Neonatal Mortality, Young Calf Slaughter and Milk Production during the Early Neolithic of North Western Mediterranean

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ABSTRACT

The North-Western Mediterranean witnessed a rapid expansion of farmers and their livestock during the Early Neolithic period. Depending on the region, cattle played a more or less important role in these communities; however how these animals were exploited for their milk is not clear. Here we investigate calf mortality to determine indirectly whether cattle dairying was practised by Early Neolithic stock herders. Age-at-death (AtD) frequencies for calves from two sites: Trasano (Italy, Impressa culture: 7–6th millennium BC) and La Draga (Spain, Cardial culture: 6th millennium BC) were estimated from dental eruption and development stages, and measurements of un-fused post-cranial material. Adult age classes are well represented in the dental AtD frequencies and were interpreted as the result of the slaughter of prime beef and retired lactating females. For calves aged less than 12 months, there was no statistical difference in the AtD frequencies based on dental and post-cranial material indicating that the data is a good representation of the mortality patterns of calves, either natural or deliberate. At both sites there was a strong mortality peak at 3–6 months in all AtD profiles. At La Draga, this peak was clearly differentiated from a peak at 0–1 month, which can be interpreted neonatal mortality possible a consequence of the birthing season coinciding with the end of winter during more humid climatic conditions that at present. The deliberate slaughter peak around 3–6 months is discussed, and we propose that stock herders controlled the mortality of infant classes, possibly in response to variable external environment pressures while maintaining animal productivity. Copyright © 2014 John Wiley & Sons, Ltd.

Key words: cattle; dairy husbandry; early neolithic; mortality frequencies; neonatal mortality; North-Western Mediterranean; young calf slaughtering

Introduction

The status of milk in prehistoric societies has long been debated (Chapman, 1982; Sherratt, 1983, 1997). However in the last 20 years, ceramic residue studies have demonstrated without a doubt that humans have processing milk since the beginning of the Neolithic (Evershed et al., 2008). The publication of Payne (1973) subsistence models and further reference ethnographic scenarios (Vigne & Helmer, 2007) have provided means for archaeozoologists to study dairy husbandry. These models, however, were based on small stock, all dairy species have different physiological reactions to the removal of the young (Balasse, 2003). The presence of the calf has been argued to be necessary for Neolithic dairy husbandry (Clutton-Brock, 1981; Peske, 1994; Balasse et al., 1997; Balasse & Tresset, 2002, Balasse, 2003). This is based on the fact that non-specialised cows can become inhibited to let-down milk without the presence of the calf (Labussière, 1999; Balasse, 2003); consequently if milk is exploited, it is shared between calves and humans. However, at Grimes Graves (Middle Bronze Age, UK), calves were culled between 2 and 3 months, which was interpreted as the result of dairy husbandry (Legge, 1981, 1992). This is similar to the present industrial systems where calves are removed from their mothers at birth or within the first weeks of birth. Then, depending on their sex, either culled or kept
for breeding stock or beef production. If cows are inhibited by the removal/death of the calf, there are methods to stimulate milk production such as creating a dummy using the dead calf skin, blowing into the uterus (Balasse, 2003; Le Quellec, 2011) or providing a live calf substitute (Vigne & Helmer, 2007). There is long history of these techniques being used in Europe from the medieval period onwards (Lucas, 1989). Consequently, it is possible prior to the development of specialised dairy breeds that calves could have been slaughtered during the lactation period by stock herders to increase milk supply for human consumption.

The role of cattle in the Impressa, and the Franco-Iberian Cardial cultures of North-Western Mediterranean are only partially known (Rowley-Conwy et al., 2013). Specialised cattle breeding is believed to have taken place in South-Eastern Italy from the 7th millennium BC onwards (Vigne & Helmer, 1999; Vigne, 2003) while further west, sheep and goat dominate assemblages (Helmer & Vigne, 2004; Tresset & Vigne, 2007; Vigne & Helmer, 2007). For the Iberian Peninsula, Early Neolithic assemblages predominately come from cave sites with questionable representation of the whole herding system (Saña, 2013). However, recent discoveries of well-preserved open air sites (La Draga, Banyoles; Sant Pau del Camp, Barcelona) indicate that cattle were important in Spain as in South-Eastern Italy. The initial review carried out by Vigne & Helmer (2007) identified high frequencies of young calf mortality from Early Neolithic contexts in Southern Italy, which were tentatively interpreted as the result of natural mortality due to birth accidents/postnatal infections or deliberate slaughter to optimise milk production. Distinguishing neonatal mortality from deliberate slaughter was not possible until recently as there were no means of predicting the age-at-death of calves with narrow standard errors. Here we take advantage of the recent publication of predicting age-at-death (AtD) from un-fused post-cranial bone measurements (Gillis et al., 2013a) together with dental AtD frequencies to investigate neonatal mortality and young calves culls (<6 months) at two sites in the North-Western Mediterranean region: Trasano and La Draga.

Material and methods

Trasano (Matera, Italy; Figure 1) is a dry open air site of the Impressa tradition dating from the mid-7th to the early 6th millennium BC (Guilaine & Cremonesi, 1987; Radi, 2003). La Draga (Banyoles, Girona, Spain) is a Cardial open air site situated on the Eastern submerged Neolithic shore line of Lake Banoyles and dates from the second half of the 6th millennium BC (Bosch et al., 2000). The faunal remains have been processed by J-DV & IC, (*unpub.*; Trasano) and M S-S (Saña Segui, 2001; La Draga). At both sites, the cattle dental and un-fused bone material was studied by RG.

All contexts were sieved at both sites; however, taphonomic conditions differed at both sites. Using the ratio of humerus and tibia MNEprox/MNEdist as an index of preservation (see Binford, 1981) indicates that at Trasano the ratios were lower than that of La Draga (Trasano: humerus: 1/42; tibia: 6/17; La Draga: humerus: 20/28; tibia: 17/18). The low density un-fused bones are more subject to fragmentation and gnawing by dogs (Munson, 2000). The percentage of carnivore gnawing on bones at La Draga was 0.1%, which suggests that there were low rates of attrition (Saña Segui, 2001). This was not recorded at Trasano, so we can make no comparison.

Archaeozoological mortality profiles are commonly constructed using AtD frequencies estimated from dental eruption, development and wear. Dental remains provide more precise and reliable estimates compared to epiphyseal fusion timings of post-cranial elements (Halstead, 1998; Helmer, 2000; Greenfield & Fowler, 2005; Vigne & Helmer, 2007). There are some discrepancies for eruption timings for M1 between different authors (Silver, 1963: 5–6 months; Legge, 1992: 2–3 months). Gillis et al. (2013a) have demonstrated that the absolute age references given by Legge (Legge, 1992) are more accurate than those based on traditional veterinarian observations of tooth eruption through the gum (Silver, 1963; Higham, 1967). In addition, to Legge’s (Legge, 1992) scheme, crown height ratios were used to identify adult mortality following...
Both lower and upper teeth were used in this study (Table 1). The mortality data is presented as a histogram following Brochier (2013), without using the a priori correction initially proposed by Vigne & Helmer (2007). The a priori correction is related to the un-equal probability of recruitment between age classes; we have not used it here as further investigation is required in understanding how affects the final resulting morality profiles.

Estimates of AtD from bone epiphyseal fusion events begin at 7 months, which excludes examination of the perinatal mortality. Gillis et al. (2013a) have developed linear models for the prediction of AtD from measurements following von den Dreisch (von den Driesch, 1976; GL, Bp, Dp, SD, Bd and Dd) of un-fused diaphyses and epiphyses of post-cranial long bones as well as astragalus and calcaneus. The post-cranial elements studied for each site are detailed in Table 2. The AtD estimates for post-cranial bones for Trasano and La Draga were from 45 and 46 elements, respectively.

The excellent preservation conditions are evident at La Draga and of the 120 possible measurements 89% were measurable (Table S1b), whereas at Trasano of the 236 measurements, only 42% were (Table S1a).

The number of bins chosen for the AtD frequencies from bone measurements histograms was based on the square root of the total sample number. To identify whether there was one or more culls within the AtD frequencies predicted from un-fused bones, mixture analyses were performed. The Akaike information criterion (AIC, Akaike, 1974) is the most reliable parameter for determining the best mixture model with reference to the actual distribution of the frequencies. The preferred model is the one that has the lowest AIC and that minimises information loss. The relative probability of the model (Eq.1) can be interpreted as the ith model which minimises the information loss (Burnham & Anderson, 2004).

Relative probability = \[ \exp \left( \frac{(AIC_{\text{min}} - AIC_i)}{2} \right) \] (1)

The raw AtD frequencies predicted from dental and un-fused bone remains were compared using a Chi² test. For processing this test, the ages predicted from the un-fused bones were grouped into the following age classes: 0 to 1 months, 1 to 4 months, 4 to 6 months and 6 to 12 months following the dental age predictions (Table S2). It is difficult to refine these age classes further due to the large intervals associated with eruption and development stages.

The age predictions from the linear models were calculated using the free-platform R package (version 2.13.1) and the PAST program (version 3.0; Hammer, 2013) was used for the mixture analysis modelling. Microsoft Excel software was used for all other statistical calculations.
Results

The mortality profiles based on dental material

The Trasano (phases I–III) dental mortality profile (Table 1; Figure 2a) indicates a low frequency of mortality in age class 0 to 1 months (N = 1), which then increase in age class 4 to 6 months (N = 7). For adult age classes, 2–4 years constitute the strongest peak (N = 20), which is classically interpreted as the result of slaughter for prime beef (Helmer, 1992). Age classes >4 years are also well-represented (N = 22), possibly a reflection of retired lactating females slaughter. Overall, the dental mortality profile at Trasano suggests that the early culling of infants coupled with adult age classes is the result of mixed husbandry practices towards beef and dairy production.

At La Draga, there is a strong peak in age classes 0 to 1 months (Table 1; Figure 2b). The high frequency of neonatal mortality (N = 5) is consistent with the previous findings of Saña (Saña Segui, 2001). The peak in the following age class (1 to 4 months; N = 21) could be the result of deliberate slaughter rather than natural mortality. The interpretation of the mortality pattern for adults is similar to Trasano with the slaughter for beef (2–4 years; N = 24) and of retired lactating females (adults >4 years old; N = 29).

Mortality profiles based on un-fused bones measurements

For Trasano, the histogram and the distribution of the Kernel densities show one peak between 4 and 5 months (Figure 3a). For La Draga, the histogram shows two distinct peaks, between 0–1 months and 3–4 months (Figure 3b). The models for one to three cull groups predicted from the mixture analyses of the AtD frequencies distributions are presented in Table 3.

For Trasano, the difference of the AIC for a model for one, two or three groups is small. Moreover, when we compare the relative probability for information loss between the model for three groups (lowest AIC) and
one or two groups, it is very low (<0.005 for both groups). Due to the sample size and the number of outliers, it is wise not to conclude more than one group. The mean age of mortality for one group is 5 ± 2 months (p > 0.05). This result is congruent with the mortality profile (Figure 2a) based on dental material, where the largest peak for calves is in age class 4–6 months. The 0–1 month mortality peak is very small, as previously seen for AtD frequencies based on dental remains (Figure 2a).

For La Draga, the relative probability for information loss between the model for two groups and that for three groups is 0.09. This small difference between the two models is also evident in the predicted mean ages (Table 3). The first centres on the neonatal age class 0–1 month (Model 2 groups: mean = 0.6 ± 0.5, p > 0.05; Model 3 groups: mean = 0.7 ± 0.6, p > 0.05) and the second between 3 and 4 months (for both Models: mean = 3.5 ± 1, p > 0.05). The final mean age predicted by the model for three groups is 7.1, p = 0.02. These mean ages predicted are congruent with the dental mortality profiles, with two main peaks: 0–1 month and 3–4 months (Figure 2b) and a smaller one between 6 and 12 months.

Teeth and bones are affected differently by taphonomic conditions (Brain, 1981; Lyman, 1984). Unfused bones are more open to destruction from carnivore attack and abiotic processes due to their fragility. To a lesser extent, these factors are also a threat to infant and juvenile dental remains. The Chi² test between the raw AtD results (Table S2) predicted indicate no significant differences between age distributions from unfused bone and dental material (Trasano phases I to III (X² = 3, df = 3, p = 0.4); La Draga (X² = 0.8, df = 3, p = 0.05). The close congruencies presents a strong case that the age structure is the same for both dental and post-cranial remains. Consequently, we believe that the dental and bone AtD predicted frequencies at both sites provide an accurate representation of prehistoric mortality.

### Interpretation and discussion

Halstead (1998) proposed that equifinality problems related to partial recovery, sampling and preservation conditions for cranial and post-cranial elements could lead to interpretation problems. The presence of calves

### Table 3. Akaike information criterion (AIC) and mean ages for the models for 1, 2 and 3 mortality peaks generated from mixture analysis of AtD predicted from un-fused cattle bones

<table>
<thead>
<tr>
<th>Mixture analysis (no. of bins = 7)</th>
<th>No. of groups = 1</th>
<th>No. of groups = 2</th>
<th>No. of groups = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AIC</td>
<td>Mean age (months)</td>
<td>AIC</td>
</tr>
<tr>
<td>Trasano</td>
<td>118.5</td>
<td>5</td>
<td>119.3</td>
</tr>
<tr>
<td>La Draga</td>
<td>104.3</td>
<td>2.6</td>
<td>97.82</td>
</tr>
</tbody>
</table>
younger than 6 months could be interpreted as any of the following: over-representation of neonatal disposal areas, natural mortality, specialised slaughtering practice and symbolic disposal. Over-sampling of calf disposal areas could be a concern at La Draga as the site has not been completely excavated (Tarrús, 2008). There are no apparent differences in mortality frequencies between the excavation sectors, which suggest the sample is not biased. Calf remains at both sites were not found in ‘specialised’ contexts, which may have suggested a ritual/symbolic disposal. Natural mortality can be differentiated from deliberate slaughter assuming natural mortality will be highest in the first month. In the following sections we will focus on evaluating and determining the possible animal husbandry practices, which may have caused the mortality frequencies from Trasano and La Draga.

**Accidental death and natural mortality**

At present, neonatal mortality can be as high as 25% during the first month of life due to poor husbandry and non-sterile birthing stalls (Mellor & Stafford, 2004). With reference to this rate, Trasano had a low frequency of neonatal mortality; this may be due to poor preservation of low density neonatal bones. The low frequency of age class (0–2 months) in the caprine mortality profile (S-Figure 1a) from Trasano supports this conclusion. For La Draga caprines (S-Figure 1b), where the preservation was better, there is also a low frequency in this age class. The use of caves/rock shelters as birthing stations evident from truncated mortality profiles is a common feature in caprine husbandry during the Neolithic (Helmer & Vigne, 2004). Absence or presence of very young calves at La Draga and Trasano appears to be an accurate representation of neonatal mortality in the two sites.

High levels of neonatal mortality could be a reflection of poor husbandry practices or climatic conditions (Halstead, 1998). The birthing season for calves usually coincides with March to May, based on regional ethnographic references of traditional and feral cattle (Gomez et al., Gómez et al., 1997; Soysal & Kök, 2006). The modern Mediterranean climate has been characterised by annual levels of precipitation between 450 and 750 mm with 80% precipitation occurring from December to March (Harding et al., 2009). The stability of the summer temperatures and indeed the climate in general in the western Mediterranean is influenced by the Atlantic. During the periods of both sites' occupation, the climate was significantly wetter than today (up to 800–1000 mm per year), where winters/springs were considerably more humid particularly at La Draga (Aguilera et al., 2011). The high neonatal mortality at latter could be a reflection of very humid climate, where the wet season would have coincided with the beginning of the birthing season (Figure 4). This may have forced the Neolithic people to stall their animals, potentially increasing infection amongst calves (Halstead, 1998: 14). Winter periods were drier at Trasano, which would explain the low rate of neonatal mortality with reference to La Draga.

This difference can also result from different management practices. Stalling animals may have led to a more direct control of milk production. If lactating cows were affected by the loss of the calf, methods such as substitution and artificial stimulation could have been employed. If so, the different rates of neonatal mortality for the two sites may be due to more controlled cattle husbandry at La Draga than at Trasano. However, it is difficult to determine whether this difference in neonatal mortality is a direct result of poor
climatic conditions or a deliberate husbandry practice. Further AtD studies from un-fused bone and dental material at the scale of the North-Western Mediterranean area will push ahead research into the effects of climate and husbandry practices on neonatal survival.

**Deliberate slaughter of calves**

At Trasano, the dental and bone AtD frequencies reflected deliberate mortality taking place between 4 and 6 months old, whereas at La Draga, it was focused between 1 and 4 months. Evidence from lipid residues analysis indicates that milk processing was taking place at La Draga and in the region of Trasano (Salque et al., 2012). As we have ruled out a ritual motive, we will examine in more detail the possibility that the slaughter timings were the result of seasonal culls associated with dairy production. The role of the calf is believed to be integral to prehistoric cattle dairy management due to cows’ sensitivity to being milked without them (Peske, 1994). Identification of calves slaughtered at 6–12 months, during the period when they are being weaned from their mothers, has been suggested to be indicative of dairy management. However, the timing of the annual culls will also reflect actions resulting from external climatic pressures. For example, at the Northern French site of Bercy (5th millennium BC; Chasséen) calf mortality between 6 and 12 months was interpreted as evidence for post-lactation slaughter (Tresset, 1996). Further isotopic examination, confirmed that these animals were within weaning process or had been recently weaned, therefore indicating that the lactation period had finished or that animals had been removed from the mother (Balasse et al., 1997). The timing of this slaughter as well as being a direct result of dairy husbandry practices was proposed to have coincided with the onset of winter (Balasse & Tresset, 2002). In Northern France the winter months would have been a difficult time for farmers, with the necessity of constant procurement of fodder and shelter for 4 to 6 months. Therefore, the removal of unwanted animals, particularly males, would have taken place prior to this seasonal change. Consequently, calf slaughter timings are a result of interplay between the pressures of the external environment and of the stock keeping practices to maintain health and productivity of the herd.

In the Mediterranean lowlands, it was not necessary to provide shelter and fodder for cattle during winter, since it was rarely too cold and there would be sufficient naturally available fodder. However, previous studies have indicated that during the height of summer (July to September) in Italy and Greece, there is a shortage of water and fodder (Molenat & Casabianca, 1979; Halstead & Jones, 1989; Rosati, 2000). At Trasano, assuming the animals were born around April, the slaughter peak of animal in age class 4 to 6 months coincides with the height of summer (August/September; Figure 5a). During the middle Holocene in this region temperatures were similar as to today (Magny et al., 2011, 2012). For La Draga, it is possible that herd numbers were reduced prior to the onset of the dry season to ensure sufficient fodder sources for the remaining animals. The differences in climate between the Atlantic-temperate and Mediterranean regions will lead to different birthing seasons (Balasse & Tresset, 2007). Consequently, the timing of the seasonal cull and the age of the infants would vary between North (September to November) and South (June to August).

Central to the post-lactation model for cattle dairy management is that the lactation length for Neolithic cattle would be consistent between regions. In modern animals, it can vary depending on the breed history and

![Figure 5. The modern average temperatures (°C) for the Matera (Italy) and Banoyles (Spain) regions. The study sites dental AtD frequency densities have been superimposed to aid the interpretation of the timing of mortality patterns.](image)
Country Breed Breed type Duration (days)

Croatia

Busa Multi 180

Czech republic

Ceska Cervinka Dual 300

Estonia

Eesti Punane Milk 305

France

Bretonne pie-noire Dual 259

Salers Dual 249

Aubrac Dual 248

Normande Milk 275

Abondance Dual 285

Brune des Alpes (Schwyz) Milk 286

Germany

Holstein-Friesian Milk 308

Dopelnutzung Milk 305

Rotburg

Iceland

Icelandic Dual 340

Italy

Modicana Multi 250

Agerolese Dual 200–300

Regginia Dual 305

Mongolia

Mongolian Multi 152

Slovenia

Cika Multi 300

Spain

Ariéña-Negra Ibérica Multi 180

Pirenaica Multi 290

Turkey

Southern Anatolian Dual 188

Yellow

Anatolian Black Multi 257

Gray Steppe Multi 220

Killis Dual 238

East Anatolian Red Multi 270

Southern Anatolian Red Dual 275

UK

Gloucester Multi 300

Table 4. The duration of lactation for cattle European and Asian cattle breeds

The external environment. For example, lactation lengths can vary from 152 days in Mongolian cattle to 340 days in Icelandic cattle (Table 4). The Icelandic cattle are from improved stock whereas those from Mongolian are not. Therefore a cull timed between 3 and 6 months could be a signature of shorter lactation length in the North-Western Mediterranean, whereas the slaughter of animals between 6 and 12 months at Bercy may be a reflection of a longer lactation length. Cattle were generally more widespread in temperate Europe than in the Mediterranean area during the Early Neolithic (Tresset & Vigne, 2007). The longer lactation lengths would mean that more milk was produced and consumed in the Northern region, which may have led to differences in the lactase persistence frequency evident between these two regions (Gerbault et al., 2011). Further investigation in terms of stable isotopic analysis of dental enamel could determine the rhythm and season of births (Balasse et al., 2003; Blaise & Balasse, 2011), and of bone collagen to investigate the suckling and weaning phases of calves (Balasse & Tresset, 2002; Gillis et al., 2013b). This would elucidate in what season the La Draga and Trasano calves were born and died, and whether they were weaned prior to slaughter. These may provide the finer resolution to the already complex story of calf mortality during the Early Neolithic as described by the analysis of AtD.

Conclusions

The primary aim of this study was to investigate calf mortality at Early Neolithic two sites in the North-Western Mediterranean. This was achieved by using two methods of age determination based on dental eruption, development and wear and on the measurements of un-fused post-cranial elements. These techniques allowed us to distinguish natural neonatal mortality from deliberate cull of young calves. The regional differences in climate appear to have played an important role in the variation of neonatal mortality. The high rate of neonatal mortality at La Draga, where the climate was wetter during the Early Neolithic than today, could either be a reflection of death from exposure or increased stalling of animals leading to high infection rates. Whereas at Trasano the low frequency of neonatal age classes is probably a combination of both poor preservation and a reflection of a more favourable climatic conditions. Further analysis of neonatal mortality at sites in the same region with different taphonomic and climatic conditions is needed for comparison.

The secondary aim was to determine whether the calf mortality was a reflection of dairy husbandry. The strong presence of adults possibly retired lactating females (>4 years), and the presence of dairy lipids in ceramics, supports the idea of the existence of a lactating herd. Both the dental and un-fused bones’ AtD indicated that there was deliberate slaughter around 3–6 months at both La Draga and Trasano. This would have coincided with the dry season at both sites, and therefore the cull would have removed un-wanted calves to ensure sufficient fodder and water supply. The removal of animals this young would also increased the milk production as the milk would no longer be shared between the suckling calf and human competitors. On the other hand, if the calves were an integral part of the husbandry strategy, a cull of 3–6 months could suggest that the length of lactation periods was shorter for Early Neolithic cattle at these North-Western Mediterranean sites. The methods presented here can correctly determine the timing of...
calf slaughter. However, whether it can determine whether dairy husbandry was practised requires other lines of evidence to confidently confirm our initial hypothesis.

The investigation into calf culls in different European regions is important for understanding the evolution of cattle husbandry during the Neolithic and assessing the effect of physical and cultural environments on slaughter practices. Overall, our work has demonstrated that dental and un-fused bone AtD predictions can be combined to investigate neonatal mortality and young calf slaughter. Future studies of this type will elucidate further how Early Neolithic farmers in the NW Mediterranean adapted husbandry practices to maintain herd productivity.

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**Supporting information**

Supporting information may be found in the online version of this article at the publisher’s web site.