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Osteometric sex determination of burned human skeletal remains

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ABSTRACT

Sex determination of human burned skeletal remains is extremely hard to achieve because of heat-related fragmentation, warping and dimensional changes. In particular, the latter is impeditive of osteometric analyses that are based on references developed on unburned bones. New osteometric references were thus obtained which allow for more reliable sex determinations.

The calcined remains of cremated Portuguese individuals were examined and specific standard measurements of the humerus, femur, talus and calcaneus were recorded. This allowed for the compilation of new sex discriminating osteometric references which were then tested on independent samples with good results. Both the use of simple section points and of logistic regression equations provided successful sex classification scores.

These references may now be used for the sex determination of burned skeletons. Its reliability is highest for contemporary Portuguese remains but nonetheless these results have important repercussion for forensic research. More conservative use of these references may also prove valuable for other populations as well as for archaeological research.

1. Introduction

Assessing the biological profile of an individual from its burned remains is a very challenging task. The heat-induced changes (such as fragmentation) make bioanthropological analyses considerably more difficult because they restrict the use of the conventional methods usually adopted in this field.[1,2] Although the implications of this are also critical to the research of archaeological remains, this is particularly troublesome for forensic science since positive identification of victims is often only possible if focused on skeletal remains. This can occur since the soft tissues which are of great use in a number of identification methods are frequently too damaged to be of use. For example, decomposition may negate facial recognition or the use of fingerprints, while high temperatures will denature DNA.[3] As a result, forensic anthropology and forensic odontology often offer the best chances for achieving positive identification, and indeed have been quite successful in doing so in the past.[4,5]

Positive identification is based on the comparison of features using ante-mortem records but the assessment of the biological profile helps to narrow down the list of individuals included in that comparative approach. Biological profiling assumes then a significant importance in this process because the determination of sex, age-at-death, stature or ancestry will allow one to do that – through the elimination process of ineligible individuals – and thus save considerable time and resources. Determining the sex of unknown individuals is usually a straightforward procedure on unburned quite complete skeletons but the same cannot be said for burned skeletons. Besides fragmentation being particularly destructive of our more morphological sexually dimorphic bones – the pelvis and the skull – heat-induced warping and dimensional changes interfere with our conventional osteometric techniques. The latter is especially damaging because it can range from a bone expansion of 4.5% to a bone shrinkage of 40.1% depending on the type of bone, its mineralization and the temperature at which it was subject to.[2,6–11] Theoretically, this should prevent the reliable use of osteometry. Nonetheless, it has been previously demonstrated that this is not necessarily true. Several authors found that sexual dimorphism was still present in the calcined bones of adults.[12–16] As a result, it has long been argued that osteometric methods may be of some use for the analysis of burned skeletal remains.[17–21] The biggest problem

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Table 1
Age and sex composition of the sample.

Age cohort	Females	Males	Total
20–29	0	1	1
30–39	1	9	11
40–49	13	16	29
50–59	17	33	50
60–69	20	50	70
70–79	32	58	90
80–89	69	52	121
90–99	15	13	28
>100	1	0	1
Unknown	0	1	1
Total	168	233	401

seems to reside less in its potential but more in determining under which conditions those methods can be applied. It has been confirmed that heat-induced shrinkage is greatest in bones heated at temperatures leading to calcination than in bones that merely present pre-calcination burning. Therefore, osteometry should be more problematic when dealing with calcined bones.

This paper focuses on the potential of osteometry to achieve sex determination in calcined skeletons. It presents new references for the sex determination of unknown individuals through the use of standard measurements of the humerus, femur, talus and calcaneus. In order to investigate this problem, a comprehensive study was carried out at a modern crematorium. The main goal was to assess if osteometric sex determination is reliably achievable in calcined bones. If so, this would be of considerable importance for the bioanthropological analysis of burned bones because opportunities to determine sex in such cases are often rare. The usefulness for forensic cases is also obvious moreover when cremains are becoming more frequently found in such contexts. Although osteometric features should ideally maintain a supporting role in sex determination and thus leave the main role to the analysis of morphological features, the former may often be the only diagnostic features at our disposal. The validation of additional techniques for sex determination would enhance the probabilities of achieving this key parameter of the biological profile.

2. Methods

Permission was granted by the municipal authorities of Porto to collect data at the local crematorium after its legal department approved our request. The cremator was a gas-fuelled Diamond Mark III model from J.G. Shelton. The research was carried out on the calcined skeletal remains of individuals that were cremated soon after death – 24–48 h. The sample was not representative of the natural population for a number of reasons. First of all, only adults were chosen for this investigation. In addition, more skeletons from males than females were analyzed because the former tended to preserve better thus allowing for a larger number of observations.

The full sample was composed of 401 individuals (168 females and 233 males) with ages ranging from 27- to 99-years-old

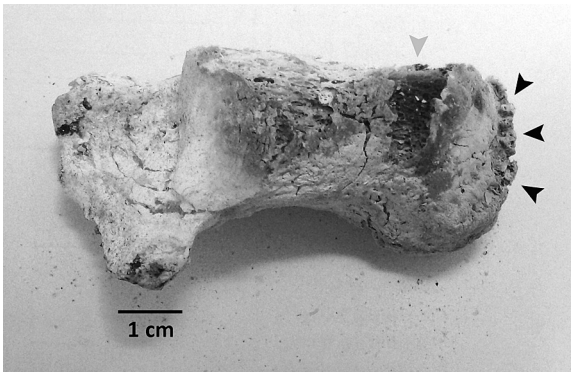

Fig. 1. Calcined calcaneus ineligible for measurement. Although it had a less than 10 mm area of black colour (grey arrow), entheseal changes (black arrows) prevented correct measurement of the maximum length.

(mean = 71.4; sd = 15.2). About 90% of the individuals were more than 50 years-old so young adults were poorly represented. When broken down by age cohorts, the 80–89 interval was the prevalent on the female sample and the 70–79 interval was the prevalent on the male sample (Table 1).

The intensity of combustion was recorded for every cremation and the descriptive statistics according to three age cohorts are given in Table 2. The duration of the cremation of cadavers ranged between 50 and 250 min (mean = 93.8). The maximum temperature of the cremations ranged between 750 °C and 1050 °C (mean = 925.8). The statistics presented in Table 2 do not include 160 individuals because, in these cases, the cremation procedure was somewhat more intricate thus complicating its codification in terms of the duration of the combustion. More specifically, an important part of the cremation was carried out while the cremator was switched off and taking advantage of the heat that had been previously accumulated inside the chamber. This allowed for the completion of the cremation without resorting to any additional fuelling. Given this, such cremations benefiting from this procedure were not used to calculate the mean durations and maximum temperatures of combustion. The latter was recorded by using 25 °C increments.

Only bones free of major osteoarthritic alterations in joint contour and major entheseal changes of the calcaneal tendon and of the distal humerus were measured after cremation (Fig. 1). This was done because these alterations are susceptible to interfere with dimensions. In addition, only the measurements carried out on bones presenting the typical colours of calcination – white, light grey and light blue[9,22] – on more than 90% of its surface were selected for this investigation (Figs. 1 and 2). Bones were subjected to three measurements with a digital calliper and the median value was then recorded in millimetres. The standard measurements included the transverse and vertical head diameters of the humerus (HHTD and HHVD), the epicondylar breadth of the humerus (HEB) and the transverse and vertical head diameters of the femur (FHTD and FHVD) as defined by Martin and Saller.[23] In addition, the maximum lengths of the talus and the calcaneus (TML and CML) as defined

Table 2
Descriptive statistics for the intensity of combustion according to sex and age cohort.

Age	*n*	Duration ♀		Temperature ♀		*n*	Duration ♂		Temperature ♂	
		Mean	SD	Mean	SD		Mean	SD	Mean	SD
0–59	21	99.3	19.8	885.7	67.8	41	98.9	23.0	931.7	72.7
60–79	29	92.8	24.4	914.7	62.9	61	95.7	27.8	934.8	68.1
≥80	54	86.0	21.4	921.8	57.9	35	94.0	21.6	942.1	51.7