the most dimorphic structures, achieving a 74% rate of correct classification of sex in a univariate analysis. In multivariate analysis, when the mentioned variables were combined, an 81.41% rate of correct classification was achieved. Our results show that our method can be applied with other methods at the same time to determine the sex of individuals in forensic and archaeological contexts.

1. Introduction

Sex determination is useful to complete an individuals' biological profile.[1] Knowing the sex of skeletonized human remains is important in order to estimate other parameters such as stature or age in forensic cases or diet and occupation in archaeological cases.[2–4] Specific morphological techniques based on the skull and pelvis are usually employed for sex determination.[5–8] A significant problem with relying on these bones is that they can be fragmented, broken or poorly preserved, which makes it necessary to search for new techniques to do our work as anthropologists.[3,7,9]

Anthropometry consists of the collection of measurements related to the size and proportions of bones in order to be able to estimate individuals' traits.[10,11] Those techniques are very useful when morphological traits are altered, for example when bones are broken or all the individual's parts can't be obtained, being complementary to each other and adding objectivity to our estimation.[2,12,13] In some cases, the most representative bones, such as the skull and pelvis, or even long bones, are broken so we have to search for other structures that allow us to identify the individual.[14,15] Moreover those new techniques have to be adapted to every single population with their individual traits.[16]

The sacrum is not always preserved in some contexts, but it has been demonstrated that the sacrum has enough discriminant qualities either on a morphological level[17–19] or on a metric level.[20–26] Flander, Kimura, Tawald, Plochoki or Steyn[13,22,23,27–29] studied the sacrum obtaining similar percentages but each author set different parts of the bone as the most dimorphic using their own samples. Thus, the reviewed literature clarifies the sacral dimorphism.[27–30] However, sacra have not be studied enough and specifically not enough in the Spanish population. Our study examines sexual dimorphism of sacra in that population. Our hypothesis is that sacra have enough discriminant power to create new regression formulas to determine individuals' sex in Mediterranean populations.

The objectives of our study were as follows: (1) To systematize and to evaluate the precision and accuracy of our measurements in order to assess their reproducibility; (2) To determine the level of sexual dimorphism of the sacral bone in Mediterranean populations; and (3) To develop logit regression equations for sex determination based on the proposed measurements.

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2. Methods and material

2.1. Sample

This study was conducted in a total of 170 individuals (99 males and 71 females) of Spanish origin from the Granada osteological collection. This sample is part of a large and expanding contemporary collection of identified individuals from the Granada Municipal Cemetery of San José. Complete skeletons, well preserved, of adult individuals (age range from 50 to 90 years old) from the Mediterranean group, compose the sample. Key data available about the population include sex, age, date and cause of death. Table 2 shows the size of the sample for each of the different measurements.

2.2. Inclusion and exclusion criteria and measurements

Only adults were selected for the study because sacra are fused, allowing us to take the most measurements. Nevertheless, sacra with pathologies such as osteoarthritis, ankylosis, etc. or anatomical variants such as sacralization have been excluded. Sacra were divided into four dimensions so as to define the variables based on their anatomical position. We decided to take measurements on both sides of the bone. All measurements were taken using a digital caliper with a precision of 0.01 mm. However, some measurements of some sacra were not possible for inclusion due to their state of conservation.

Measurements were established according to those defined by Wilder[26] and Flander.[22] We also considered the added or redefined measurements by other studies.17–21[,23–25,31,32] Furthermore, new measurements with the purpose of considering the greatest quantity of discriminant parts of the bone were suggested (Fig. 1). Table 1 shows the list of measurements, abbreviations and their definitions.

Altogether, 23 measurements of the sacrum were taken. To analyze the intra and inter-observer error, a further 28 randomly chosen individuals were selected so that we could take all the measurements. Both observers used these 28 individuals to do the analysis. Both observers used the same model of caliper with a minimum period of two weeks and maximum period of three months between both measurements. This number of individuals is useful to check the reproducibility of the measurements. The second observer had no prior training in measurements of sacra and the principal observer provided the second observer with the definition of the different measurements and the images of their location.

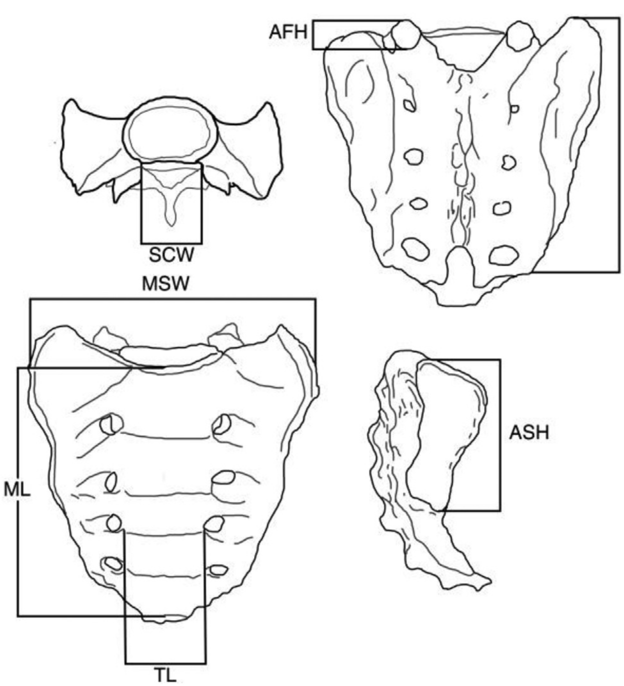

Fig. 1. Sacral measurements. (Made by the authors).

2.3. Statistics

Statistical analysis was performed using SPSS v21.0 for MacOS[33] and Microsoft Excel 2011 for Mac v 14.0.0.[34]

Our first step was to assess the intra and inter-observer error to check the reproducibility of the measurements using Linn's concordance correlation coefficient (CCC). In order to determine the level of agreement, we compared the CCC results with the criteria proposed by McBride,[35] which set four different levels of qualitative assessment as follows: almost perfect, for CCC values greater than 0.99; substantial, from 0.95 to 0.99; moderate, from 0.90 to 0.95; and poor from CCC values below 0.90.

Afterwards, normality was assessed using the Kolmogorov-Smirnov test. Then, a descriptive analysis was performed to determine the sample size, the mean and standard deviation. This analysis characterized the sample and allowed us to detect errors in the database collection as well as processing.

The homogeneity of variance and the differences between mean values of males and females were analyzed, using the Student's t-test when the homogeneity of variance was fulfilled and the non-parametric Mann-Whitney *U* test when it was not. Significant differences were defined as those where $p \le 0.05$.

Finally, a logistic regression analysis was performed to create a list of formulas that, applied to populations with similar traits, would discriminate between males and females. There were not set a minimum or maximum number of steps for the analysis. A stepwise method following the likelihood ratio to include the variables in the equations was used for this logistic regression analysis. The entry and removal probabilities for the stepwise analysis were 0.05 and 0.10 respectively. First of all, univariate analysis was performed and, subsequently, we did the multivariate analysis using the variables that showed differences between mean values. This ensures that variables were included based on their discriminant power.

Calculating the global correct percentage for each formula, independently of estimated sex, assessed the efficacy of the equations. In order to avoid errors due to the different distribution of sex in the sample, these results were sorted and weighted by sex.[36]

Coefficients and a constant for each measurement are included in the model of the logistic regression analysis for each variable. In order to obtain these data to assess the sex of an individual, a log-odd or logit must first be calculated using the following formula:

$$L_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$$

where the logit (L_i) is a linear function of the independent variable X1, B0 is the value for the constant, B1 is the first coefficient, X1 is the first measurement, and so on. The logit value can also be used to calculate the probability of female sex (pf) using the function:

$$pf = \frac{1}{1 + e^{-L_i}}$$

3. Results

3.1. Intra- and interobserver error analyses

Following the criteria outlined before, the results for interobserver error range from 0.64 to 0.95 (from poor to substantial). For intraobserver error, the results range from 0.68 to 0.96 (from poor to substantial). Table 2 shows the results for each variable.

All of the variables are concordant between both observers except for Right Lateral Crest Rope (RLCR). This variable was eliminated from the analysis.

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