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ORIGINAL ARTICLE

The cremation of infants/small children: An archaeological experiment concerning the effects of fire on bone weight

Jonas Holm Jæger*[1], Veronica Liv Johansen[1]

[1] Department of Prehistoric Archaeology, University of Copenhagen, 2300 Copenhagen S, Denmark

*Corresponding author: jonashjaeger@gmail.com

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ABSTRACT

The graves and especially the cremation graves of infants and small children (aged less than one year old) make up a relatively sparse category in the Danish archaeological records as well as in other areas. The reason for this startling under-representation has been debated for some time, but for some reason experimental studies of the cremation of infants and small children is as sparse in literature as the evidence for infant cremation graves. Even in non-archaeological literature (i.e. forensic and medico-legal literature), the cremation of infants is a rare subject of debate. Here we propose an experiment designed to show whether or not the bones of infants and small children (using domesticated pigs as substitutes for humans) can withstand the thermic stress they would have been exposed to in a simplistic reconstruction of a prehistoric funerary pyre. The results are measured in the post-cremation skeletal weight of the cremains and the data

is then compared to our knowledge of modern-day commercial cremations of infants and small children. Our results show firstly, that the bones can indeed withstand a simplistic cremation process and secondly, that the post-cremation skeletal weight matches our knowledge of modern commercial cremations.

Keywords: cremation; Biological Anthropology; Experimental Archaeology.

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RESUMO

As inumações, e particularmente as sepulturas de cremação de crianças pequenas, constituem uma categoria relativamente rara no registo arqueológico dinamarquês, bem como em outras regiões. As razões para esta sub-representatividade têm sido debatidas, no entanto existe uma enorme lacuna ao nível da realização de estudos experimentais visando cremações de indivíduos pertencentes a estes grupos etários. Mesmo na bibliografia de âmbito forense ou médico-legal, esta temática raramente constitui objecto de debate. No presente artigo propomos uma experiência planeada para determinar se os ossos de não-adultos e crianças pequenas podem suportar o estresse térmico a que estão sujeitos numa cremação feita em moldes tradicionais (mediante reconstrução simplista de uma pira funerária). Para cumprir tal propósito, foram utilizados porcos domésticos (*Sus domesticus*) juvenis e o peso ósseo pós-cremação foi utilizado para comparações com cremações contemporâneas de não-adultos e crianças pequenas. Os resultados demonstram que os ossos podem de facto suportar o processo de cremação e que o peso ósseo pós-cremação coincide com o que é reportado para cremações actuais.

Palavras-chave: cremações; não-adultos; Antropologia Biológica; Arqueologia Experimental.

Introduction

Human cremains and the effects of fire on human corpses have been the focus of various studies ranging from archaeological to forensic or medico-legal research for a long time (Lange *et al.,* 1987; Schmidt and Symes, 2008; Bontrager and Narwocki, 2008; Gonçalves *et al.,* 2013; Harvig and Lynnerup, 2013), but only a few have focused on or included infants or small children (aged less than one year old) in their research (Schrader, 1938; Sigvallius, 1994; Warren and Maples, 1997).

Looking through the literature it is clear that, graves containing cremated as well as non-cremated remains of infants and small children are quite rare, compared to graves with cremated or non-cremated remains of

adults. Even though the evidence of buried infants or small children (cremated as well as non-cremated) in Southern Scandinavia and present day Denmark go as far back as the Mesolithic sites of Gøngehusvej and Henriksholm-Bøgebakken, Vedbæk (Petersen, *et al.,* 1993) the graves of infants or small children are somehow missing. Arguably, one example is not enough to make a general rule, but even in the Late Bronze Age when cremation becomes the norm, as far as burial customs go, the number of cremation graves containing infants and small children is low, especially compared to those of adults or older children (Bennike, 1985). Even in periods of high mortality rates among this particular age group, only a small number of graves have been found (Bennike, 1985).

Determining the cause of the aforementioned under-representation is no doubt hard to do through the means of traditional archaeological analysis. The problem has previously been discussed (Bennike 1985; Holck, 1997 Alexandersen *et al.,* 2008), even so, it is possible to investigate some aspects of this conundrum experimentally: could the under-representation of cremated remains of infants and small children be explained by the bones not being able to endure the thermic stress they would experience in the cremation process, thus making the known examples exceptions to the rule? Or are the cremains so fragmented or fragile that they would be hard or impossible to handle, thus making it difficult or impossible to transfer the cremains from the funerary pyre to the urn?

Material and Methods

For legal and ethical reasons it was necessary to find a suitable substitute for human subjects to use in the experiment. Three small pigs (*Sus scrofa domesticus*), according to the pig farmer aged between a few days and little more than one week old, were chosen as human substitutes. Pigs have often been used as substitutes for humans in medical and forensic research and have previously been used in experimental archaeological research (Henriksen, 1993; Mayer and Vasconcelos, 2013; Sutherland *et al.,* 2013). To reach a proper conclusion it was decided to use piglets of different weights, namely between 2000 g and 6000 g (Table 1). This assured that the weight spectrum of the piglets covered the low and high extremes of what was somewhat expected of a human child aged less than one year old. The weights of the pigs were measured on a luggage weight with an accuracy of 1 g. The pigs were kept in a freezer until the day of the experiments but they were not taken out in time to thaw completely before burning. Considering the amount of skeletal remains recovered from the experimental pyres and compared to the results of previous studies on cremations (Warren and Maples, 1997; Mays, 1998), this seems not to have had a major effect on the amount of bones left after the cremations.

Each funerary pyre was built as simplistic arrangements in three permanent, outdoor fireplaces in the *"Båldålen"* of the Land of Legends. Each fireplace was situated on the south-facing slope of a small hill (Figure 1).

Table 1- Weight of each pig.

Pig I	*2210 g*
Pig II	*2820 g*
Pig III	*5760 g*

Table 2- Amount of wood used in the pyre construction and as extra firewood.

Pyre I	0.5 m^3
Pyre II	0.5 m^3
Pyre III	1.0 m^3

Figure 1- Pig III, 10 minutes after igniting the pyre.

The topography along with the weather conditions maintained a somewhat steady, natural ventilation of the pyres. The pyres were constructed using unspecified firewood provided by the Land of Legends. Apart from a few extra blocks of firewood the only wood used in the experiments were the blocks used to construct each pyre (Table 2). Temperatures in the pyres were measured using an AMTEK ETM-2000 thermometer on loan from the pottery workshop at the Land of Legends. The instruments were quite sensitive and measured temperatures with an accuracy of 0.01 °C in temperatures between 0-100 °C and with an accuracy of 0.1 °C between 100-1000 °C. Temperatures were measured in the centre of the pyre and directly under the pig. After the conclusion of each experiment the remains were covered with grey plastic overnight while they cooled

down and became possible to handle manually. Intact bones, bone fragments and charred flesh, along with some dirt and ash from the pyres were collected by hand and stored in transparent 1 litre plastic bags for transport to the laboratory at the SAXO-Institute. Intact bone and fragmented bone was sorted from each plastic bag by using tweezers. Bones with charred flesh were de-fleshed as well as best as possible while not risking further damage or fragmentation of otherwise intact bone. This was done manually using tweezers and double end dental explorers. De-fleshing the bones was necessary to get a clear picture of the weight of the cremated bones themselves and to provide a better comparison to previous studies (Warren and Maples, 1997). Then, all the cremated bones were weighed on a digital kitchen scale from Soehnle with an accuracy of 1 g between 0-1000 g and 2 g between 1000-2000 g.

Description of the experiments

Pyre I

The first pyre was built and arranged in dimensions of approximately 55 cm in width and 50 cm in height and the first pig was placed on top. After a discussion of whether or not to include three support posts in the construction, it was decided to place two support posts along the sides of the pyre for support. These support posts proved rather ineffective in supporting the pyre during the experiment, since their weight alone was not enough to support the structure.

The fire caught the pyre rather quickly. Just two minutes into the experiment, the pig began emitting smoke and after just three minutes the body caught fire. During the course of the experiment it became clear that the natural ventilation from the wind was essential in keeping up the temperatures. After approximately 11 minutes, the first of the support posts failed and three minutes later the pyre started sliding a bit to the side. It was difficult to say whether or not the support posts had any real effect. After 30 minutes, the pyre had decreased 20 cm in height and the first bone, the left tibia, was exposed through the burnt flesh. The construction started to look a little unstable and an extra log was placed as support for one side of the pyre. After 36 minutes the second support post failed and after 41 minutes, the dental enamel started to suffer under thermic stress and began cracking. After 55 minutes, the pig had been de-fleshed almost completely by the fire. Sixty minutes into the experiment, the core of the pyre reached temperatures exceeding 1000 °C and 10 minutes later the first calcined costae were visible through the side of the pig and after just 95 minutes, all soft tissue had burned away.

Pyre II

The second pyre was built in the same dimensions as the first. Whereas the first pyre had a more massive construction the second was built with a cavity in the middle like a chimney to further the ventilation. The cavity was then filled with brushwood and dried bark. Contrary to the first pyre, support posts were not used since they did not prove effective in the first experiment.

The cremation of pig II followed roughly the same course as the first. After 9 minutes, the pig caught fire and after 20 minutes the pig started secreting a thick yellow fluid through the nose. At the same time the first exposed bone started to show. It was noted that the ventilation cavity in the pyre caused the body of the pig to start sinking through the pyre construction. After 38 minutes, the incisors had taken a bluish colour and after 60 minutes, large areas of the skull and humeri were exposed and shortly afterwards all soft tissue had burned away.

Pyre III

The third and last pyre was built in the same manner as the second, but larger to compensate for the larger pig. The ventilation cavity in the centre of the pyre was used again since this had had a positive effect on the effectiveness of the cremation process.

The cremation followed the same course of the previous two through the first 30 minutes. After 30 minutes, the pyre started sliding a bit and the pig needed to be rearranged on the pyre a few times during the course of the experiment. Also, as a consequence of the pyre instability some extra logs needed to be used to maintain stability. After 45 minutes, the first bones were exposed in the extremities and a considerable amount of charring of the soft tissues started to show (Figure 2). Past 60 minutes, the exposed bones in the extremities showed signs of calcination. 10 minutes later a large charred area around the belly started to form some kind of thick mantle around the remaining costae and vertebrae (Figure 3). This mantle was not burned away and after 75 minutes the pyre started having problems maintaining a constant, high temperature. This was made even more difficult as sporadic gusts of wind changed the temperature significantly from one moment to the next. As it got harder to keep the temperatures above 700 °C, it was decided to stop adding fuel and let the fire burn out. At the end of the experiment the only soft tissue left was the thick, black mantle of burnt flesh on the side of the pig.

Results and Discussion

The empirical data of the three experiments are presented in Table 3 and Figure 4.

Our results showed that the skeletal remains make up between 2.18 and 3.28 % of the total body weight of the pigs before cremation. This is in accordance to the previous studies of human cremations done by Warren and Maples (1997). By cremating 100 individuals of different sex and age at a commercial crematorium the study showed that the weight of the remaining bone fragments on average made up about 3.5 % of the total body weight in adult individuals, 2.5 % in small children and 1.0 % in infants (Warren and Maples, 1997). As mentioned, this study was made using commercial cremation furnaces, which operate at higher and more constant temperatures than our experimental pyres did. Also, a cremation furnace constitutes an almost sealed system with fewer if not any uncontrollable variables, which is in stark contrast to our

open-air cremations. If Warren and Maples (1997) results are used to compare with our own results, we see a small deviation between both weight data.

From the above, it is shown that our collected data deviates from the data collected by Warren and Maples (1997). Given the different circumstances surrounding the two experiments a deviation should be expected. If our experiments were to reflect the cremation of infants, we obtained more remains compared to the above-mentioned data and a little fewer when compared to the data on small children. It is important though, to bear in mind that the research of Warren and Maples (1997) was done on humans, not pigs, and with a much larger scale than ours. With these factors in mind, a deviation of 2.28 percentage points in our results seems more acceptable than it did at first. Our results also find support in a study done by Mays (1998) in which the mean weight of the cremains of 0-6 months old children was calculated to be 54 g and 6-36 months old children was calculated to be 185 g.

Figure 2 - Pig III, one hour after igniting the pyre.

Figure 3 - The undisturbed cremains of pig III. Note the charred mantle.

Table 3 - Pigs total weight before the experiments ($Weight_{total}$), the weight of the cremains ($Weight_{cremains}$) and the weight of the cremains relative to the total weight of the pigs in percent ($Weight_{cremains\ \%}$).

Specimen	$Weight_{total}$	$Weight_{cremains}$	$Weight_{cremains\ \%}$
Pig I	2110 g	46 g	2.18 %
Pig II	2820 g	89 g	3.15 %
Pig III	5670 g	186 g	3.28 %

Table 4 - The relative skeletal weight of our cremated pigs in relation to pre-cremation weight ($Weight_{cremains\ \%}$) and deviations calculated from the mean values obtained by Warren and Maples (1997).

Specimen	$Weight_{cremains\ \%}$	$Deviation_{small\ children}$	$Deviation_{infants}$
Pig I	2.18	- 0.32	+ 1.18
Pig II	3.15	- 0.65	+ 2.15
Pig III	3.28	+ 0.78	+ 2.28

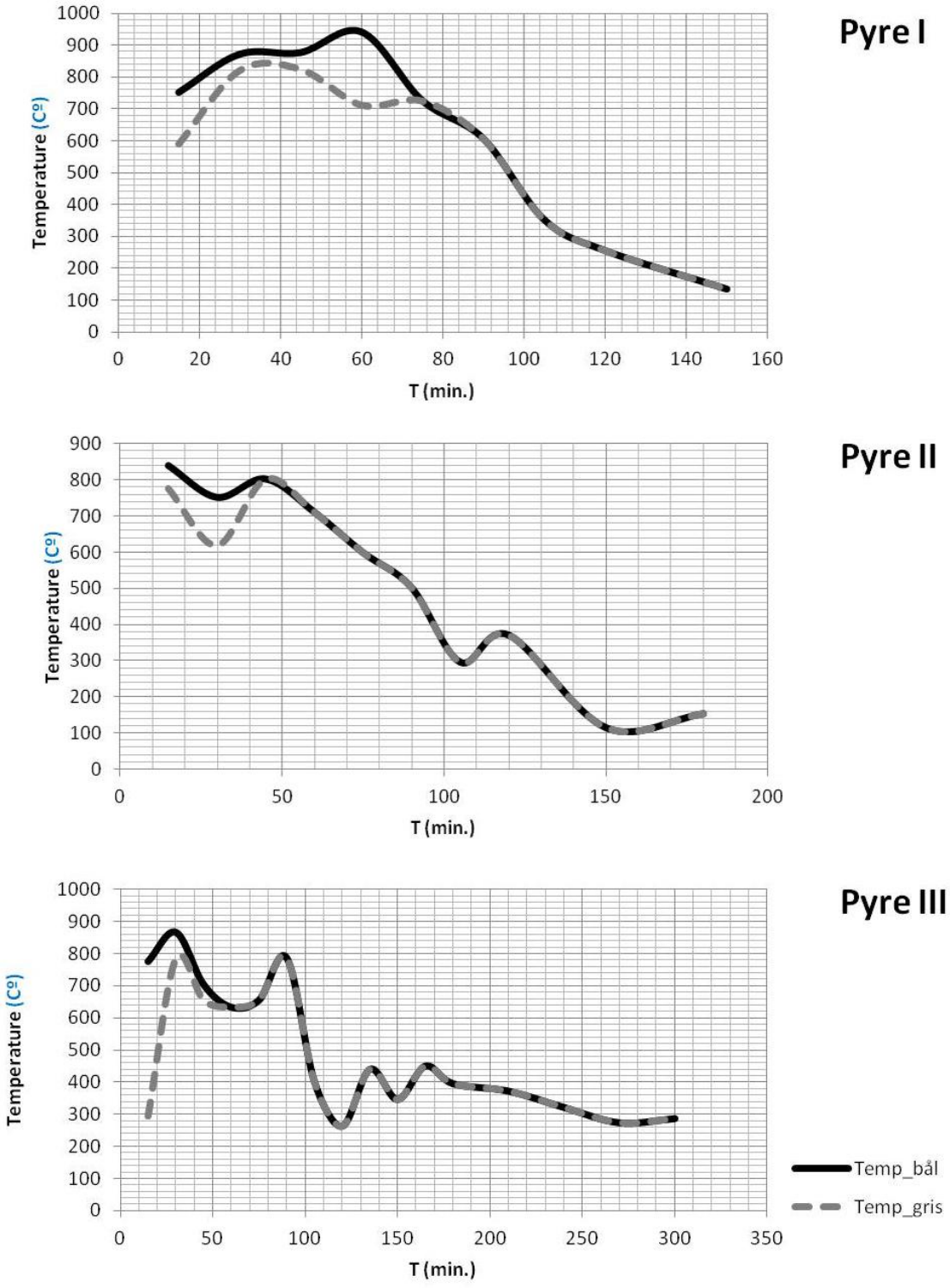

Figure 4 - temperatures of the pyres relative to time. Temp_bål = temperatures measured in the centre of the pyre. Temp_gris = temperatures measured directly under the pig.

It seems that the bones of infants or small children are more than able to withstand the thermic stress of a cremation on a simple pyre. A selection of these is shown in Figures 5-7. This means that this cannot be the reason why we do not find as many children cremation graves as we do for adult cremation graves. Could the explanation then lie in the fact that the remains are not able to survive inhumation?

Figure 5 - A selection of the least fragmented bones from pyre I.

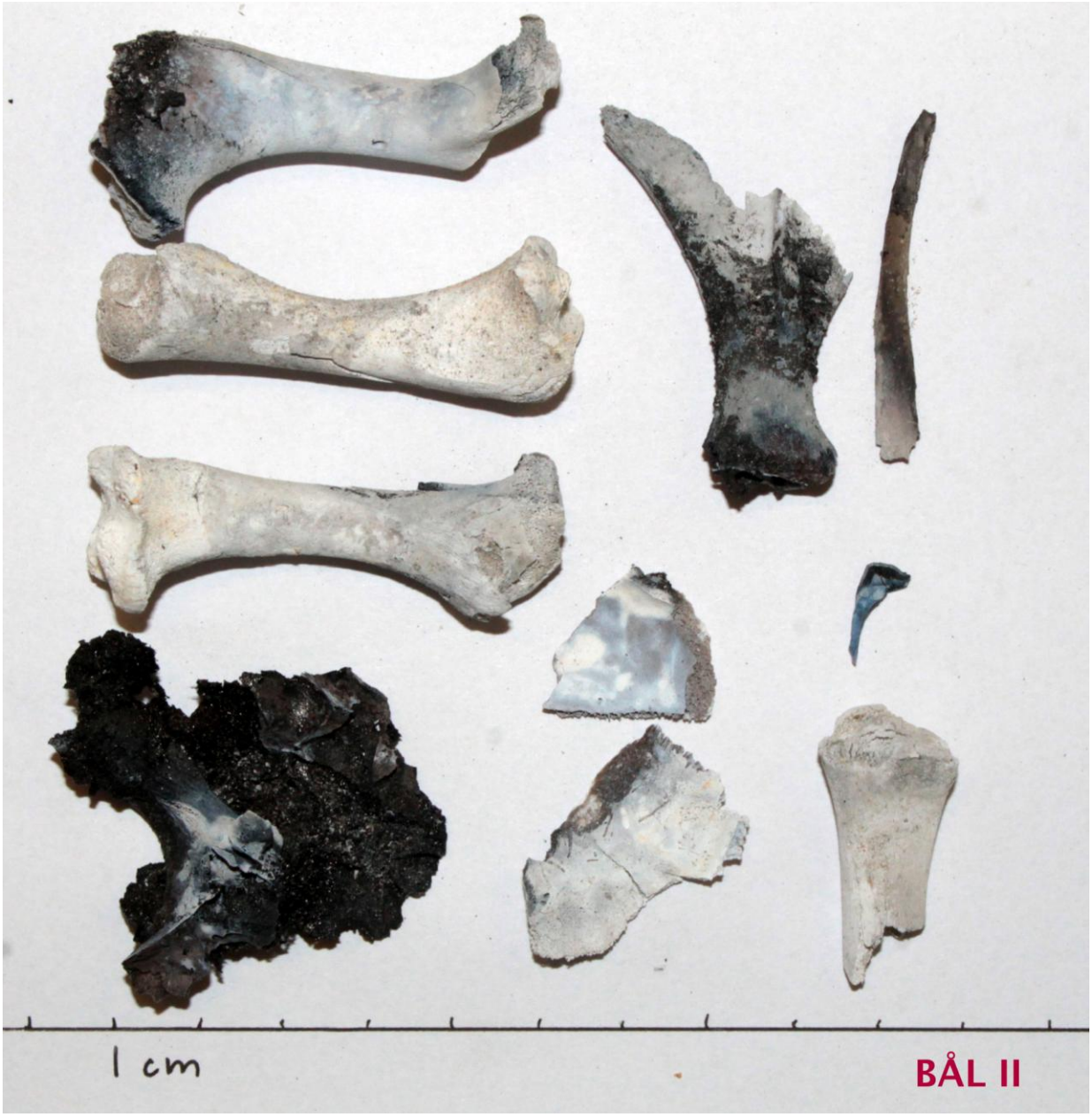

Figure 6 - A selection of the least fragmented bones from pyre II.

There are various reasons why bones may not be preserved in the ground: microbiological or chemical factors, bioturbation and physical disturbances (Magnell, 2008). Still, Mays (1998) notes that archaeological bone is very resistant to destruction in the soil, possibly due to an uptake of water in the soil and to conversion and re-conversion of hydroxyapatite into beta-tricalciumphosphate, and reverse. He also notes that well fired bones lacking any organic components are not subject to decomposition by microorganisms. Still, this does not mean that all cremation graves can

stand the test of time, but it might explain why our evidence of cremated infants can be traced back several thousand years into prehistory (Petersen *et al.,* 1993; Schmidt *et al.,* 2008). What it still does not explain is why there are so few of them. When these graves remain rare even in periods of high mortality rates (Bennike, 1985; Alexandersen, *et al.* 2008) perhaps the under-representation should be viewed in a socio-anthropological light, rather than in terms of preservation, thus making the scarcity of these graves the consequences of a culturally conditioned choice of not giving cremated children the same treatment as older individuals, or it could just simply mean that we are not looking in the right places.

Figure 7 - A selection of the least fragmented bones from pyre III.

Conclusion and Further Research

The results of our experiments have shown that pigs may be good human substitutes because results are somewhat comparable to similar experiments on commercially cremated human subjects. They also showed that, the remaining burnt bone was neither fragile nor fragmented enough to make it difficult or impossible to handle, thus the experiments proved to be successful.

It can be concluded from our results on a simplistic funerary pyre and under the intensity of combustion used on our experiments,, that a cremation of a small pig comparable in size to an infant or a small

child younger than one year of age, will leave measurable traces of cremated remains. The reason for the under-representation of infants and small children in cremation graves is probably partly explained in terms of cultural choices in relation to the burial customs, through poor preservation conditions after burial or simply by the fact that we do not know where to look for them.

The experiments have helped answering one question, but further questions still need answering. It would be reasonable to repeat the experiment to generate a larger and more representative sample and cremation conditions but it would also be interesting to bury some of the burned bones under various conditions and mediums (e.g.: burial directly in the ground, wrapped in cloth and buried in an urn) for a given time period. This would help shed some light on to which degree different preservation conditions affect the cremated remains. Other than giving insights into centuries old burial customs, our results might also have some importance in fields other than prehistoric archaeology, forensics and especially forensic archaeology and anthropology. Knowledge of cremated remains proves useful in investigations of crimes, accidents and catastrophes involving burned victims and it seems that research into younger victims has been neglected in favour of adults and older individuals (Haglund and Sorg, 2002; Blau and Ubelaker, 2009; Bass and Jantz, 2004).

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