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The postmortem fate of osteometric measurements: taphonomic alteration of landmarks and its implication for biological profiling

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Abstract. The aim of this research was to identify the measurements that are most frequently retrieved from buried skeletal remains to create the most applicable discriminant functions for osteometric assessments. The study sample was composed of 644 adult skeletons from IV-III BC Italy (Pontecagnano). All burials were in the supine position and individuals were buried either directly in the ground or in large stone coffins. The burial context did not present any environmental conditions that could have a detrimental effect on bone preservation either in general or differentially between anatomical regions. Due to its complexity, the skull was divided in different regions (two macro areas and five regions, plus the mandible), while the long bones and scapula were examined as anatomical units. The results show that cranial measurements cannot be reliably used for anthropological analyses, as main landmarks are frequently affected by taphonomic factors. Given the higher frequency of their preservation, postcranial measurements are more appropriate for the creation of usable discriminant functions for the construction of biological profiles.

Keywords: forensic anthropology, osteometry, taphonomy, postmortem trauma.

Introduction

Osteometry enables the quantification of physical characteristics that define the biological profile of an unknown skeleton, as well as the

understanding and appreciation of human variability. Almost all answers to questions about the biological profile (sex, age at death, stature, ancestry, ergonomic and osteobiographic indicators) can utilize metrics characterized by relevance, reliability and validity necessary for scientific evidence (Bono, 2011) in contrast to morphological assessments, generally affected by the subjectivity of the examiner (Kimmerle *et al.*, 2008).

Unfortunately, the scientific literature often presents new discriminant function analyses based on the relationship of various metric traits without taking into account the actual availability of the related osteometric landmarks. However, the stress put on the high scientific and forensic value of the data (principles of relevance, reliability and validity) seems to ignore the important issue of data availability (principle of applicability), particularly important not only for scientists but also for forensic practitioners.

The lack of discussion of this issue, with rare exceptions (Komar and Potter, 2007), is most likely due to the samples used for anthropological and forensic studies, which are represented by anatomical skeletal collections where most or all elements are preserved. Some notable examples of such collections are the Terry Collection hosted at National Museum of Natural History of the Smithsonian Institution in Washington (Hunt and Albanese, 2005), the WM Bass Donated Skeletal Collection at the University of Tennessee, and the Hamann-Todd Collection housed at the Cleveland Museum of Natural History.

These collections are based on material from departments of medicine or cadaver donations and have complete and reliable data on each specimen; these circumstances allow the samples to be considered as real anatomical specimens, almost perfectly preserved and are useful to create and test methods for biological profile assessment. While this is the optimal situation for performing morphometric analysis on skeletal remains, it does not represent the daily reality of biological and forensic anthropologists, who must often deal with bodies damaged in different ways by taphonomic events and trauma.

For this reason, as part of a larger research project conducted at the University of Tor Vergata (Borrini, 2011), it was decided to statistically evaluate how often the landmarks, and measurements associated with them, can be traced in a real sample and to evaluate the possible theoretical and practical implications.

The aim of the study is therefore to identify the bone segments with the highest rate of preservation. This can in turn aid our understanding of the measurements which we can employ in order to create reliable and accurate discriminant functions that can be used for biological profiling.

Materials and methods

The study used 644 archaeological adult skeletons from Italy (Pontecagnano). The sample was composed by 376 males and 268 females (Donatelli and Scarsini, 2007; Borrini, 2011): all of the individuals were adults as they had completed their skeletal development, therefore any factors related to incomplete mineralization of the bones have been excluded.

The burial site (Bailo Modesti and Salerno, 1998) did not show any peculiar environmental conditions (e.g. moisture, very acidic or basic soil pH, etc..) that could influence the bone preservation, either in general or between different anatomical regions.

Burial conditions were quite typical for forensic contexts: supine bodies directly deposited in the ground or in confined spaces such as stone cists (sarcophagi) that can be considered to simulate the containers sometimes used to hide bodies of victims of crime. For these reasons, the taphonomic alterations identified are surface exfoliation, delamination, warping due to the pressure of the sediment, fractures caused by the action of the earth or poor handling during recovery.

For the assessment of taphonomic alteration, the software *Taphonomy Reader beta version* (Borrini and Tumbarello, 2011) was used, even though still in an experimental stage. This Hyper Text Markup Language (HTML) software, open source and freely downloadable at the time of this research, has been developed to help anthropologists, archaeologists and forensic scientists in the analysis of contextual taphonomy. With this type of software it is possible to recognize the most common taphonomic imprints and how their combination corresponds to one or more of the eight typical taphonomic syndromes (Borrini *et al*., 2011b): forensic interest; possible forensic interest; historical remains; burial; surface exposure; animal activity; cremation or fire alteration; aquatic taphonomy.

The measurements used in this work represent the combination proposed in a forensic protocol for the osteometry of human skeletons (Borrini, 2011), based on the standards by Martin and Saller (Martin and Saller, 1957), but sorted according to a new coding system (Borrini, 2022) to avoid the problems linked to the ambiguities of previous standards. The complete list of measurements, with a table of conversion to the most common systems such as the standards proposed by Buikstra and Ubelaker (1994) or those of Howell (1973), has been presented for the first time at the Annual Meeting of the American Academy of Forensic Sciences (Borrini 2013) and later published (Borrini, 2022).

The proposed protocol also overcomes the problem presented by common anthropometry manuals that tend to «explain» the measurements

in a discursive manner, giving rise to misunderstandings and the need for interpretation. The internal structure of the text is built as a standard operating procedure (SOP) with step-by-step instructions for the operator, indicating in a clear, unambiguous and precise manner how to record each measurement, from which landmark to proceed, and which instrument to use.

Due to its complexity and in order to create a useful and scientifically valid combination of measurements, the skull was divided into different regions: the neurocranium and the splanchnocranium represent two macro areas, which were further subdivided. In the neurocranium, the calva and the base were identified, while for the splanchnocranium the orbital region, the nasal region and the palate were considered as different regions. The mandible, the only mobile bone of the cephalic district, was analyzed as a separate area. This proposed division is based on an anatomical perspective, but at the same time it allows to take measurements that describe each specific area for forensic purposes and also for traditional physical anthropological evaluations. Long bones and the scapula were studied without specific internal divisions (Tab. 1).

Area	Number of measurements
Neurocranium	24
Calva	14
Base	7
Splanchnocranium	21
Orbital region	5
Nasal region	4
Palate	4
Mandible	10
Humerus	10
Ulna	7
Radius	5
Femur	14
Tibia	10
Fibula	4
Patella	3
Sacrum	5
Scapula	8
Clavicle	6

Tab. 1. *The measurements have been used to describe each cranial region and each postcranial element.*

Results

Despite the fact that assumptions about the effect of taphonomic alteration had been made by the authors of the present work, their magnitude was not anticipated. Analyses showed that it is almost impossible to process a complete skull. Notwithstanding this unexpected result, every single measurement was analyzed.

The first significant result is that male measurements (Fig. 1), compared to those of females, are better preserved in the sample, possibly because of greater robusticity of the bones. In addition, the situation appears more severe in the cephalic area, where a complete skull, in which all landmarks are intact and all measurements can be obtained, occurs only in 0.53% of the entire sample. These findings confirm the results of a preliminary analysis conducted on this skeletal material (Borrini *et al*., 2011a).

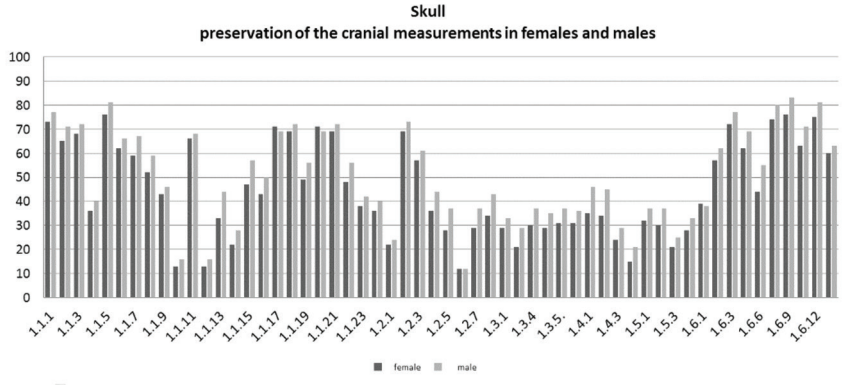

Fig. 1. C*omparison between male and female percentage of preservation of each measurement in the skull.*

Moreover, when the means of female and male values for the skull measurements are evaluated (Fig. 1), the maximum cranial breadth and the breadth of the mandibular body are the two measurements where the least taphonomic influence is evident. These two measurements are present in 64% of the entire sample. Measurements that have survived in a significant portion of the sample (more than 60%) are the maximum cranial length (61%), the bimental breadth (61%) and the mandibular minimum ramus breadth (63%).

The least preserved measurement is the maximum breadth in the middle of the face (10%). Additional measurements with a poor preservation rate (less than 15%) are the nasion-gnathion height (13%) and the porion-vertex height (13%).

After a careful evaluation of the various measurements of the skull and how they survive in the archaeological record, certain trends can be identified: more than a third of the measurements (22 of 55) can be obtained in more than half of the sample. The mandible appears to be the best preserved area as six out of ten measurements are available in more than half of the sample. The neurocranium also has a good preservation rate, as it has 12 measurements present in more than half of the sample, and only two preserved in less than 25%. The area with the worst preservation is that of the nasal region; here two measurements are present in 33% of the sample, and other two in a smaller percentage (22% for the nasal-malar cord and 16% for the nasal-malar breath).

In order to suggest proactive strategies for the creation of multivariate discriminant functions that describe specific areas of the skull, it was decided to evaluate the effective simultaneous conservation of measurements (Fig. 2), according to the areas previously identified.

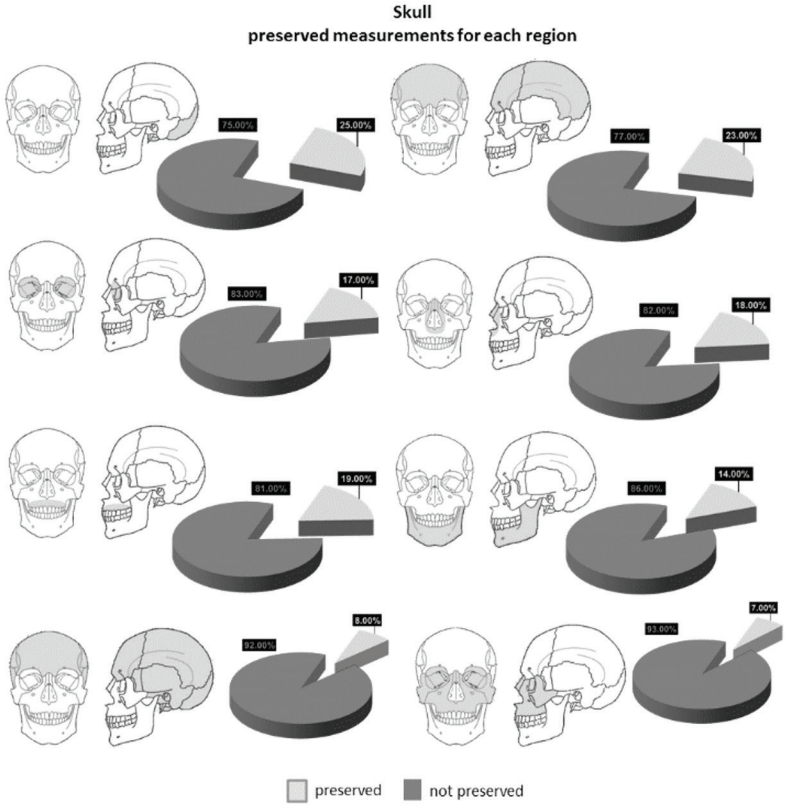

Fig. 2. *Percentage of measurements preservation in the different regions of the skull. The values represent the means between male and female data.*

Notwithstanding the rather negative result obtained for the complete skull, all individual areas are more frequently preserved for osteometric analyses: base 25%, calva 23%, orbital region 17%, nasal region 18%, palate 19%, mandible 14%.

If the areas are considered together, all the neurocranium measurements (calva and base) are present in only 8% of samples; similarly, the splanchnocranium, which includes the palate, facial and nasal areas, can only be measured in 7% of cases.

An extensive study of postcranial elements detected a uniform trend in long bones, whereby metaphyseal landmarks are preserved most frequently (approximately 80%), followed by those of the epiphyses (about 50%).

Long bone lengths seem more affected by diagenetic phenomena and all the measurements show differential preservation by sex and laterality in favour of male and right-side samples. Fig. 3 shows an example of this trend for the humerus.

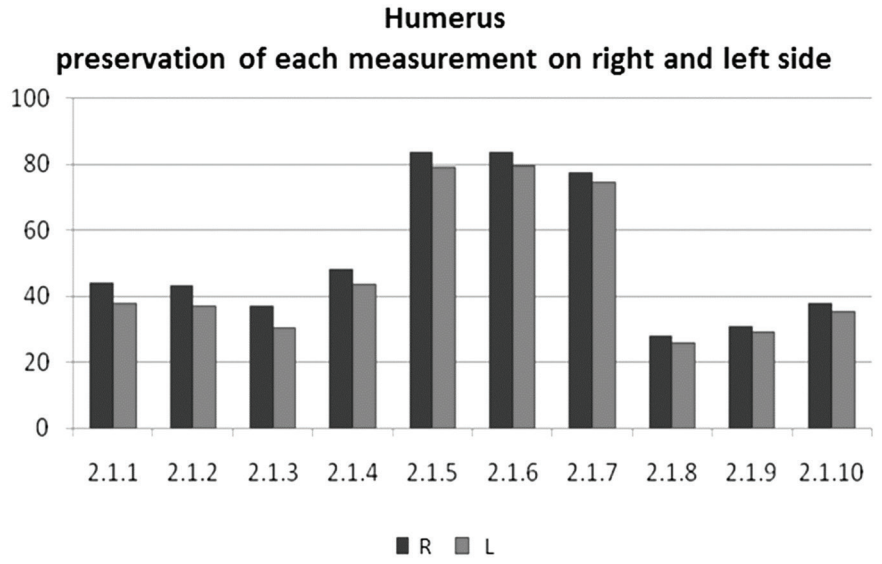

Fig. 3. E*xample of differential preservation by laterality in long bones measurements. The values represent the means between male and female data.*

In addition to the long bones, the sacrum, patella and scapula have been analyzed. With the exception of the scapula which will be discussed below, generally all the measurements seem to be preserved in no less than 50% of the sample. Only the inferior breadth of the sacrum reaches levels of preservation which do not exceed 35%, on average between male and female.

Particularly dramatic is the situation of the scapular body, where measurements are present in less than 5% of the cases, and the only high values are observed for the glenoid cavity, which is present in about 75% of all cases.

Discussion

The results of this study demonstrate a greater preservation for measurements in males, and the very low probability to have a complete skull to process. This leads to various possible conclusions on the feasibility of methods that are treated as a comprehensive analysis of the cephalic district.

The differences detected between preservation of bone measurements in the different skull areas could originate from the nature of the bones on which they are found: the mandible, for instance, seems more robust and generally easier to reassemble when reduced in fragments. In contrast the splanchnocranium, anatomically characterized by thin plates and fragile bones, displays poorer preservation.

The most resistant landmarks and the related measurements seem to be scattered in the different skull areas, consequently an evaluation of the interdependencies between the measurements from different skull regions is planned as a continuation of this project.

In long bones, low preservation of length measurements could be related to the location of the landmarks on the ends of the bones, usually placed on fragile epiphyses and processes. The observed differential measurement preservation by sex and laterality is instead presumably related to sexual and functional characteristics (Capasso *et al.*, 1999; Danforth and Thompson, 2008); male and right side samples seem to be the ones best preserved.

The poor preservation obtained for the scapula is probably due to the particularly thin and fragile structure of this bone. In addition, its anatomical position increases taphonomic destruction: in supine bodies, the scapula could be more subjected to diagenetic phenomena from stagnation in moisture and in decomposition fluids. Better results observed for the glenoid cavity support this statement in view of its morphological (greater thickness) and topographical (lateral placement) characteristics, shielding this area from the issues that affect the scapular body.

Conclusion

Although the length of time since burial can potentially modify the rates found in this study, these data shed light on some interesting trends of measurement degradation in buried bodies. Therefore, the authors suggest a

reflection regarding methods of statistical analysis for bone measurements, both for physical and forensic anthropological studies.

In anthropology, the skull is the most analyzed anatomical area, therefore the predominance of some single measurements or small cranial regions would support the idea of developing statistical methods localized to specific anatomical regions or individual measurements. Otherwise, the required measurements may not be available.

In general, new anthropometric functions for biological profiling based on bone measurements will need not only to focus on principles of relevance, reliability and validity necessary for scientific evidence, but also on the availability of measurements and their applicability of the function.

If a highly accurate function obtained from an anatomical collection is rarely applicable, it risks being impractical and therefore not useful to scientific research and forensic investigations.

In conclusion, the authors advocate that the principles of relevance, reliability and validity for good scientific evidence in the future, should be complemented with the principle of applicability.

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