



Perinatal infant death at the Roman villa site at Hambleden, Buckinghamshire, England

S. Mays^{a,*}, J. Eyers^b

^a Archaeological Science, English Heritage, Fort Cumberland, Eastney, Portsmouth PO4 9LD, UK

^b Chiltern Archaeology, High Wycombe HP14 3LG, UK

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ABSTRACT

The aim of the current work is to investigate whether perinatal infant burials at Hambleden Roman villa (1st–4th century AD), England, more likely represent infanticides, as has been contended by earlier workers, or natural deaths. Previous work has noted that when infanticide is practiced it is normally carried out immediately after birth and so will produce an age at death distribution tightly clustered around the gestational age of a full-term infant. By contrast, natural deaths in the perinatal period produce a rather flatter age distribution. In foetal and perinatal infants, long-bone length bears a close relationship to gestational age. The distribution of age at death in the Hambleden perinatal infants is compared with those from Roman Ashkelon, Israel, where earlier work showed evidence for infanticide, and Mediaeval Wharram Percy, England, where previous studies demonstrated a perinatal age at death distribution consistent with natural deaths. The comparisons between the sites are undertaken using four different methodologies: direct comparison of distributions of long-bone lengths, and comparison of ages at death estimated using two different regression methods and using a Bayesian methodology. Results consistently show a strong clustering in the Hambleden age distribution at an age approximately corresponding to a full-term infant. In this respect they resemble results from Ashkelon and differ from those from Wharram Percy. This was interpreted as supporting the suggestion of infanticide at Hambleden.

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1. Introduction

Infanticide is the killing of unwanted babies. Until recently, it was a practice that was widely tolerated in human societies around the world (Williamson, 1978; Warren, 1985). Prior to modern methods of contraception, it was one of the few ways of limiting family size that was both safe for the mother and effective. Despite being a widespread practice in past societies, infanticide has only begun to command significant attention from archaeologists in the last 20 years. This recent interest is in part a reflection of the increasing attention paid to the archaeology of children and childhood (Sofaer-Derevenski, 1994; Moore and Scott, 1997; Lewis, 2007: 1–4; Crawford and Lewis, 2008). It also reflects advances in methods for identifying infanticide in the archaeological record using human skeletal remains.

Few infant skeletons show evidence of cause of death. Ethnographic and historic studies indicate that infanticide is normally

carried out by means, such as suffocation, that would leave no trace on the bones (Langer, 1974; Williamson, 1978). Therefore some indirect method is needed for its identification in the archaeological record. Infanticide is normally carried out immediately following birth (Williamson, 1978; Scrimshaw, 1984), and therefore one might expect that the regular practice of infanticide would lead to a perinatal age at death distribution with a strong peak at an age corresponding to a full-term infant. By contrast, natural deaths tend to show a rather more dispersed age distribution.

Smith and Kahila (1992) measured long-bone lengths of nearly 100 infants from Ashkelon, Israel. They found the data to be tightly clustered around lengths corresponding approximately to a full-term child, and argued for infanticide as an explanation. The observation that the infants from this site were not accorded normative burial treatment, but rather were cast into a sewer that ran beneath a brothel, supported this idea. A parallel study conducted a comparative analysis of Roman and Mediaeval perinatal infants from Britain (Mays, 1993). During the foetal and perinatal period, bone growth is rapid and bears a close relationship to age, so that age at death can be estimated from long-bone lengths to within about 2 weeks (Scheuer et al., 1980). Using regression

* Corresponding author. Tel.: +44 2392 856779; fax: +44 2392 956701.

E-mail address: simon.mays@english-heritage.org.uk (S. Mays).

analysis (Scheuer et al., 1980) to estimate age (in weeks gestation) from long-bone length, it was found that the Romano-British perinates ($N = 164$) showed a strong peak in their age distribution at about 38–40 weeks, an age corresponding to about a full-term infant. The Mediaeval data (from Wharram Percy churchyard ($N = 61$)) showed a flatter, more dispersed distribution with no pronounced peak at full term. The flat Mediaeval gestational age distribution resembled that of recent stillbirths and natural deaths in the immediate post-birth period. The Romano-British distribution was dissimilar to this natural pattern and was interpreted as evidence for infanticide. Of course, this does not mean that all the Romano-British infants were victims of this practice, only that infanticide was practiced with sufficient regularity to exert an appreciable effect on the overall perinatal age at death distribution.

Since those studies in the early 1990s, other workers have investigated perinatal age at death distributions in archaeological material using regression analysis to estimate age at death from long-bone lengths. Of those with reasonably large sample sizes (at least 25 individuals), some have produced fairly flat distributions lacking strong peaks at an age corresponding to full term, a pattern characteristic of natural perinatal deaths. These include various cemetery sites from prehistoric Thailand (Halcrow et al., 2008), Roman Kellis, Egypt (Tocheri et al., 2005), and Mediaeval Raunds and post-Mediaeval Spitalfields, both in England (Lewis and Gowland, 2007). Others have produced distributions with strong peaks around full term. These include prehistoric Khok Phanom Di, Thailand (Halcrow et al., 2008), and prehistoric Lepinski Vir and Vlasac, Serbia (Borić and Stefanović, 2004). Whilst recognising that tightly clustered gestational age distributions were unlike those expected of the full range of natural perinatal deaths, these authors resisted interpreting them in terms of infanticide. At Lepinski Vir and Vlasac, Borić and Stefanović (2004) argue against infanticide principally because they felt that the nature of the burials showed communal concern toward the individuals involved, but they do not attempt to explain why the age at death distribution did not match that expected of natural deaths. At Khok Phanom Di, Halcrow et al. (2008) argue against infanticide because the infants were accorded normative burial treatment and because, in the historic period at least, there was no tradition of infanticide in that region. The peaked age distribution was posited to have arisen due to burial of pre-term babies elsewhere and selection of full-term babies for burial in the part of the cemetery which lay within the excavated area, and/or a naturally high mortality at birth.

In 2002, Gowland and Chamberlain presented a reconsideration of the interpretation of age at death profiles of perinatal burials. Whilst not disputing the idea that an age distribution tightly clustered around full term may potentially be indicative of infanticide, they suggest that the peak observed at around full term in the distribution of Romano-British infants by Mays (1993) may be a statistical artifact of the regression method used to age the remains. This is because there may be a tendency for the distribution of estimated ages in the target population (the archaeological group) to mimic that in the reference sample used to derive the regression equations. This phenomenon has been termed 'age-structure mimicry' (Mensforth, 1990). The age structure of the Scheuer et al. (1980) BCH reference population (which was used to generate the regression equations used to estimate age in the Romano-British infants) does indeed show a peak at full term. Gowland and Chamberlain (2002) advocated the application of Bayesian statistics to remove this perceived bias. They re-aged the Romano-British infants of Mays (1993) using this method and found that the peak at full term was less pronounced. A critique (Mays, 2003) of Gowland and Chamberlain (2002) provides empirical evidence that the bias they claim for the regression approach to ageing perinates from long-bone length does not exist

to any appreciable extent, and points out that for theoretical reasons one would not expect it to be an important effect. However, until the performance of various Bayesian and non-Bayesian methods of recovering perinatal age distributions from long-bone lengths are assessed on samples of perinates of known age at death, the issues remain essentially unresolved. Until then, perhaps the best approach when investigating perinatal age at death distributions estimated from long-bone lengths is to apply multiple analytical methods.

The current work is an investigation of the perinatal age at death distribution of infants buried at Yewden Roman villa, at Hambleden, Buckinghamshire, England (Fig. 1). The aim is to shed light upon whether infanticide was likely practiced at that site. Hambleden was chosen for two reasons. Firstly, it dates to the Roman period, and documentary sources show that infanticide was practiced in the Roman world (Harris, 1982, 1994; Wiedemann, 1989). Motivations included limiting family size, or that the child was not of the desired sex or was deformed (Brunt, 1971: 150; Langer, 1974; Wiedemann, 1989: 37). Secondly, although infant burials are not uncommon in Romano-British domestic contexts (Philpott, 1991: 97; Moore, 2009), Hambleden has yielded the largest number of perinatal burials (said to number 97 by the excavator (Cocks, 1921)) of any Roman site in Britain. The sheer number was noted as remarkable by the excavator, who thought it suggested infanticide with surreptitious disposal of the bodies (Cocks, 1921). Subsequent commentators have repeated this interpretation (e.g. Watts, 1989; Philpott, 1991: 98) and some have specifically viewed the infants

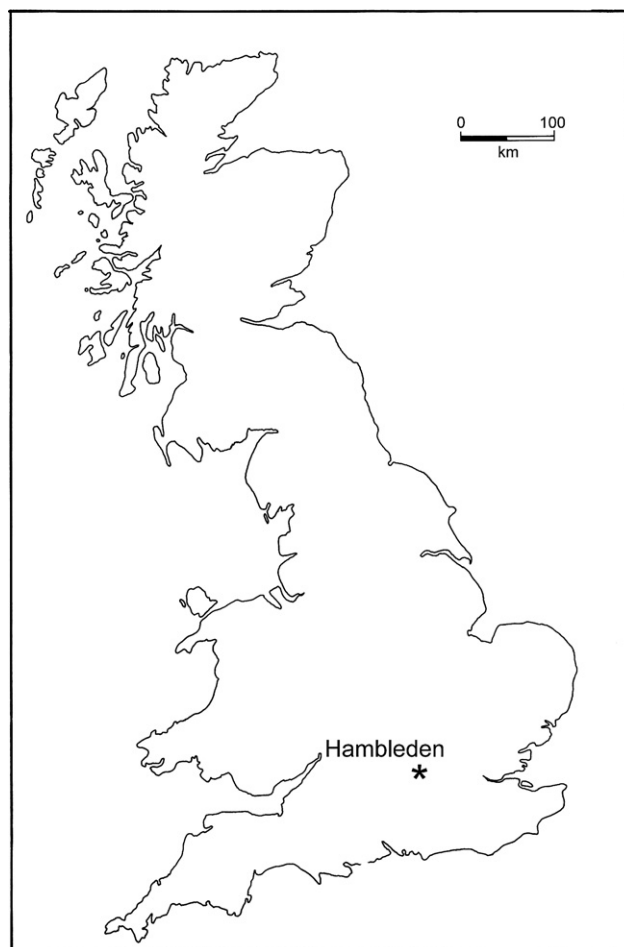


Fig. 1. Location of Hambleden.

Table 1

Femur diaphysal lengths of known age individuals versus gestational age. Data from Scheuer et al. (1980) and Sherwood et al. (2000). The style of the table is based on Gowland and Chamberlain (2002).

Gestational age (weeks)	Femur length (mm)																Total
	10–	15–	20–	25–	30–	35–	40–	45–	50–	55–	60–	65–	70–	75–	80–	85–	
16–18	1	1															2
17–19		2	2	2													6
20–22		2	5	3	3	3											16
23–25			2	2	2	7	5										18
26–28						2	1	2									5
29–31						1	1	2									5
32–34									1	1	2	1					5
35–37											2	1	2				5
38–40											1		6	3	3		13
41–43												1	1	2			4
44–46																1	1
Total	1	5	9	7	5	13	7	4	1	2	5	2	9	4	5	1	80

as unwanted offspring of slaves at the villa (Frere, 1967: 266–7; de la Bédoyère, 1993: 83). To investigate whether infanticide is a likely interpretation in the Hambleton case, the distribution of long-bone lengths of the Hambleton infants, and that of their estimated ages at death, are compared with those from two other archaeological sites: one for which previous work indicated infanticide, the other where earlier work suggested natural deaths.

2. Materials and methods

Villas are country houses found in Britain from the 1st to 4th centuries AD when it was a province of the Roman Empire (de la Bédoyère, 1993). They were working farms. The buildings varied in their degree of Romanisation. Some were large, high-status Roman-style country houses, others were simpler dwellings. Some functioned as estate centres.

Yewden villa at Hambleton was excavated in 1912 (Cocks, 1921). The villa's use spans the mid 1st to the late 4th century AD. It was a complex of buildings with a surrounding boundary wall. It featured tessellated pavements, baths, and 14 kilns interpreted as corn dryers. High-status finds were plentiful (Cocks, 1921; Evers, 2008). The excavations were said by the excavator to have yielded 103 burials, of which 97 were infants, three were children and three were adults (Cocks, 1921). Although there is an osteological report on the adult skeletons, by Keith (1921), there is no published scientific examination of the infants. The infant remains were long thought lost, but remains from 62 contexts have recently been re-located. Many of these are isolated bones or bone fragments, but 35 represent discrete individuals. The infants were chiefly from a yard on the north side of the villa complex. Most cannot be more precisely dated than to the general period of use of the villa, but of the 16 that can be dated more closely, the dates are confined to between about 120 and 200AD. The remainder are all post first century, but cannot be dated more closely due to lack of stratigraphic on-site recording. The infant burials therefore accumulated over a period of up to about 280 years.

The gross bone preservation is good with minimal post-depositional surface erosion. Only 12 infants have surviving dental remains, and smaller elements such as vertebrae and the bones of the extremities are missing, presumably reflecting the hand recovery methods on site. The remains were still in their original packing, and Sir Arthur Keith had noted their approximate ages at death (mostly full term) on the labels. The only other work on the remains of which we are aware is an unpublished PhD thesis (Hillier, 1992) in which deciduous teeth from 6 perinates were sectioned to search for neonatal lines; none were found, which suggests that they were either born dead or died within about 14 days of birth (Whittaker and Richard, 1978).

The comparative sites selected for the current work are Ashkelon and Wharram Percy. As discussed above, the tight clustering of the long-bone lengths at Ashkelon suggested infanticide, as did the disposal of the remains in a sewer beneath a brothel. Wharram Percy is a deserted Mediaeval village in North Yorkshire, England. Unlike Ashkelon, the perinatal infants from the churchyard there received normative burial treatment, and two different regression ageing methods (Mays, 1993, 2003) and Bayesian ageing (Lewis and Gowland, 2007), indicate a dispersed age distribution resembling that expected if they represented some combination of stillbirths and natural deaths during the immediate post-natal period. In the current work, the comparison with Wharram Percy uses the data generated from that site by one of us (see Mays, 1993, 2003, 2007); that with Ashkelon uses data presented in Smith and Kahila (1992).

Thirty-three infants from Hambleton had one or more measurable long-bones preserved. Maximum diaphysal lengths of long-bones were measured using sliding callipers. If both elements of a bone pair were present then the mean of left and right lengths was used as the data point for the individual. The sites were compared using four different methods: the distribution of raw diaphysal long-bone lengths, and three methods of estimation of age at death from those measurements. Ages at death were estimated from diaphysal long-bone lengths using the BCH regression equations of Scheuer et al. (1980), and the regression equations of Sherwood et al. (2000). These two sets of equations were used because the reference samples used to generate them have very different age structures which makes them useful for evaluating the claims of some (e.g. Gowland and Chamberlain, 2002; Chamberlain, 2006: 120–123) that when using regression of age upon bone length to estimate perinatal age, the age distribution of the target population may tend to mimic that of the reference population from which the regression equations were derived. The other ageing method used is a Bayesian approach. The methodology follows a modified version of that described by Gowland and Chamberlain (2002). This involved producing a contingency table

Table 2

Calculation of prior probabilities for Bayesian age at death estimation.

Gestational age (weeks)	Stillbirths plus deaths in first week of life ^a	Prior probability for Bayesian age estimation
29–31	63	0.107
32–34	73	0.124
35–37	105	0.178
38–40	227	0.384
41–43	108	0.183
44–46	15	0.025
Total	591	

^a Data from Gibson and McKeown (1951).

Table 3
Posterior probabilities of age given femur length.

Gestational age (weeks)	Femur length (mm)									
	45–	50–	55–	60–	65–	70–	75–	80–	85–	
<32	1.0		0.46							
32–34		1.0	0.54	0.33	0.41					
35–37				0.47	0.59	0.24				
38–40				0.20		0.60	0.66	0.49		
41–43						0.16	0.34	0.51		
44+										1.0

of femur length, divided into 5 mm categories, with gestational age, using data from reference populations of known age. This contingency table is then used in conjunction with appropriate prior probabilities to assign posterior probabilities that individuals in the target population belong to particular age categories based on their femur lengths. The contingency table presented by [Gowland and Chamberlain \(2002\)](#) is not used in the current study. To prepare their table of femur length versus age, [Gowland and Chamberlain \(2002\)](#) relied heavily on data from [Fazekas and Kosa's \(1978\)](#) study of Hungarian foetal and perinatal skeletal material, and on the studies of [Maresh and Deming \(1939\)](#) and [Maresh \(1955\)](#) of American infants. In [Fazekas and Kosa's](#) study material, gestational age was undocumented, and was estimated from body length prior to maceration. This introduces an inherent circular argument to their work, a problem that has been recognised previously (e.g. [Molleson, 1989](#); [Scheuer and Black, 2000: 9–21](#); [Tocheri and Molto, 2002](#); [Mays, 2003](#)). That a reference population be of documented age is a fundamental requirement when formulating an ageing method, and the fact that [Fazekas and Kosa's](#) was not precluded the use of their data. [Maresh and Deming \(1939\)](#) measured infant bones radiographically every 6 weeks from birth, and [Maresh \(1955\)](#) provides radiographic bone lengths of infants two months old. In these studies, only age since birth not gestational age was known, so this data cannot be used to construct a table of bone length versus gestational age. In recognition of these difficulties, a new contingency table of femur length versus gestational age was drawn up ([Table 1](#)) using the data of [Scheuer et al. \(1980\)](#) and [Sherwood et al. \(2000\)](#).

Bayesian approaches require initial assignments of probabilities that individuals in a target population belong to particular age categories – so called prior probabilities. Prior probabilities of individuals belonging to particular age classes can be uniform or modelled. Uniform priors assume an equal likelihood of an individual belonging in any particular age category. In reality, human mortality samples exhibit an uneven distribution of individuals across age classes, not least because risk of death varies with age. The use of uniform priors is therefore not usually appropriate ([Chamberlain, 2006: 114–5](#)). The alternative is to base one's prior probabilities on some age distribution thought likely for the target population, the so-called model prior. For perinatal age estimation, it is probably most appropriate to use model priors based upon

natural perinatal mortality patterns ([Gowland and Chamberlain, 2002](#); [Lewis and Gowland, 2007](#)). For the current purposes, the model priors were generated using the combined gestational age distributions for stillbirths and infants dying in the first week *post-partum* ($N=591$) in mid 20th century England ([Gibson and McKeown, 1951](#)) ([Table 2](#)).

The posterior probability of a particular age (age_i) for a given bone length ($length_j$) is given by the prior probability of age_i ($p_{prior}A_i$) multiplied by the probability of that length given age_i ($p(L_j|A_i)$), divided by the sum of probabilities of that length given age across all age categories each multiplied by the appropriate prior probability – i.e.:

$$p(A_i|L_j) = \frac{p_{prior}A_i \times p(L_j|A_i)}{\sum (p(L_j|A_i) \times p_{prior}A_i)}$$

([Gowland and Chamberlain, 2002](#)).

For the contingency table approach used here this becomes:

$$p(A_i|L_j) = \frac{p_{prior}A_i \times (\text{cell/row})}{\sum (p_{prior}A_i \times (\text{cell/row}))}$$

This was used to produce the contingency table of posterior probabilities of age given femur length shown in [Table 3](#). This was used to age the archaeological samples.

3. Results

[Table 4](#) summarises the long-bone length data for Hambleden and for the comparative sites of Ashkelon and Wharram Percy. The data for the humerus for all three sites are depicted graphically in [Fig. 2](#). The Hambleden data are clustered tightly around bone lengths which earlier work (e.g. [Scheuer et al., 1980](#); [O'Brien and Queenan, 1981](#); [Hadlock et al., 1982](#); [Hohler and Quetel, 1982](#); [Chitty et al., 1994](#); [Hill et al., 1992](#); [Sherwood et al., 2000](#); [Adalian et al., 2002](#); [Olsen et al., 2002](#)) has established correspond approximately to a full-term infant. The Hambleden data contrast with the more dispersed Wharram Percy distribution. The coefficients of variation in the Hambleden material are, for each bone, less than half those at Wharram Percy. The statistical significance of the difference between the coefficients of variation of the long-bone length distributions at Hambleden and Wharram Percy was evaluated using the variance ratio test ([Lewontin, 1966](#); [Zar, 1999: 141–142](#)). A requirement of this test is that the log transformed data (not the raw data) be normally distributed. K-S Lilliefors tests indicate that the log transformed bone lengths in the current data sets do not deviate from normality. The variance ratio tests indicate that, for each bone, the coefficients of variation differ significantly at the two sites ([Table 5](#)). Thus the dispersion of the Hambleden long-bone lengths is significantly less than at Wharram Percy. In terms of central tendency and dispersion, the Hambleden distributions resemble those at Ashkelon ([Table 4](#)).

Table 4
Summary statistics for long-bone lengths (mm).

	Hambleden				Ashkelon				Wharram Percy			
	N	Mean	sd	cv	N	Mean	sd	cv	N	Mean	sd	cv
Femur	23	74.1	5.3	7.2	51	70.9	6.4	9.0	39	75.2	12.2	16.2
Tibia	18	62.4	4.2	6.7	70	62.6	4.0	6.4	37	61.1	8.7	14.2
Fibula	9	60.8	3.9	6.4	24	59.7	5.2	8.6	17	59.9	9.2	15.4
Humerus	20	64.1	3.4	5.3	55	63.2	4.0	6.3	48	67.4	9.5	14.1
Radius	17	51.6	2.8	5.4	39	50.5	3.1	6.2	37	54.4	7.2	13.2
Ulna	7	59.0	2.4	4.1	76	57.6	3.2	5.6	12	59.3	10.6	17.9
Clavicle	6	42.7	2.5	5.9	–	–	–	–	27	44.9	6.7	14.9

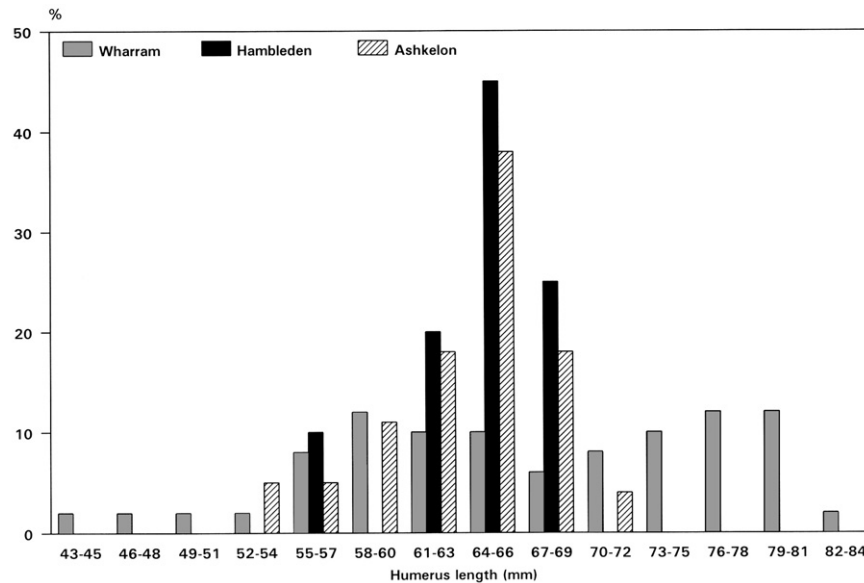


Fig. 2. Humerus lengths.

The distribution of gestational ages, estimated using the regression equations of Scheuer et al. (1980), is shown in Fig. 3. The Hambleden distribution shows a strong peak at 38–40 weeks, an age approximately corresponding to a full-term foetus. It resembles the Ashkelon site rather than the flatter Wharram Percy distribution. The ages estimated using the Sherwood et al. (2000) regression equations show similar patterns (Fig. 4).

The age structure of Sherwood et al.'s (2000) reference sample and Scheuer et al.'s (1980) BCH group are very different, the former being generally younger than the latter (Fig. 5). Ageing the same target populations using both sets of regression equations is a useful empirical test of whether there is a tendency toward the age distributions of the target samples resembling that of the reference sample used to derive the ageing method. If this effect were important, then we might expect the age distribution in the target populations inferred from the Sherwood et al. (2000) method to be biased downward toward Sherwood et al.'s reference sample median age compared with those generated from the Scheuer et al. (1980) regression equations. Comparison of Figs. 3 and 4 shows that in fact the opposite is the case: for each site the ages estimated using Sherwood et al. (2000) are in general older by about a week. This is evident as a slight shuffling to the right of the age distributions generated using this method (Fig. 4) compared with those produced by the Scheuer et al. method (Fig. 3).

The age distributions for Hambleden and Wharram Percy generated using the Bayesian approach are shown in Fig. 6 (the data on Ashkelon are not presented by Smith and Kahila (1992) in a way which permits reanalysis using the Bayesian method). The contrast between the Wharram Percy and the Hambleden data seen in the

regression methods persists, with Hambleden showing a clustering around an age corresponding to a full-term infant. The peak around full term is less pronounced than with the regression approaches. For the distributions generated using the Scheuer et al. (1980) and the Sherwood et al. (2000) equations, 72% and 67% respectively of the Hambleden infants fall into the 38–40 week age class; for the Bayesian method the figure is 52%.

4. Discussion

The dispersion of the Hambleden long-bone length data is low and the distribution clusters around bone lengths which

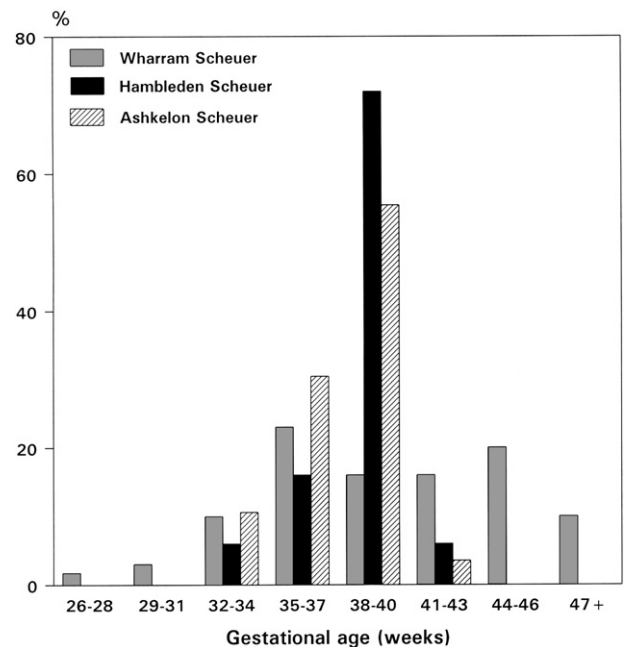


Fig. 3. Perinatal age distributions, ages estimated using the BCH regression equations of Scheuer et al. (1980). $N = 32, 55, 61$ for Hambleden, Ashkelon and Wharram Percy respectively.

Table 5
Variance ratio tests, long-bone lengths at Hambleden versus Wharram Percy.

	<i>F</i> statistic	<i>p</i>
Femur	5.1	<0.001
Tibia	4.33	0.002
Fibula	5.75	0.2 > <i>p</i> > 0.01
Humerus	6.67	<0.001
Radius	5.67	<0.001
Ulna	21.0	0.02 > <i>p</i> > 0.01
Clavicle	6.57	0.05 > <i>p</i> > 0.02

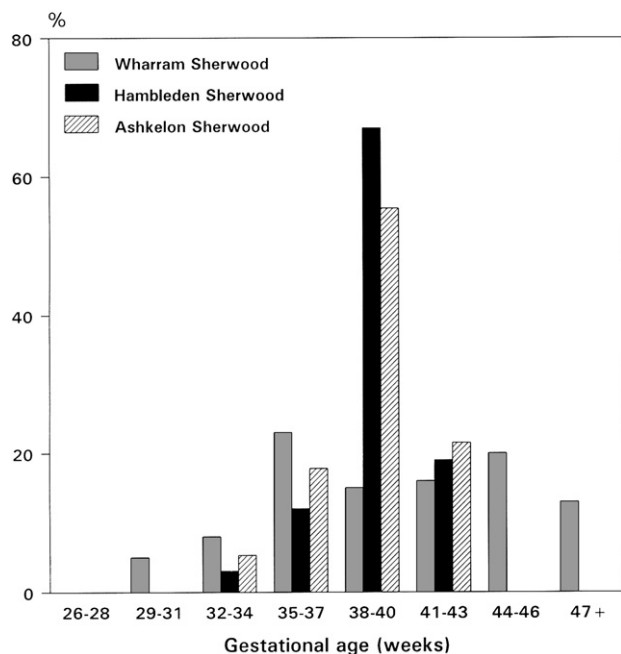


Fig. 4. Perinatal age distributions, ages estimated using the regression equations of Sherwood et al. (2000). $N = 33, 55, 61$ for Hambleden, Ashkelon and Wharram Percy respectively.

approximately correspond with those expected of a full-term foetus. The coefficients of variation of bone lengths are significantly less than in a group of infants from Wharram Percy, an archaeological site where perinatal infant burials appear to represent natural deaths. The central tendency and dispersion of bone lengths at Hambleden resemble those from an archaeological site at Ashkelon where infants likely represent infanticides. Age at death, in

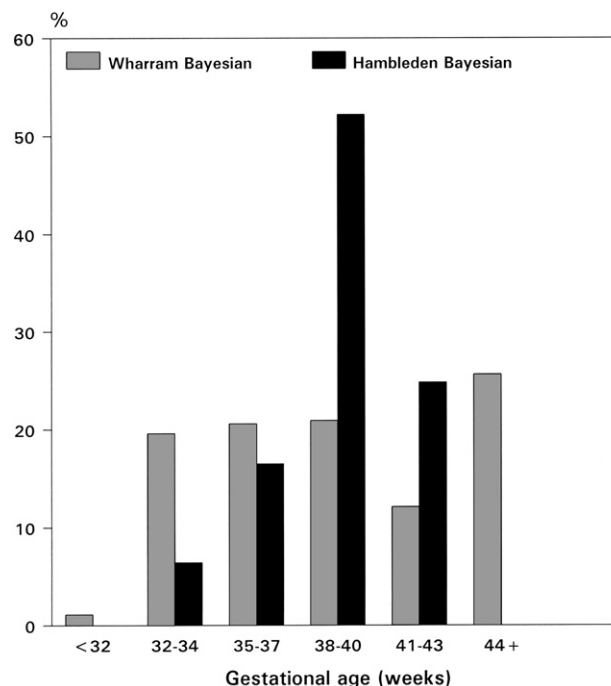


Fig. 6. Perinatal age distributions, ages estimated using Bayesian analysis. $N = 23$ and 39 for Hambleden and Wharram Percy respectively.

weeks gestation, was estimated from long-bone lengths using three different methodologies, two regression-based and one Bayesian. For Hambleden, these indicated a tightly constrained distribution of ages centred on about 38–40 weeks gestation, which corresponds approximately to a full-term infant. These patterns contrasted with those from Wharram Percy – for each analysis the Wharram Percy infant ages at death showed a more dispersed distribution than Hambleden, with a greater proportion of deaths pre-term and in the first few weeks of post-natal life – but they resemble those for Ashkelon.

The study provides empirical evidence that, for perinatal ages estimated from long-bone lengths using regression methods, the tendency of age distributions of target populations to mimic those of the reference populations used to generate the regression equations does not exist to any appreciable extent. In general, the poorer the correlation between an age indicator and age, the greater the tendency toward age-structure mimicry (Konigsberg and Frankenberg, 1992). For foetal and perinatal infants, the correlation between long-bone lengths and age is generally high – for example for the femur, the most widely studied bone in this age class, correlation coefficients between length and age of about 0.95 or higher are routinely reported (e.g. Scheuer et al., 1980; Hadlock et al., 1982; Yeh et al., 1982; Warda et al., 1985; Ejalde and de Ejalde, 1986; Hill et al., 1992; Sherwood et al., 2000; Adalian et al., 2002). The lack of an observable age-structure mimicry effect is thus largely as expected on theoretical grounds. The clustering of the Hambleden data is seen not only in the age profiles constructed from the regression methods, but also in the raw bone measurements and in the Bayesian analysis. This constitutes further evidence that the peak at full term is not an artifact of ageing using regression equations of bone length upon age, as does the fact that the regression approaches do not produce this peak when applied to the Wharram Percy material. The reason that the Bayesian analysis produces a less pronounced peak at ages corresponding approximately to full term than do the regression-based techniques is not removal of an age-structure mimicry effect in

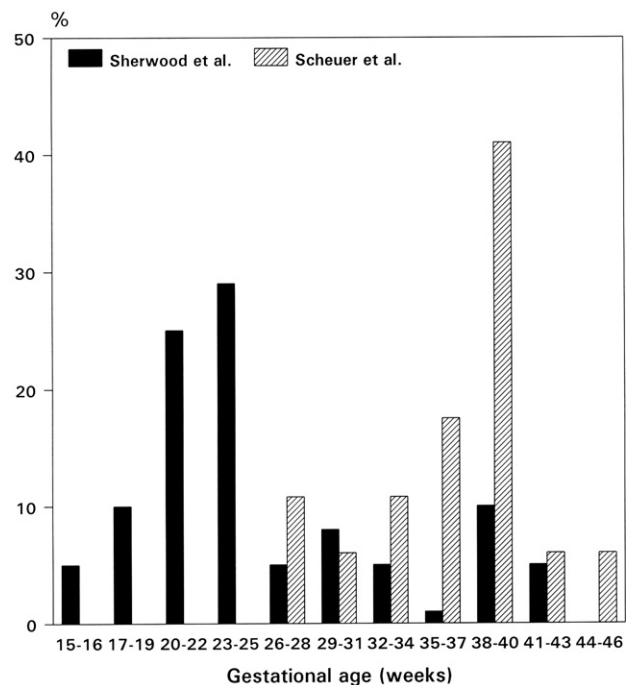


Fig. 5. Age distributions of reference samples of Sherwood et al. (2000) ($N = 63$) and Scheuer et al. (1980) (BCH data, $N = 17$).

the regression-based methods but rather the introduction of a bias inherent in the Bayesian method. The maximum percentage that could be placed into the 38–40 week category using the Bayesian methodology outlined here is only 66% (this would occur if all the infant femurs measured between 75 and 79 mm (Table 3)). The contingency tables produced by Gowland and Chamberlain (2002) have a similar bias – the maximum percentage of infants that could be placed in their age category centred on 40 weeks gestation using their contingency table of femur length based on model priors (Gowland and Chamberlain, 2002: Table 5) is 64%.

Because the Hambleden perinatal age distribution does not resemble that expected of natural deaths, some explanation is called for. The excavator noted 97 infant burials on site (Cocks, 1921), but only 35 infant skeletons could be located in the site archive. This leaves open the possibility that the age distribution found in the current work may not be representative of that of all the burials noted by Cocks (1921). For this to be the case, there would need to have been selective retention in the site archive of those aged about 38–40 weeks gestation, which seems improbable. It also seems unlikely that the age distribution could be an artifact of bone survival or on-site recovery methods. This would require selective destruction, or non-recovery, of many infants slightly younger and older than full term, whilst those of full-term age were recovered in abundance. In addition, the age distribution at Wharram Percy was very different even though this site had similar recovery methods (hand recovery without sieving for small bones) and soil conditions (chalk geology) to Hambleden. A further possibility is that for some reason, the excavated area at Hambleden was used for burial of mainly full-term infants with most slightly younger or older ones being buried elsewhere. The Hambleden perinatal age distribution resembles those produced from other Roman sites in Britain (Mays, 1993), so for this to be an explanation it would have to apply more generally, with interment of pre-term fetuses and infants dying in the first few weeks of life in ways which have left no trace archaeologically. We know of no evidence that this sort of burial selection process was carried out in the Roman world.

One could argue that the age distribution of natural perinatal deaths was simply different in the past, with a larger percentage of stillbirths occurring at full term, and/or the gestational ages of a larger percentage of infants dying immediately after birth being in the 38–40 weeks category than was the case in recent times. There seems little reason to believe that the gestational ages of stillbirths in the past were very different from those of recent infants. The medical care available to infants in recent times means that perinatal mortality is much lower than in the past. However, it is difficult to think of reasons why the gestational ages of natural deaths in the immediate *post-partum* period should be more strongly clustered about 38–40 weeks in antiquity. If adverse extraneous factors, such as disease, resulted in high numbers of 38–40 week gestation infants in the mortality sample then one would also expect high numbers of deaths among pre-term and, in particular, slightly older infants who lived a little longer, so that there would not be a pronounced peak in the age distribution at the 38–40 week cohort. Secondly, a study of perinatal mortality in modern Americans showed that whilst mortality was higher in socially disadvantaged groups, this made no difference to the pattern of mortality with respect to gestational age (Allen et al., 2000), suggesting that living conditions did not greatly influence this latter. Lastly, the observation that perinatal age distributions from many archaeological sites, such as Wharram Percy, and at the others discussed in the introduction to this paper, are fairly flat with no pronounced peak at full term shows that in many cases gestational age distributions of perinatal infants from archaeological sites do in fact resemble those of modern perinatal natural deaths.

Although other possibilities cannot be definitively excluded, the most plausible explanation for the patterns of long-bone lengths and estimated ages at death among the Hambleden infants appears to be infanticide. The results need not, of course, imply that all the infants from Hambleden were killed deliberately, but rather than infanticide victims make up a sufficient proportion of the total to exert a marked effect on the perinatal age at death distribution.

5. Conclusions

The results of the current work support the interpretation made by the excavator (Cocks, 1921) that the Hambleden infant burials provide evidence for infanticide. The current study, together with previous work on perinatal infants from other Romano-British sites (Mays, 1993, 2003), suggests that infanticide may have been regularly practiced in Britain when it was a province of the Roman Empire. This parallels the work at Ashkelon (Smith and Kahila, 1992), which provides archaeological evidence for infanticide in the eastern part of the Empire. However, evidence for infanticide is not present from some other parts of the Empire. The material from Roman Kellis in Egypt failed to show evidence for infanticide, the perinatal age distribution being consistent with natural deaths (Tocheri et al., 2005).

The current work adds to the archaeological studies which show perinatal age distributions consistent with infanticide (Owsley and Jantz, 1985; Mays, 1993; Smith and Kahila, 1992; Borić and Stefanović, 2004; Halcrow et al., 2008). That this should be a fairly frequent finding should not surprise us. Infanticide was widely practiced in premodern societies. In a survey of 393 recent human societies, Divale and Harris (1976) found that infanticide was practiced to some extent in nearly 80%. Indeed, infanticide is an act often carried out in private and easily concealed (Mays, 2000), so its true prevalence may have been even higher. Although most modern societies find the practice of infanticide abhorrent, it was not uncommon in the past.

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References

- Adalian, P., Piercecci-Marti, M.-D., Bourlière-Najean, B., Panuel, M., Leonetti, G., Dutour, O., 2002. Nouvelle formule de détermination de l'âge d'un fœtus. *C.R. Biologies* 325, 261–269.
- Allen, M.C., Alexander, G.R., Tompkins, M.E., Hulse, T.C., 2000. Racial differences in temporal changes in newborn viability and survival by gestational age. *Paediatr. Perinat. Epidemiol.* 14, 52–158.
- de la Bédoyère, G., 1993. Roman Villas and the Countryside. Batsford/English Heritage, London.
- Borić, D., Stefanović, S., 2004. Birth and death: infant burials from Vlasac and Lepinski Vir. *Antiquity* 78, 526–546.
- Brunt, P.A., 1971. *Italian Manpower 225BC–AD14*. Clarendon, Oxford.
- Chamberlain, A.T., 2006. *Demography in Archaeology*. Cambridge University Press, Cambridge.
- Chitty, L.S., Altman, D.G., Henderson, A., Campbell, S., 1994. Charts of fetal size: 4. Femur length. *Br. J. Obstet. Gynaecol.* 101, 132–135.
- Cocks, A.H., 1921. A Romano-British homestead, in the Hambleden valley, Bucks. *Archaeologia* 71, 141–198.
- Crawford, S., Lewis, C., 2008. Childhood studies and the society for the study of childhood in the past. *Childhood Past* 1, 5–16.
- Divale, W.T., Harris, M., 1976. Population, warfare and the male supremacist complex. *Am. Anthropol.* 78, 521–538.
- Ejalde, B.R., de Ejalde, M.M., 1986. The prenatal growth of the human body determined by the measurement of bones and organs by ultrasonography. *Am. J. Med. Genet.* 24, 575–598.
- Evers, G., 2008. Romans in the Hambleden Valley Project. Geophysical and Desk Top Study. Report 1. Chiltern Archaeology Report No. 117. Chiltern Archaeology, High Wycombe.
- Fazekas, I.G., Kosa, F., 1978. *Forensic Foetal Osteology*. Akademiai Kiado, Budapest.

- Frere, S., 1967. *Britannia, a History of Roman Britain*. Routledge & Keegan Paul, London.
- Gibson, J.R., McKeown, T., 1951. Observations on all births (23,970) in Birmingham, 1947. III. Survival. *Br. J. Soc. Med.* 5, 177–183.
- Gowland, R.L., Chamberlain, A.T., 2002. A Bayesian approach to ageing perinatal skeletal material from archaeological sites: implications for the evidence for infanticide in Roman Britain. *J. Archaeol. Sci.* 29, 677–685.
- Hadlock, F.P., Harrist, R.B., Deter, R.L., Park, S.K., 1982. Fetal femur length as a predictor of menstrual age: sonographically measured. *AJR* 138, 875–878.
- Halcrow, S.E., Tayles, N., Livingstone, V., 2008. Infant death in late prehistoric south-east Asia. *Asian Perspect.* 47, 371–404.
- Harris, W.V., 1982. The theoretical possibility of extensive infanticide in the Graeco-Roman world. *Class. Quart.* 32, 114–116.
- Harris, W.V., 1994. Child exposure in the Roman Empire. *J. Roman Stud.* 84, 1–22.
- Hill, L.M., Guzik, D., Hixson, J., Peterson, C.S., Rivello, D.M., 1992. Composite assessment of gestational age: a comparison of institutionally derived and published regression equations. *Am. J. Obstet. Gynecol.* 166, 551–555.
- Hillier, R., 1992. The striae of Retzius as indicators of disease experience in children. PhD thesis, University of Sheffield.
- Hohler, C.W., Quetel, T.A., 1982. Fetal femur length: equations for computer calculation of gestational age from ultrasound measurements. *Am. J. Obstet. Gynecol.* 143, 479–481.
- Keith, A., 1921. Report on the human remains. In: Cocks, A.H. (Ed.), *A Romano-British Homestead, in the Hambleden Valley, Bucks*. *Archaeologia* 71, 141–198.
- Konigsberg, L.W., Frankenberg, S.R., 1992. Estimation of age structure in anthropological demography. *Am. J. Phys. Anthropol.* 89, 235–256.
- Langer, W.L., 1974. Infanticide: a historical survey. *Hist. Child. Quart.* 1 (3), 353–365.
- Lewis, M., 2007. *The Bioarchaeology of Children: Perspectives from Biological and Forensic Anthropology*. Cambridge University Press, Cambridge.
- Lewis, M.E., Gowland, R., 2007. Brief and precarious lives: infant mortality in contrasting sites from Mediaeval and Post-Mediaeval England (AD850–1859). *Am. J. Phys. Anthropol.* 134, 117–129.
- Lewontin, R.C., 1966. On the measurement of relative variability. *Syst. Zool.* 15, 141–142.
- Maresh, M.M., 1955. Linear growth of the long bones of extremities from infancy through adolescence. *Am. J. Dis. Child.* 89, 725–742.
- Maresh, M.M., Deming, J., 1939. The growth of the long bones in 80 infants. Roentgenograms versus anthropometry. *Child Dev.* 10, 91–106.
- Mays, S., 1993. Infanticide in Roman Britain. *Antiquity* 67, 883–888.
- Mays, S., 2000. The archaeology and history of infanticide, and its occurrence in earlier British populations. In: Sofaer-Derevenski, J. (Ed.), *Children and Material Culture*. Routledge, London, pp. 180–190.
- Mays, S., 2003. Comment on 'A Bayesian approach to ageing perinatal skeletal material from archaeological sites: implications for the evidence for infanticide in Roman Britain' by R.L. Gowland and A.T. Chamberlain. *J. Archaeol. Sci.* 30, 1695–1700.
- Mays, S., 2007. The human remains. In: Mays, S., Harding, C., Heighway, C. (Eds.), *Wharham XI: The Churchyard. Wharham: A Study of Settlement in the Yorkshire Wolds XI*. York University Press, York, pp. 77–192. 337–397.
- Mensforth, R.P., 1990. Palaeodemography of the Carlston Annis (Bt5) late Archaic skeletal population. *Am. J. Phys. Anthropol.* 82, 81–99.
- Molleson, T.I., 1989. Social implications of mortality patterns of juveniles from Poundbury Camp, Romano-British cemetery. *Anthropologischer Anz.* 47, 27–38.
- Moore, A., 2009. Hearth and home: the burial of infants within Romano-British domestic contexts. *Childhood Past* 2, 33–54.
- Moore, J., Scott, E. (Eds.), 1997. *Invisible People and Processes: Writing Gender and Childhood Into European Archaeology*. Leicester University Press, London.
- O'Brien, G.D., Queenan, J.T., 1981. Growth of the ultrasound fetal femur length during normal pregnancy. *Am. J. Obstet. Gynecol.* 141, 833–837.
- Olsen, O.E., Lie, R.T., Maartman-Moe, H., Pirhonen, J., Lachman, R.S., Rosendahl, K., 2002. Skeletal measurements among infants who die during the perinatal period: new population-based reference. *Pediatr. Radiol.* 32, 667–673.
- Owsley, D.W., Jantz, R.L., 1985. Long bone lengths and gestational age distributions of post-contact period Arikara Indian perinatal infant skeletons. *Am. J. Phys. Anthropol.* 68, 321–328.
- Philpott, R., 1991. Burial practices in Roman Britain. A survey of grave treatment and furnishing AD43–410. In: *British Archaeological Reports (British Series)*, vol. 219. Tempus Reparatum, Oxford.
- Scheuer, L., Black, S., 2000. *Developmental Juvenile Osteology*. Academic Press, London.
- Scheuer, J.L., Musgrave, J.H., Evans, S.P., 1980. Estimation of late foetal and perinatal age from limb bone length by linear and logarithmic regression. *Ann. Hum. Biol.* 7, 257–265.
- Scrimshaw, S.C.M., 1984. Infanticide in human populations: societal and individual concerns. In: Hausfater, G., Hrdy, S.B. (Eds.), *Infanticide*. Aldine, Hawthorne, pp. 439–462.
- Sherwood, R.J., Meindl, R.S., Robinson, H.B., May, R.L., 2000. Fetal age: methods of estimation and effects of pathology. *Am. J. Phys. Anthropol.* 113, 305–315.
- Smith, P., Kahila, G., 1992. Identification of infanticide in archaeological sites: a case study from the late Roman – early Byzantine periods at Ashkelon. *J. Archaeol. Sci.* 19, 667–675.
- Sofaer-Derevenski, J., 1994. Where are the children? Accessing children in the past. *Archaeol. Rev. Camb.* 13 (2), 7–20.
- Tocheri, M.W., Molto, J.E., 2002. Ageing foetal and juvenile skeletons from Roman period Egypt using basiocciput osteometrics. *Int. J. Osteoarchaeol.* 12, 356–363.
- Tocheri, M.W., Dupras, T.L., Sheldrick, P., Molto, J.E., 2005. Roman period fetal skeletons from the east cemetery (Kellis 2) of Kellis, Egypt. *Int. J. Osteoarchaeol.* 15, 326–341.
- Warda, A.H., Deter, R.L., Rossavik, I.K., Carpenter, R.J., Hadlock, F.P., 1985. Fetal femur length: a critical reevaluation of the relationship to menstrual age. *Obstet. Gynecol.* 66, 69–75.
- Warren, M.A., 1985. Reconsidering the ethics of infanticide. *Philos. Books* 26, 1–9.
- Watts, D.J., 1989. Infant burials and Romano-British Christianity. *Archaeol. J.* 146, 372–383.
- Whittaker, D.K., Richard, D., 1978. Scanning electron microscopy of the neonatal line in human enamel. *Arch. Oral Biol.* 23, 45–50.
- Wiedemann, T., 1989. *Adults and Children in the Roman Empire*. Routledge, London.
- Williamson, L., 1978. Infanticide: an anthropological analysis. In: Kohl, M. (Ed.), *Infanticide and the Value of Life*. Prometheus, Buffalo, pp. 61–75.
- Yeh, M.-N., Bracero, L., Reilly, K.B., Murtha, L., Abroulafia, M., Barron, B.A., 1982. Ultrasonic measurement of femur length as an index of fetal gestational age. *Am. J. Obstet. Gynecol.* 144, 519–522.
- Zar, J., 1999. *Biostatistical Analysis*, fourth ed. Prentice-Hall, London.