# CREMATION UNDER FIRE: A REVIEW OF BIOARCHAEOLOGICAL APPROACHES FROM 1995 TO 2015

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## ABSTRACT

The study of bioarchaeological evidence associated with burials is essential for achieving a global perspective on cremation as a funerary practice, its chronological and geographical distribution, as well as its inner socio-cultural and technological diversity. However, for that purpose, similar and consistent analyses must be adopted by bioarchaeologists to enable intra- and inter-sites comparisons. The 1995-2015 literature encompassing 84 geographically representative articles concerning bioarchaeological studies of burned human skeletal remains is reviewed herein. The objective was to assess methodological variability. Information concerning colour, fragmentation, skeleton completeness, 'skeletal region' representation, non-human funerary assemblage, pre-burning condition of the remains, minimum number of individuals, biological profile, trauma and pathologies was considered. The results demonstrate that certain methods were used by almost all researchers. That was the case for colour description (91%), skeleton completeness (91%), minimum number of individuals (96%), age-at-death (100%) and sex of the individuals (95%). Researchers are much more divided about the implementation of the remaining methods. Methodological choices also vary. The asymmetries in the selection of the analyses that are undertaken can lead to different interpretations and conclusions of the contexts under study. This may prevent consistent comparisons within the same site and between different sites. We emphasize the need for bioarchaeologists to discuss and standardize analytical procedures for studying cremated remains.

Keywords: biological anthropology; osteoarchaeology; burned bones; funerary practice; human remains.

## 1. Introduction

Our main goal here is to review and discuss analytical approaches used by biological anthropologists to examine burned skeletal remains from archaeological contexts. The analysis of a human skeleton (burned or unburned) is seldom straightforward. Bioarchaeologists do not always pose the same set of questions. This can impair the study of cremation from a much needed global perspective as advocated by Williams (2008) and Cerezo-Roman and Williams (2014). Moreover, methods tend to be chosen to suit the characteristics and preservation of the skeletal remains.

Despite their varied methodological approaches, biological anthropologists tend to be coherent when dealing with unburned remains. Some methods are very popular. This denotes a good degree of cohesion within the community. Techniques may vary regionally due to inter-population variability but the methods of choice tend to be the same when examining unburned human skeletal remains. However, that does not seem to be the case with burned skeletal remains, since the analyses and procedures for their study are more diversified. This may, in part, be due to the challenges that heat-induced changes pose to biological anthropologists. When subjected to heat, skeletal remains will change their appearance and structure (Figure 1). Changes in colour, dimensions, mass (which is more often described as weight in the literature), porosity and crystal structure may occur, depending on heat intensity (Thompson, 2004). Fractures and warping may also ensue. For an in-depth description of heat-induced changes see Mayne-Correia (2002) and Thompson (2004).

A discussion of the way that bioanthropologists study burned human skeletal remains from archaeological contexts is much needed. In order to do that, a retrospective study is necessary to identify which analyses authors believe to be more important. We hope that this article will serve as groundwork and thus contribute to that discussion.

## 2. Material and Methods

We undertook a bibliographic revision to assess which analyses biological anthropologists chose for the examination of burned human skeletal remains from 1995 to 2015. This brief period was chosen to ensure that all the papers shared the same *zeitgeist*. Given the impossibility of considering all relevant papers, we assembled an approximately representative sample of 84 papers for our review. Several types have been used. These range from conventional articles (n = 64) to grey literature, such as theses (n = 5) and technical reports (n = 16). All included bioarchaeological examinations of burned human remains. The main criterion used for the selection of papers was their accessibility. The sample included all papers that we were able to gather from online repositories, journals or by direct requests addressed to the authors. Some were excluded from the sample because bioarchaeological methods were not described in detail and/or to avoid the inclusion of too many papers from the same author or authors. Although most were from authors based in European institutions, an effort was made to include papers from other regions. Thus, 27 countries from 4 continents were represented (Table 1). Papers from African countries were not found or were not accessible. The archaeological sites examined in these papers derive from 22 countries. Most were written by authors in France and the United Kingdom.

The papers were examined to assess what information authors regarded as important in a bioarchaeological analysis. For each paper, the undertaking of specific analyses was coded as 0 (not done) or 1 (done). The individual analyses considered can be consulted in Table 2 which provides a description of the focus, key information and relevancy of each analysis. Key information focused on the relative frequency of specific methods or techniques chosen by the authors to carry out those analyses or on the specific questions authors asked. The frequencies of each analysis were calculated.

No additional key information was collected in four cases. With the exception of metric methods for non-adults and microscopic methods such as osteon counting and tooth cementum annulation which are both rarely used in the bioarchaeological analysis of burned remains, the estimation of skeletal age-at-death based on morphological features is not dramatically impaired by heat-induced changes. Therefore, we concluded that a complete documentation of all methods adopted by authors was not useful. Also, no additional key information was gathered regarding trauma and pathologies since these are very variable from skeleton to skeleton and no systematic observation could be applied to all of them.

## 3. Results

The frequencies of specific analyses and respective key information are given in Table 3. The description of colour was addressed by most authors to estimate the maximum temperature to which skeletal remains had been subjected (*e.g.* Lenorzer 2006; Liston 2007; McIntyre 2011; Zachar et al. 2013). In this respect, other methods such as the ones based on crystallinity changes or histology were not used by any author, although this kind of approach has been investigated and validated for more than 20 years (for a review see Ellingham et al. 2015).

The most popular method to describe fragmentation was based on the measurement of bone fragments, although different parameters were often reported – such as the largest fragment; the mean size of fragments; and the range between the smallest and the largest fragments. The mass of sieved skeletal remains was also frequently reported (*e.g.* McKinley 1995; Silva 2015; Van den Bos and Maat 2002). In the last, 70% of the papers were from British authors and all used the sieving meshes recommended in British guidelines (*e.g.* McKinley and Roberts 1993; McKinley 2004). The authors who chose to qualitatively describe fragmentation used terms such as "poor fragmentation" or "small fragments" (*e.g.* André et al. 2013; Minozzi et al. 2006). Of particular note was the use of methods based on the recommendations of Buikstra and Ubelaker (1994) to record bone completeness although this does not provide a precise description of fragmentation. Other methods were used less frequently. Hałuszko (2013) used an approach based on the amount of fragments per bone mass category. In two other papers (Ansieau and Polet 2003; Polet 2003), the authors decided to report the number of fragments present in each urned cremation.

By a large margin, skeletal mass was the preferred method to report the completeness of the skeleton (*e.g.* Cavazzutti and Salvadei 2014; Squires 2011; Veselka and Lemmers 2014; Wahl 2008). Among the papers that reported the representation of skeletal regions, the class "skull-trunk-upper limbs-lower limbs" was the most usual (*e.g.* Blaizot 2005; McKinley 2008; Rottier et al. 2012; Subirá et al. 2011). A large diversity of classes was used. Some included almost every bone (*e.g.* Ansieau and Polet 2003; Scott et al. 2010; Sołtysiak and Fazeli Nashli In press)

The estimation of the pre-burning condition of human remains was a concern for 55% of the authors. Heat-induced features such as warping and fractures were the most used indicators. The analysis of the frequency of bones with labile joints, which may indirectly help to assess the pre-burning condition of human remains, was only explicitly carried out by one author (Lemmers 2012). Inferences from objects suggestive of the burning of whole bodies, such as clothing artefacts (*e.g.* buttons; fibulae) (Gonçalves et al. 2015b), were never considered.

The minimum number of individuals (MNI) was estimated by almost all authors (96%), but it should be noted that one third of them did not disclose the method they used. Despite this, it became clear that the skeletal mass method, which is almost exclusively used to examine burned remains, was much less frequently adopted than were other methods. An attempt to estimate age-at-death was always included (*e.g.* Anderson and Parfitt 2002; Boyle 2012; Cavazzutti and Zamboni 2012), although this was sometimes prevented by poor skeletal preservation. While almost all authors (95%) tried to estimate sex, the lack of diagnostic features generally meant that this was impossible. Stature (*e.g.* Baerlocher et al. 2012; Smits 2013) and ancestry (*e.g.* Potter et al. 2011; Schmidt et al. 2008) estimations were rarely attempted (3.6%). Finally, the description of trauma and pathologies – or the reporting of their absence – was carried out by 67% of the authors (*e.g.* Arabaolaza 2014; Garcia Prósper et al. 2002/2003; Gómez Bellard 2002; Hernández 2004; Slobodyan 2014; Mendonça de Souza et al. 1998).

In summary, colour description, age-at-death, sex, the minimum number of individuals and the inventory of remains were the most frequently analysed parameters. The less frequent analyses were the ones focusing on the representation of skeletal regions and the estimation of pre-burning conditions. These were undertaken in only about 50% of the papers, thus demonstrating some lack of cohesion among researchers.

## 4. Discussion

### 4.1. *The preference for some analyses was regionally based*

The high frequencies of analyses regarding the inventory of remains and the estimation of age-at-death, sex and the minimum number of individuals were expected since these are related to the assessment of the biological profile. This is the main focus of bioanthropologists. Other parameters such as the representation of skeletal regions were less often reported, possibly because they are very specific to the analysis of burned skeletal remains and therefore may be less known by bioanthropologists who only examine cremations occasionally. An exception was the description of colour for inferring the maximum burning temperature. This was undertaken by the majority of authors, thus demonstrating that it is a well-established procedure.

Although analytical goals tended to be shared by most researchers, some were clearly more popular in some regions than in others, and this is apparently due to the influence of what may be called bioarchaeological ‘schools’, especially in Europe. Clearly, there seems to be a British school that is strongly influenced by the work of Jacqueline McKinley (*e.g.* 1989). We can also point to a French school influenced by the archaeothanatological teachings of Henri Duday (*e.g.* Duday et al. 2000), and a Spanish school which mainly stems from the work of Reverte Coma (*e.g.* 1990) and Gómez Bellard (*e.g.* 1996). Other schools may exist but could not be identified from our sample. There may, for example, be a German school influenced by Joachim Wahl (*e.g.* 1982).

The disposition of human remains inside cremation urns, which is used to find out if the deposition of remains followed a specific logic (e.g. cranium on top), was not taken into consideration in this review because it cannot be applied to all contexts involving burned skeletal remains and would therefore bias the results. Nonetheless, this procedure was largely followed by authors under the influence of the French school, for example including French (*e.g.* André et al. 2013; Duday et al. 2000) but also Italian researchers (*e.g.* Cavazzuti 2011; Cavazzuti and Salvadei 2014), but less so by others.

*4.2. Current descriptors prevent inter-skeletons comparisons of fragmentation*

Large asymmetries were observed regarding the methods used to assess the pattern of fragmentation of skeletons. Fragmentation is the result of all destructive procedures, including burning, affecting the remains from the moment of death of the individual until anthropological analysis in modern times (McKinley 1994a). Therefore, in most cases, it is difficult to use fragmentation to make inferences about the destructive power of the burning event itself or about any other related funerary procedure that followed (*e.g.* intentional crumbling). Although inter-skeleton comparisons may be possible in some cases, the fragmentation description usually just gives an indication of the general condition of the remains. Most fragmentation descriptors are probably effective in doing just this. However, they lose their efficiency if the goal is to make intra- and inter-context comparisons. A procedure that can be applied objectively in every case allowing unbiased comparisons and that minimizes the risk of further fragmentation is yet to be developed.

The British school puts an emphasis on weighing sieved fractions combined with the measurement of the largest fragment (*e.g.* Gamble and Fowler 2012; McIntyre 2011; McKinley 2008). This procedure was much less frequently used in other regions (*e.g.* Georges et al. 2005; Silva 2015) - possibly because some authors feel that it may cause additional fragmentation to skeletal remains as argued by Lorenzo (2015) and Waterhouse (2013). Fragment measurement also seems to have its own problems, since skeletons may have different sizes and may be affected differentially by heat-induced dimensional changes. For example, fragments of 2 mm in one skeleton may actually indicate less fragmentation than fragments of 3 mm in another skeleton if the former skeleton was from a smaller individual or was subjected to larger heat-induced shrinkage, or both. This problem is also present in methods involving mass, including sieving. In addition, indicators such as mean mass per fragment may be deceiving since they do not take into account the non-normal distribution of the mass that is expected in burned skeletal remains. High levels of skewness and kurtosis are expected since the amount of smaller fragments is frequently much higher than medium and larger fragments. Therefore, heavy-tailed distributions for this parameter are common. Also unusually heavy outlier fragments can interfere with the result making mean mass a poor indicator. Even if conditions to compare fragmentation among skeletons are met, all procedures seem to have their problems. Therefore, a more objective procedure is needed, ideally one that is unaffected by heat-induced changes and that can be applied to all cases.

*4.3. No method guarantees a reliable assessment of skeleton completeness*

Another aspect that requires a more adequate method than the existing ones is skeleton completeness. Both inventory and mass-based methods have clear limitations. Inventory is not a very successful procedure because burned skeletal remains usually have large portions of anatomically unidentifiable fragments. Only a limited inventory is thus provided which can be quite distant from the real one.

The approach based on skeletal mass results from the assumption that a comparison with reference values obtained from modern crematoria may provide an approximate indication of how complete the remains are (Duday et al. 2000; McKinley 1993). However, the selection of a specific reference is problematic because skeletal mass is extremely variable between individuals and depends on factors such as age, sex, regional affinity or burning intensity (Person, 1996; Bass and Jantz 2004; Chirachariyavej et al. 2006; Gonçalves et al. 2013a; Malinowski and Porawski 1969; May 2011; McKinley 1993; Van Deest et al. 2011; Warren and Maples 1997). Therefore, it is extremely difficult to indicate/propose a reference value against which bioanthropologists may compare their findings. Besides that, the post-excavation skeletal mass may be considerably lower than the original mass of the assemblage, as demonstrated by Harvig and Lynnerup (2013). Several authors were well aware of the problem of recording skeleton completeness and tried to minimize it by both inventorying and documenting mass. Again, a more reliable method is required.

*4.4. Incomplete anatomical identification compromises the assessment of skeletal region proportion*

Bioanthropologists seemed divided about reporting the representation of each skeletal region as a function of total skeletal mass. Among those who reported it, a large array of categorizations was adopted. Clearly, the "skull-trunk-upper limbs-lower limbs" classification was the most popular choice among French and British authors (*e.g.* Blaizot 2005; McKinley 2008; Rottier et al. 2012). However, this alternative has one disadvantage. For some long bone fragments, it may be difficult to attribute them either to the upper or the lower limbs. This often leads to the creation of a category of "undetermined long bones" which will bias a comparison with skeletal mass reference values, which have been obtained from unburned skeletons with completely identified bones and teeth (Lowrance and Latimer (1957) and Silva et al. (2009)).

One possible solution to this problem could be the regression equations formulated by Gonçalves et al. (2015a) who estimated the expected proportion of each region on a skeleton-by-skeleton basis based upon their investigation of 129 skeletons burned at a modern crematorium. However, further validation of these equations is required since they are based on the percentage that the mass of anatomically identified fragments represents in terms of the total skeletal mass. Since anatomical identification may vary from person to person, the equations may not be valid for general use. Alternatively, the shortcoming of the "skull-trunk-upper limbs-lower limbs" class can be partially eliminated if the "skull-trunk-limbs" classification is used instead. Even in this case, a substantial amount of bones will end up in the bag of undetermined bones, thus leading to a predictable bias.

*4.5. Evidence of pre-burning condition is rarely conclusive*

The estimation of the pre-burning condition of human remains is important because it can help reconstruct funerary practices, especially in archaeological contexts. In brief, this estimation may indicate if the burning was carried out as a primary or a secondary practice. It is likely that the only clear indicators of fleshed bodies are the ones related to tissue shielding – leading to typical patterned thermal alteration – and to traumatic injury of burned bone (for a review, see Symes et al. 2014). When the skeleton is uniformly burned – as in complete oxidation – or presents no trauma, the pre-burning condition is more difficult if not impossible to assess with certainty. Other indicators are, forcibly, seldom used. For example, pre-burning condition can be inferred from bones in anatomical position resulting from primary depositions but it cannot be inferred from secondary depositions as in urned cremations. The presence of soft tissues can also be used as an indicator of the pre-burning condition but this is rare. However, skeletal remains can always be examined for the presence of features such as warping and thumbnail fractures but these are not entirely reliable indicators of the pre-burning condition (Gonçalves et al., 2011, 2015b). The best option is probably to use as many indicators as possible - a strategy adopted by many authors (*e.g.* Arabaolaza 2013; Gamble and Fowler 2012; Schifauer and Lamotte 2014).

*4.6. The burials were analysed as a whole*

The artefacts associated with the human remains were not always described. At first sight, this could be interpreted as the result of bioanthropologists giving exclusive attention to the human remains without taking into consideration all the other aspects of the burial. However, the fact that about one third of the papers did not include such description is somewhat deceiving. In multidisciplinary reports, the description of funerary artefacts is usually to be found in the archaeological section. Some reports that only included the bioanthropological examination made no mention of artefacts. This deflated the overall relative frequency of artefact description which must therefore be assumed to be a minimum figure. However, most articles and theses do indeed include this description. In general, most bioanthropologists described artefacts as well as other archaeological data and seemed to be well aware of the multidisciplinary approach that is required to have a more comprehensive view of the bioarchaeological context.

*4.7. The minimum number of individuals may often be underestimated*

Estimating the minimum number of individuals is very complicated due to fragmentation and the usually large portion of anatomically unidentified fragments. Doubled or multiple bones and teeth as well as incompatible ones may not be recognized as such. Assemblages where parts of the skeleton have been anatomically identified with greater success will usually lead to more reliable MNIs and vice-versa. However, only in rare cases will the certainty be unchallengeable. Even in modern crematoria, cremations from several individuals get accidentally commingled (Warren 2008). That is probably why some authors have chosen to complement those more popular methods with an analysis of skeletal mass. This approach is useful in cases involving very heavy remains that fall well outside the range of individual skeletal mass documented in modern crematoria (Gonçalves et al. 2015a). Then, a minimum number of more than one individual can be proposed. The usefulness of skeletal mass for the assessment of the minimum number of individuals seems to be limited to that. Very light skeletal remains can nonetheless include bones and teeth of several individuals. Once again, the combination of several methods seems to be required for a more reliable estimation.

*4.8. Biological profile parameters were differently addressed*

Our bibliographic review suggested that most authors believed that the estimation of the four profiling parameters – ancestry, age at death, sex and stature – are affected differently by heat-induced changes. The low estimation frequency of ancestry was probably in part related to the fact that many discriminant features are located in the viscerocranium and the dental crowns which tend to preserve poorly in burned skeletal remains (Fairgrieve 2008). Also, this parameter is rarely estimated in archaeological contexts, especially in Europe. Among the three papers describing ancestry, two were from America (Schmidt et al., 2008; Potter et al., 2011) and only one was from Europe (Pereira, 2014) although European papers represented almost 85% of the sample. Therefore, the low frequency may be in part related to the geographical location of the sites included in our sample.

A greater degree of confidence was placed on age-at-death, probably because it is mainly based on morphological features that are less affected by heat-induced warping, fractures and dimensional changes. Although a lot of confidence was put on morphological features for sex estimation, only a third of authors attempting to estimate sex put their trust in metric features. Even when this was the case, the vast majority of authors used them in combination with morphological features. Therefore, metric techniques were mistrusted due to heat-induced dimensional changes and fragmentation. This was certainly the reason why so few authors chose to estimate stature as well. The possibilities of i) using correction factors for shrinkage (Buikstra and Swegle 1989); ii) metric references for sex classification that were specific for calcined bones (Gonçalves et al. 2013b; Van Vark et al. 1996; Wahl 1996); or iii) enlarging the confidence intervals of the measurements (Gonçalves In press; Fairgrieve 2008) were insufficient to convince most authors to adopt them.

## 5. Conclusion

The contribution of bioarchaeologists to the study of cremation is critical since archaeological evidence can provide information concerning several stages of the act of cremation (Cerezo-Román and Williams 2014; McKinley 1994b; Williams 2008). However, if bioarchaeologists hope to approach broad cross-cultural themes and simultaneously understand the chronological and geographical diversity of cremation-related funerary practices, as advocated by Williams (2008), they need to rethink and standardize their procedures.

Guidelines, updates and recommendations for both archaeological and forensic examinations have been published (Arora et al. 2010; Gómez Bellard 1996; Duday et al. 2000; McKinley 2004; Symes et al. 2008; Ubelaker 2009; Kurila, 2015) but none was able to influence the majority of researchers. What is apparent from this review is that guidelines tended to be followed regionally and in turn, this tended to prevent inter-regional comparisons as well as standardized examinations. Another reason is probably the lack of reliability that many researchers still link to some of the procedures regarding the analysis of burned skeletal remains due to heat-induced changes (for a review, see Thompson 2005).

Despite recent efforts for the improvement of methods, more research is needed to validate them. In addition, the latest methodological proposals are not being applied generally, thus increasing asymmetry. Therefore, a comprehensive discussion is needed to standardize procedures that may allow for enriched intra- and inter-sites comparisons.

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FIGURE CAPTION

**Fig 1 Left radius from skeleton CEI/XXI 51 of the Coimbra 21st century identified skeletal collection (on the left side of the picture) and its experimentally burned right antimere (on the right side). Heat-induced warping as well as colour, fracture and size changes are clearly visible. Mass reduction of 40% was also observed (Photo was taken under the HOT project: www.hotresearch.wix.com/main)**

TABLES CAPTIONS

**Table 1 A distribution of articles by country and continent according to the location of the archaeological site and to the affiliation of the senior bioanthropologists.**

**Table 2 Analytical approaches and related key information undertaken during bioarchaeological investigation. % refers to relative frequency.**

Figure 1 BLACK & WHITE

Click here to download Figure Fig 1 - Black&white.jpg

Figure 1 COLOUR

Click here to download Figure Fig 1 colour.jpg

Table

**Table 1 Papers distribution by country and continent according to the location of the archaeological site and to the affiliation of the senior bioanthropologists.**

| Continent | Country | Location of context | Affiliation of the bioanthropologist | References |
|---|---|---|---|---|
| Europe | UK | 12 | 12 | Anderson and Parfitt (2002); Roberts (2003); McKinley (1995, 2008); Silva et al. (2007/2008, 2009/2010); McIntire (2011); Squires (2011); Boyle (2012); Gamble and Fowler (2012);Arabaolaza (2013, 2014); Inskip (2013); Cataroche and Gowland (2015) |
| | France | 11 | 13 | Duday et al. (2000); Rouquet (2003); Bendezu-Sarmiento (2004)*; Blaizot (2005); Georges et al. (2005); Lenorzer (2006); Munoz (2007)*;Pons et al. (2008); Ancel (2010); Herpöel (2011); Rottier et al. (2011); André et al. (2013); Schifauer and Lamotte (2014) |
| | Portugal | 9 | 10 | Silva and Cunha (1997); Matos (2004); Martins and Matos (2005); Rocha et al. (2005); Silva et al. (2007/2008)**; Tomé (2008); Silva and Santos (2008/2009)**; Gonçalves et al. (2010); Pereira (2014); Silva (2015)* |
| | Spain | 8 | 7 | Goméz Bellard (2002); Garcia Prósper et al. (2002-2003); Martín Córdoba (2007);De Miguel Ibañez (2010); Subirà et al. (2011); De Miguel Ibañez et al. (2014); Lorenzo (2015); Silva (2015)** |
| | Italy | 6 | 6 | Rubini et al. (1996); Trucco et al. (2005); Minozzi et al. (2006); Cavazzutti and Zamboni (2012); Cavazzutti (2011); Cavazzutti and Salvadei (2014) |

**Table 1 Papers distribution by country and continent according to the location of the archaeological site and to the affiliation of the senior bioanthropologists (cont.)**

| Continent | Country | Location of context | Affiliation of the bioanthropologist | References |
|---|---|---|---|---|
| Europe | Greece | 6 | 4 | Agelarakis et al. (2001); ; Liston (2007)**; Ubelaker and Rife (2007)**; Aidonis (2011); Antikas (2012); Moutafi (2013) |
| | Netherlands | 5 | 6 | Van den Bos and Maat (2002); Smits (2003); Lemmers (2012, 2014*); Drenth and Ogestijn (2014); Veselka and Lemmers (2014) |
| | Belgium | 2 | 2 | Ansieau and Polet (2003); Polet (2003); Lemmers (2014)** |
| | Romania | 2 | 2 | Soficari et al. (2008); Lazăr and Băcueţ-Crişan (2011) |
| | Denmark | 2 | 1 | Becker (2001)**; Harvig et al. (2013) |
| | Poland | 1 | 2 | Haluszko (2013); Sołtysiak and Nashli (In press)* |
| | Czech Republic | 1 | 2 | Jarosova (2012); Zachar et al. (2013)* |
| | Germany | 1 | 1 | Wahl (2008) |
| | Ukraine | 1 | 1 | Slobodyan (2014) |
| | Switzerland | 1 | 1 | Baerlocher et al. (2012) |
| | Bulgaria | 1 | 1 | Russeva and Kondova (2005) |
| | Albania | 1 | 0 | Munoz (2007)** |
| | Slovakia | 1 | 0 | Zachar et al. (2013)** |

**Table 1 Papers distribution by country and continent according to the location of the archaeological site and to the affiliation of the senior bioanthropologists (cont.)**

| Continent | Country | Location of context | Affiliation of the bioanthropologist | References |
|---|---|---|---|---|
| America | USA | 3 | 6 | Becker (2001); Ubelaker and Rife (2007); Duncan et al., (2008); Schmidt et al. (2008)*; Owens (2010)*; Potter et al. (2011)* |
| | Brazil | 2 | 2 | Mendonça de Souza et al. (1998); Ulguim (2015) |
| | Mexico | 2 | 1 | Hernández (2004); Duncan et al. (2008)** |
| | Canada | 0 | 1 | Liston (2007) |
| Asia | Philippines | 1 | 1 | Lara et al. (2013) |
| | South Korea | 1 | 1 | Lim et al. (2015) |
| | Iran | 1 | 0 | Sołtysiak and Nashli (In Press)** |
| | Kazakhstan | 1 | 0 | Bendezu-Sarmiento (2004)** |
| Oceania | Easter Island (Chile) | 1 | 0 | Polet (2003)** |
| | Vanuatu | 1 | 0 | Scott et al. (2010)** |
| | New Zealand | 0 | 1 | Scott et al. (2010) |
| Total | | 84 | 84 | |

*Reference refers to author affiliation only; **Reference refers to site location only; All other references refer to both fields.

**Table 2 Analyses and related key information recorded during this investigation to assess how frequently they were reported in research papers.**

| Analyses | Key Information | Comments |
|---|---|---|
| Colour Description | 1.Maximum temperature estimation | Heat-induced colour is roughly correlated with maximum temperature and is sometimes used to estimate the latter (e.g. Etxeberria 1994; Sandholzer et al. 2014; Shipman et al., 1984; Walker et al., 2008). |
| | 2. Skeletal position reconstruction | Skeletal colour pattern can be used to infer the position of an individual during the cremation (e.g. Symes et al., 2008; Symes et al., 2014). |
| Fragmentation | 1.Measurements<br>2. Qualitative description<br>3. Sieving<br>4.Mass per fragment<br>5.Mass per skeletal region | The description of fragmentation is variably carried out through a multitude of methods that range from empirical qualitative to quantitative approaches (e.g. Duday et al., 2000; McKinley, 1989). |
| Skeleton Completeness | 1.Skeletal mass<br>2. Skeletal inventory | Although conventional inventories of the remains are sometimes reported, skeleton completeness can also be calculated by weighing the remains (e.g. Duday et al., 2000, McKinley, 2004). |
| Skeleton Regions Representation | 1.Skull-trunk-upper limbs-lower limbs classes<br>2.Skull-trunk-limbs classes<br>3.Other classes | The representation of each anatomical region is frequently reported for archaeological cremations. However, many anatomical categorizations are used for that purpose (e.g. Duday et al., 2000; McKinley, 2008). |
| Funerary Assemblages | None | The description of associated objects provides important information about funerary practices. It is therefore important to assess how often this information is included in bioanthropological papers. |

**Table 2 Analyses and related key information recorded during this investigation to assess how frequently they were reported in research papers (cont.).**

| Analyses | Key Information | Comments |
|---|---|---|
| Pre-burning condition of human remains | 1.Warping<br>2.Thumbnail fractures<br>3.Other fractures<br>4.Skeletal position reconstruction<br>5.Soft tissues | The estimation of the pre-burning condition of the remains provides important information about the funerary practice. Heat-induced changes can be useful in that estimation (Gonçalves et al., 2011; Symes et al., 2008). It can also be inferred from the inventory of skeletal remains (Duday Guillon, 2006; Roksandic, 2002), the presence of objects (Gonçalves et al., 2015) or colour patterning of skeletal remains (Symes et al., 2008; Symes et al., 2014) |
| Minimum Number of Individuals | 1.Repetition of skeletal parts<br>2.Incompatibilities<br>3.Skeletal mass | The common methods used to estimate this parameter are based on the repetition of skeletal elements or on their incompatibility, for example in terms of age-at-death or sex (Ubelaker, 1974; Fairgrieve, 2008). In the case of burned skeletal remains, mass can also be used for that purpose (Duday et al., 2000) |
| Age-at-death | None | The construction of the biological profile is one of the basic tasks of biological anthropologists. Morphological and metric analyses can provide information about the biological and health profiles. However, in burned skeletal remains, it is complicated by fragmentation and heat-induced changes that may hamper systemic examinations and metric analyses of the skeleton (Thompson, 2004). |
| Sex Estimation | 1.Morphognostic methods<br>2.Metric methods | |
| Stature | None | |
| Ancestry | None | |
| Trauma and Pathologies Description | None | |

**Table 3 Relative frequency (%) of analyses and related key information undertaken during bioarchaeological investigation.**

| Analysis | % | Key information | % |
|---|---|---|---|
| Colour description | 90.5 | *Used for:* | |
| | | 1. Maximum temperature estimation | 92.1 |
| | | 2. Skeletal position reconstruction | 19.5 |
| | | 3. 1 + 2 | 17.9 |
| | | 4. No specific purpose | 4.7 |
| Fragmentation | 73.8 | *Described through:* | |
| | | 1. Measurements | 62.9 |
| | | 2. Qualitative description | 23.8 |
| | | 3. Sieving | 21.0 |
| | | 4. Mass per fragment | 12.9 |
| | | 5. Mass per skeletal region | 4.8 |
| | | 6. Other | 14.5 |
| | | 7. 1 + 3 | 14.5 |
| Skeleton completeness | 90.5 | *Estimated through:* | |
| | | 1. Skeletal mass | 86.8 |
| | | 2. Skeletal inventory | 46.1 |
| | | 3. 1 + 2 | 33.0 |
| Skeletal regions representation | 45.2 | *Assessed through:* | |
| | | 1. Skull-trunk-upper limbs-lower limbs classes | 47.4 |
| | | 2. Skull-trunk-limbs classes | 13.2 |
| | | 3. Other classes | 44.7 |
| Description of funerary assemblage | 69.1 | | |

**Table 3 Relative frequency (%) of analyses and related key information undertaken during bioarchaeological investigation (cont.).**

| Analysis | % | Key information | % |
|---|---|---|---|
| Pre-burning condition of human remains | 54.8 | *Estimated through:* | |
| | | 1. Warping | 67.4 |
| | | 2. Thumbnail fractures | 69.6 |
| | | 3. Other fractures | 41.3 |
| | | 4. Skeletal position reconstruction | 21.7 |
| | | 5. Soft tissues | 3.6 |
| | | 6. 1 + 2 | 56.5 |
| | | 7. 1 + 3 | 32.6 |
| | | 8. 2 + 3 | 26.1 |
| | | 9. 1 + 2 + 3 | 20.1 |
| Minimum Number of Individuals | 96.4 | *Estimated through:* | |
| | | 1. Repetition of skeletal parts | 66.7 |
| | | 2. Incompatibilities | 51.9 |
| | | 3. Skeletal mass | 16.1 |
| | | 4. 1 + 2 | 48.2 |
| | | 5. 1 + 3 | 14.8 |
| | | 6. 2 + 3 | 12.4 |
| | | 7. 1 + 2 + 3 | 12.4 |
| Age-at-death | 100.0 | | |
| Sex | 95.2 | *Estimated through:* | |
| | | 1. Morphognostic methods | 61.3 |
| | | 2. Metric methods | 28.8 |
| | | 3. 1 + 2 | 23.8 |
| Stature | 11.9 | | |
| Ancestry | 3.6 | | |
| Trauma and Pathologies Description | 66.7 | | |