International Journal of Paleopathology 41 (2023) 22–31

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp

Cattle health in the Iron Age and Roman Netherlands

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ARTICLE INFO

Keywords:
Livestock
Joint lesions
Dental conditions
Diachronic trends

ABSTRACT

Objective: To investigate diachonic and regional trends in the occurrence of pathologies in cattle in the Iron Age and Roman Netherlands. A key objective is to investigate whether the intensification of cattle husbandry in the Roman period was associated with an increase in pathology.

Materials: The data set consists of 167 sites with a combined total of 127,373 individual specimens for cattle, sheep/goat, horse, and pig.

Methods: A quantitative approach was used, investigating the frequency of pathologies over time and per region. For cattle, pathology frequencies were also investigated per type. Several multi-period sites were considered in more detail.

Results: Pathology frequencies increased during the Iron Age and Roman period. In cattle, joint pathology was most common, followed by dental pathology.

Conclusions: The overall frequency of pathology aligns with frequencies in other regions. Some pathological conditions in cattle can tentatively be linked to intensification, such as joint pathology at two sites in the Middle and Late Roman periods, an increase in dental pathology and trauma).

Significance: This review revealed diachronic trends and linked them to developments in animal husbandry and highlights the importance of recording and publishing pathological lesions.

Limitations: The multi-causal origin of joint and dental pathology makes it difficult to relate them to the intensification of cattle husbandry.

Suggestions for further research: It is hoped that this review will stimulate further paleopathological research globally, especially systematic studies into foot pathologies.

1. Introduction

Since the Bronze Age, when mixed farming was first adopted in the Netherlands (Brinkkemper and van Wijngaarden-Bakker, 2005), cattle dominated animal husbandry in most archaeological periods (Çakirlar et al., 2019; Brinkkemper and Van Wijngaarden-Bakker, 2005; Van, 2016). In the Iron Age, animal husbandry was part of a mixed, subsistence farming system, with cattle as the main species. Cattle management included emphases on meat, traction, milk, or a mixed exploitation at different sites (Groot and Albarella, 2022).

Cattle husbandry in the Roman period was characterised by intensification. An increase in the proportion of cattle over time is observed along with increased slaughter age, size, and the proportion of males (Groot and Albarella, 2022). The increased use of cattle for traction is probably related to the intensification of arable farming (Groot et al., 2009; Groot, 2016; Groot and Kooistra, 2009), with cattle providing labour and manure. Intensification of farming was a response to an increased demand for food and other agricultural products, caused by the development of military sites, towns and villages, and population growth (Bechert and Willems, 1995; Haalebos et al., 1995; Polak and Kooistra, 2015; Van Lanen and Groenewoudt, 2019; Willems and van Enckevort, 2009). Similar developments in cattle husbandry, including the size increase of cattle and a growing role of cattle for traction and as meat providers in towns, are observed throughout the northwestern provinces (e.g. Albarella et al., 2008; Breuer et al., 1999; Dobney et al., 1996: 31–33; Duval et al., 2012; Duval and Albarella, 2022; Grau-Sologestoa et al., 2022; Groot and Deschler-Erb, 2015; Hesse, 2011; King, 2019; Lepetz, 1996; Maltby, 2019; Peters, 1998; Pigière, 2017; Schlumbaum et al., 2003; Teichert, 1984). Outside the area of the Roman Empire, cattle show only minor fluctuations in size in the Iron Age and Roman period (Groot and Albarella, 2022). The Roman influence on cattle breeding does not appear to have reached the northern half of the Netherlands. In the Late Roman period, there was a general decline in cattle frequencies, although this varies between regions,

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https://doi.org/10.1016/j.ijpp.2023.02.003
Received 2 January 2022; Received in revised form 12 February 2023; Accepted 25 February 2023
Available online 7 March 2023
1879-9817/

possibly related to movement of people and livestock from across the Roman border, the collapse of the Roman economy, or a combination of these and other factors.

In modern livestock production, disease has a considerable economic effect. Although entire herds are often preventatively culled at the outbreak of contagious diseases such as swine fever and foot and mouth disease, without intervention large numbers of animals would be lost. While the scale of modern production may have increased the spread and impact of infectious diseases, the use of antibiotics and modern veterinary care must have decreased losses to other diseases. In economic studies of animal husbandry in the past, the impact of disease is underestimated, or not even considered, and yet disease must have severely influenced productivity. In studying the effect of disease on livestock in the past, we face a major methodological problem: diseases that are potentially most damaging to farmers – infectious diseases with high mortality rates – leave little or no archaeological evidence. One of the limits of paleopathology is that it provides information mainly on long-lasting, chronic and/or adaptive conditions, while the most devastating diseases for farmers kill animals too quickly for skeletal tissues to be affected. The burial of groups of complete animals indicates high mortality and could thus be a sign of infectious disease wiping out livestock; however, such finds are rare (Binois, 2013).

Paleopathology is a well-established field, but underdeveloped within zooarchaeology. There are several reasons for this. First, the fragmentary and isolated nature of most animal bones derived from archaeological excavations, especially when compared to human remains, makes the determination of the causes of lesions very challenging (Bendrey, 2014). Nevertheless, while complete skeletons offer great potential for undertaking differential diagnosis, limiting studies to complete skeletons could potentially skew interpretations since animals selected for burial may have been treated differently from animals that were butchered. Next, most zooarchaeologists lack the specialist knowledge required to make differential diagnoses. Moreover, many archaeologists and even many zooarchaeologists believe that paleopathology has limited potential. Finally, there is a focus on individual sites. Since fragments displaying lesions are infrequent, it is difficult to answer research questions concerning animal health based on the analysis of a single site. However, when data from multiple sites are used, the results are more promising (e.g., Bartosiewicz, 2008a, 2008b, 2021; Maldre, 2008; Murphy, 2005; Sapir-Hen et al., 2008; Siegel, 1976). Hence, smaller sites have the potential to contribute to larger syntheses but are of limited value in isolation. Bendrey (2014) emphasises the importance of synthetic and comparative studies in order to establish variability in pathology. Unfortunately, synthetic studies are still rare.

Since the only synthetic study of animal paleopathology for the Netherlands is over 40 years old (Van Wijngaarden-Bakker, L.H., M. Krauwer, 1979), little is known about the health status of domestic animals in the Netherlands in the past. Furthermore, the potential impact of changes in cattle husbandry on cattle health during the Roman period has not been investigated. Intensification of animal husbandry can take various forms: increasing herd size and stocking livestock in higher densities, managing livestock diet by providing fodder, and selective breeding for larger, heavier animals (Groot, 2020). Animals kept in higher densities suffer an increased risk of infectious disease. While we are unlikely to find evidence of infectious disease on animal bones, we may find evidence of chronic conditions that can be related to changes in animal husbandry, such as arthropathies associated with old age or traction, or changes in the prevalence of dental pathology related to a change in diet. This may lead to a higher overall frequency of pathology. Overcrowding could also lead to higher incidences of trauma (Murphy, 2005).

The size increase observed in cattle during the Roman period was likely achieved by a combination of factors: interbreeding with large, imported stock, selective breeding, improved nutrition, and changing sex ratios (e.g., Albarella et al., 2008; Grau-Sologestoa et al., 2022; Groot, 2017; Groot and Albarella, 2022; Lauwerier, 1988). The importation of and interbreeding with new genetic lineages can be investigated through aDNA analysis (Schlumbaum et al., 2003, 2006); such research has not been carried out for the Roman Netherlands. Another way to investigate this is through the analysis of inherited anatomical variations. Two particular dental variations, the congenital absence of the second lower premolar and a reduced hypoconulid (posterior cusp) of the third lower molar, are both regularly observed in cattle from the Iron Age and Roman Netherlands. The congenital absence of the second lower premolar can be caused by malnutrition during the time when the tooth bud is formed, but it has also been suggested that it is an inherited characteristic (Andrews and Noddle, 1975). Therefore, changes in the prevalence of these dental variations may reflect changes in genetic composition of cattle herds (Albarella, 1997: 45; Thomas, 2005: 74).

This paper will investigate the health of livestock, with a focus on cattle, in the Iron Age and Roman period in the area of the modern Netherlands. The aim is to investigate broad diachonic and regional trends in the occurrence of pathologies. The main research questions of this paper are:

- What is the frequency of pathologies in animal remains in the Iron Age and Roman Netherlands?
- Can any regional differences in the frequency of pathologies in cattle be recognised?
- Can we detect a change in cattle pathology with the transition from the Late Iron Age to Roman period, and during the Roman period?
- What types of pathology are most common in cattle?
- What is the prevalence of two common dental variations in cattle?
- To what degree can any occurring change be related to the impact of the Roman occupation of the southern half of the Netherlands?

2. Approach and methodology

This study adopted a quantitative approach; comparing the frequency of pathologies over time and between regions. Data from previous work in this region, zooarchaeological reports, and unpublished studies by colleagues, were collected for cattle, sheep/goat, horse and pig. Sites were only included when lesions were described or explicitly stated as not present. In cases where no pathology is described and no explicit statement is made about its absence, it is possible that it was present but not included in the report. The frequency of lesions were calculated for the main livestock species combined and for cattle, sheep/goat, horse and pig separately. Percentages were calculated for the total number of fragments identified per species or for the main livestock species combined (NISP). When possible, fragment counts for complete skeletons have been included. Considering the different methodologies of recording used by different researchers, it was not possible to analyse pathology at the level of anatomical zones.

Frequencies of pathology were investigated over time using standard time periods: Early Iron Age (800–500 BCE), Middle Iron Age (500–250 BCE), Late Iron Age (250–12 BCE), Early Roman period (12 BCE-AD 70), Middle Roman period (AD 70–270) and Late Roman period (AD 270–450) (Nationale Onderzoeksagenda Archeologie 2.0, 2019). To investigate regional differences, the Netherlands were divided into four regions: north/north-west, west, central, and south (Fig. 1). This division is based on landscape, availability of data, and the later borders of the Roman Empire. The north/northwestern region is the only one that falls outside the Roman Empire.

For cattle, pathologies were assigned to types: dental pathology; joint pathology or arthropathies; trauma; infection/inflammation/trauma; and “other”. These were analysed chronologically. A problem with classification, however, is that it is not always clear how to classify conditions appearing on a single bone, especially when all that is available is a brief description. For instance, localized inflammation can be a result of trauma, causing periosteal new bone formation, or it can be evidence of a more general infection. Because it is very difficult to

Fig. 1. Map of the Netherlands indicating the regions used in this study. Sites mentioned in the text are shown on the map.

determine the cause of inflammation, especially in the case of isolated bones, all such cases were recorded as “infection /inflammation/ trauma”. Some cases of trauma are unmistakable, such as fractures, which explains the use of a separate “trauma” category. Recording and assessment of dental pathology included abnormal tooth wear, periodontal disease, ante mortem tooth loss and abscesses. Assessment of joint pathology included new bone formation around the joint (osteophytes and enthesophytes), ankylosis of tarsal bones with each other and/or with the metatarsus, eburnation and grooving on the joint surface, asymmetry of the distal metapodials, and extension of the articular surface of phalanges. Small depressions on the articular surface as described by Thomas and Johannsen (2011) were not included. In addition, two dental anatomical variations were recorded: the absence of the second lower premolar and a reduced hypoconulid of the third lower molar. Prevalence of these variations was calculated when possible.

A few multi-period sites provide enough data to be analysed individually, both diachronically and per type of pathology. The advantage

Table 1
Number of sites per period, total NISP for the four main domesticates, number of pathologies for the four main domesticates combined and for cattle alone, and the number of dental variations recorded for cattle.

Period	Sites	NISP C, S/G, H, P*	Pathology C,S/G,H,P	Cattle	Cattle pathology	Cattle dental variations
Early Iron Age	3	682	3	376	2	0
Middle Iron Age	10	10,591	45	6561	30	41
Middle/Late Iron Age	3	694	7	447	6	1
Late Iron Age	20	6553	57	4034	39	14
Iron Age	1	213	0	194	1	0
Late Iron Age/Early Roman	9	5636	34	3353	16	4
Early Roman	19	11,119	65	5623	38	4
Early/Middle Roman	29	18,518	85	11,817	47	12
Middle Roman	52	54,616	435	38,469	297	90
Middle/Late Roman	2	6985	59	4331	32	0
Late Roman	11	5842	73	3614	53	4
Roman	8	26,762	17	16,160	11	2
Total	167	127,373	881	82,310	572	172

[*] C= cattle, S/G = sheep and goats, H= horse, P = pigs

of analysing pathology for individual sites is that the bias caused by different approaches to pathology by different researchers is removed.

3. Results

The data set on which the analyses are based consists of a total of 167 sites with a total NISP for the main domesticates of 127,373 (Table 1). The number of pathologies and NISP for sheep/goat, horse and pig separately are listed in the Supplementary table. Some periods and regions are better represented than others. The central region has the highest number of sites and the southern region the lowest. The total number of fragments with pathologies for the four main domesticates is 881, and the total number for cattle is 572. In addition, 172 dental anatomical variations were registered for cattle (not included in the pathology count).

The frequency of pathologies for all periods and regions combined for the four main domesticates and cattle alone is 0.69%. The percentage of lesions for cattle, sheep or goat, horse and pig combined shows an increase in the later Iron Age, which is followed by a decrease in the Early Roman period (Fig. 2). The percentage then increases again to reach a maximum in the Late Roman period.

The same trend is visible for the percentage of lesions for cattle and horse, alone (Fig. 3). The percentage of lesions for sheep/goat remains constant from the Late Iron Age to the Middle Roman period but is lower in the Middle Iron Age and Late Roman period. Pig shows little pathology in the Iron Age and then a rise in pathology during the Roman period.

For the southern region, only two sites were available for the Iron Age and four sites for the Roman period. The data show a strong decrease in pathology for cattle from the Iron Age to the Roman period (from 2.3% to 0.4%), but in addition to the small number of sites, the NISP for cattle for the Iron Age is also low (n = 387). The data set is therefore considered too small for a reliable comparison. While the NISP for cattle for the Iron Age in the northern region is also relatively low (n = 694), the material derives from nine sites. The data show a decrease in prevalence from 1.0% in the Iron Age to 0.2% in the Roman period (Fig. 4). The central and western regions have more robust data sets. In the central region, the percentage of pathology hardly changes from the Iron Age to Roman period (0.9% compared to 0.85%), while the western region shows a clear increase (from 0.2% to 0.7%) (Fig. 4).

For the central and western regions, the frequency of pathologies can be investigated in more detail. The central region shows an increase from Middle to Late Iron Age, then a decline in the Late Iron Age/Early Roman period, followed by a steady increase during the Roman period, which is most pronounced in the Late Roman period (Fig. 5). In the western region, prevalence is low in the Middle Iron Age, but then steadily increases to reach a peak in the Late Roman period; the 0% for the Late Iron Age/Early Roman period may be related to the relatively small NISP for that period (n = 619).

Joint pathology is the most common type of pathological condition among cattle, followed by dental pathology (Fig. 6). There is little difference in the frequency of different types of pathology between the Iron Age and Roman period, only a slight increase in dental pathology, and decrease in infection/inflammation/trauma in the Roman period is observed.

For four multi-period sites in the central region, percentages of cattle pathology can be analysed diachronically. Patterns are variable: Houten-Castellum shows an increase in cattle pathology in the Early

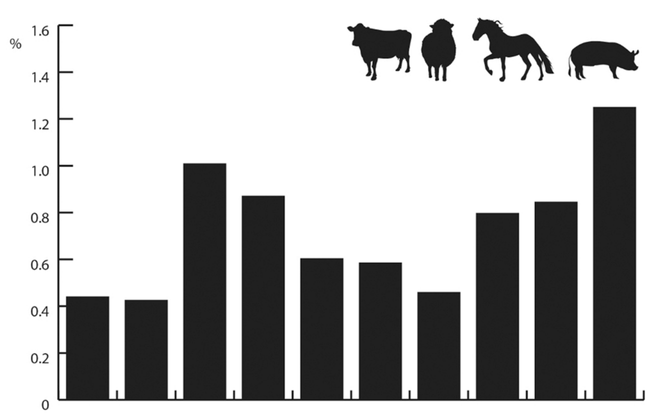

Fig. 2. Percentage of pathologies for cattle, sheep/goat, horse, and pig per period, out of the total number of fragments identified to those species. EIA =Early Iron Age, MIA = Middle Iron Age, M/LIA= Middle/Late Iron Age, LIA = Late Iron Age, LIA/ER = Late Iron Age/Early Roman Age, ER=Early Roman Age, ER/MR=Early/Middle Roman Age, MR=Middle Roman Age, MR/LR=Middle/Late Roman Age, LR=Late Roman Age.

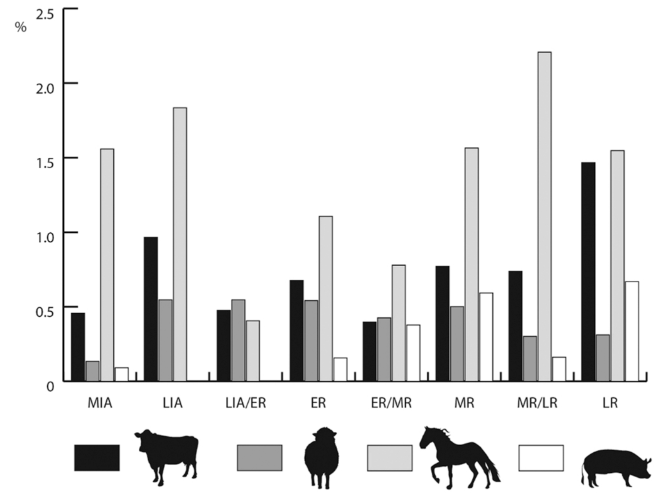

Fig. 3. Percentage of pathologies for cattle, sheep/goat, horse and pig per period, out of the total number of fragments identified for that species. Phases with a NISP lower than 1000 have been excluded. EIA =Early Iron Age, MIA = Middle Iron Age, M/LIA= Middle/Late Iron Age, LIA = Late Iron Age, LIA/ER = Late Iron Age/Early Roman Age, ER=Early Roman Age, ER/MR=Early/Middle Roman Age, MR=Middle Roman Age, MR/LR=Middle/Late Roman Age, LR=Late Roman Age.

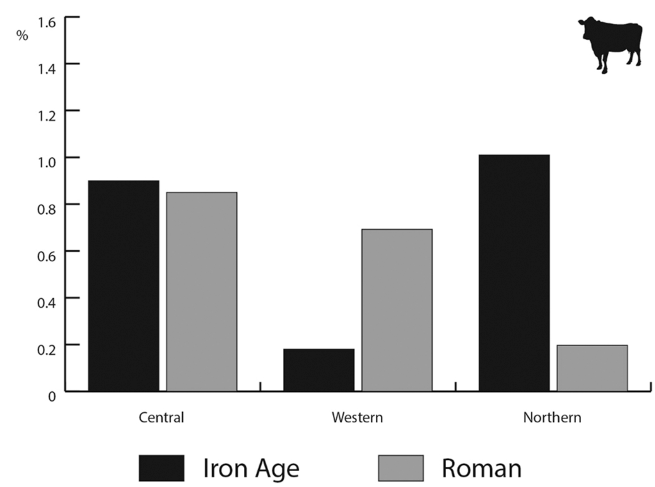

Fig. 4. Percentage of pathologies for cattle per region and period. The southern region is excluded because of the small number of sites. Number of sites: central IA: 16; central Roman: 69; western IA: 8; western Roman: 37; northern IA: 9; northern Roman: 14. n cattle: central IA: 5859; central Roman: 24639; western IA: 4405; western Roman: 36707; northern IA: 694; northern Roman: 4576.

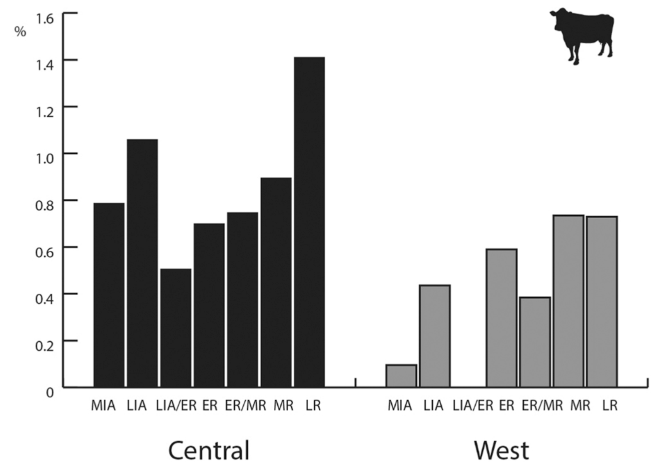

Fig. 5. Percentage of pathologies for cattle per region and period. The northern region is excluded because the number of sites for most periods is small, and the Early Roman period is not represented. The southern region is excluded because the number of sites is especially small. EIA =Early Iron Age, M/LIA= Middle/ Late Iron Age, LIA = Late Iron Age, LIA/ER = Late Iron Age/Early Roman Age, ER=Early Roman Age, ER/MR=Early/Middle Roman Age, MR=Middle Roman Age, MR/LR=Middle/Late Roman Age, LR=Late Roman Age. The number of sites in the central region: MIA: 5; LIA: 9, LIA/ER:5; ER: 16; ER/MR:15; MR: 26; LR: 9. Number of sites in the western region: MIA: 3; LIA: 4; LIA/ER: 1; ER: 7; ER/MR: 5; MR: 22; MR/LR+LR: 3. The number of cattle in the central region: MIA: 3305; LIA: 2173; LIA/ER: 2570; ER: 4436; ER/MR: 3349; MR: 10726; LR: 3476. The number of cattle in the western region: MIA: 3145; LIA: 1148; LIA/ER: 619; ER: 1187; ER/MR: 3908; MR: 29966; LR/MR+LR: 1646.

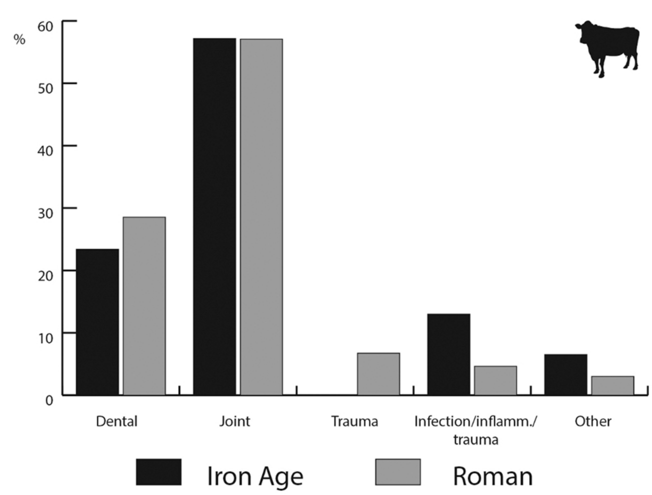

Fig. 6. Frequency of pathological conditions in cattle. All regions, Iron Age (n = 77), Roman period (n = 431).

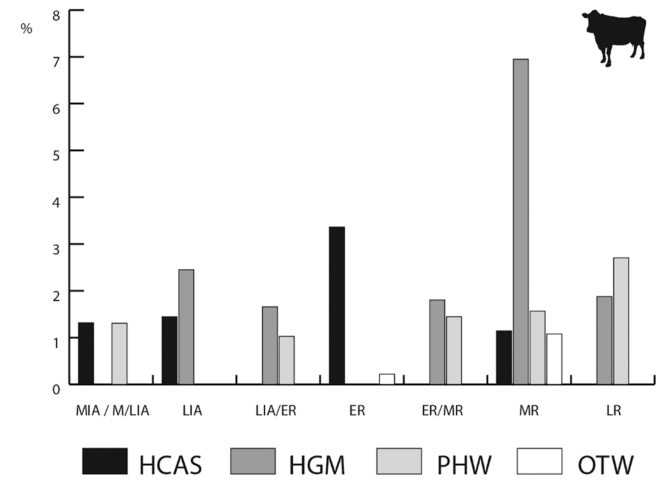

Fig. 7. Chronological prevalence of pathologies in cattle. Houten-Castellum (HCAS), Geldermalsen-Hondsgemet (HGM), Tiel-Passewaaijse Hogeweg (PHW) and Tiel-Oude Tielseweg (OTW), based on the total number of identified cattle fragments. M/LIA= Middle/Late Iron Age, LIA = Late Iron Age, LIA/ER = Late Iron Age/Early Roman Age, ER=Early Roman Age, ER/MR=Early/ Middle Roman Age, MR=Middle Roman Age, MR/LR=Middle/Late Roman Age, LR=Late Roman Age.

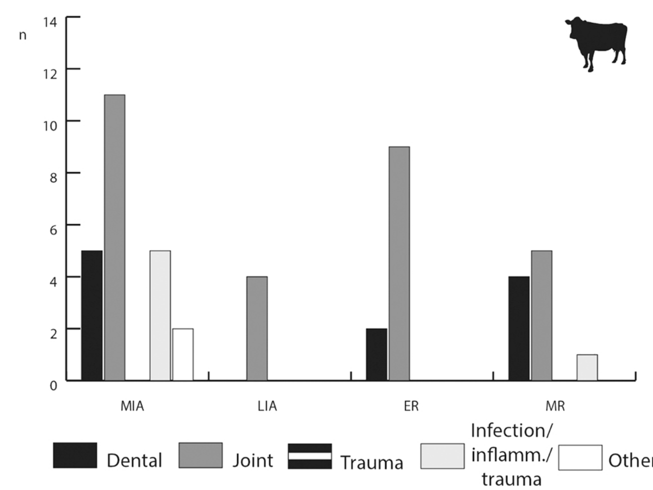

Fig. 8. Number of pathological lesions noted in cattle at Houten-Castellum. MIA=Middle Iron Age, LIA=Late Iron Age, ER= Early Roman Age, MR= Middle Roman Age.

Roman period, while in the other sites, pathology increases in the Middle or Late Roman period (Fig. 7).

Three of the multi-period sites permit investigation of the types of cattle pathology over time. In Houten-Castellum, the numbers of dental and joint pathology both decline in the Late Iron Age but then increase again in the Early Roman period (Fig. 8). Dental pathology continues to increase in the Middle Roman period, while joint pathology declines again. In Geldermalsen-Hondsgemet, dental pathology and trauma increase in the Middle Roman period (Fig. 9). Joint pathology is high in the Late Iron Age, drops in the Late Iron Age/Early Roman period and then starts to increase again in the Early/Middle Roman period, reaching a second peak in the Middle Roman period. In Tiel-Passewaaijse Hogeweg, dental pathology is somewhat more frequent in the Early/ Middle Roman period and Late Roman period compared to the other periods (Fig. 10). Joint pathology increases in the Middle Roman period and even further in the Late Roman period.

The two common dental variations for cattle included in this study are frequently mentioned in zooarchaeological reports. However, to establish the prevalence data on both presence and absence of these variations, which is not generally mentioned in reports, is needed. Data on both presence and absence of the two dental variations were available for seven sites. Six of those are located in the central region. A potential problem with combining data from different sites is that the sites may have had genetically different populations of cattle and that differences in prevalence between the populations will be disguised by combining data. However, sample sizes for most individual sites are so small that they could not be studied individually. The exception is Houten-Castellum, which has a sizable data set for the third lower molar. Data from this site were analysed separately. Since the sample sizes are small for most phases, data for the Iron Age phases and for the Roman phases are combined. This is not to suggest that introduction of new genetic lines may not have occurred in the Iron Age. In fact, we know

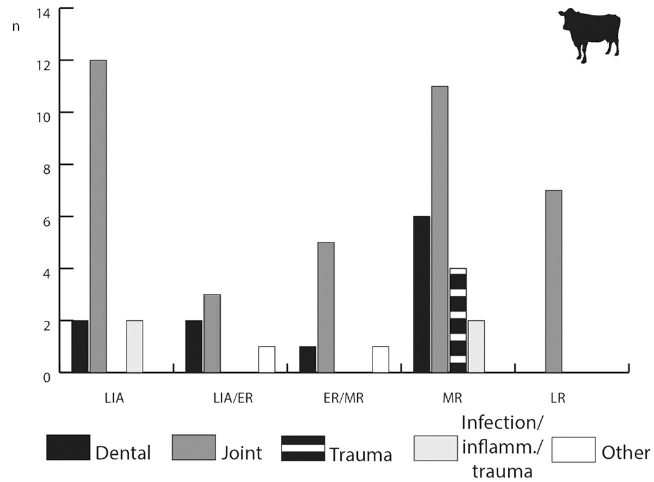

Fig. 9. Number of pathological lesions noted in cattle at Geldermalsen-Hondsgemet. LIA= Late Iron Age, LIA=Late Iron Age, ER= Early Roman Age, MR= Middle Roman Age, LR= Late Roman.

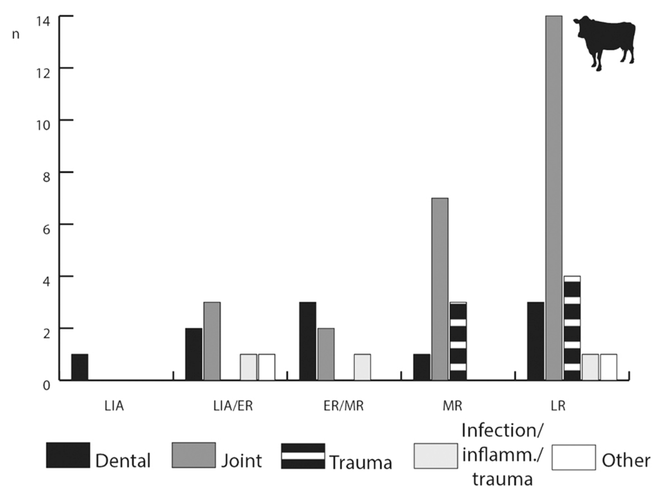

Fig. 10. Number of pathological lesions noted in cattle at Tiel-Passewaaijse Hogeweg. LIA= Late Iron Age, LIA=Late Iron Age, ER= Early Roman Age, MR= Middle Roman Age, LR= Late Roman.

that cattle were moved over large distances (Groot et al., 2020).

Prevalence of a missing second lower premolar is great in Iron Age Houten-Castellum (Fig. 11); for the Roman period this variation appears absent in four recovered mandibles. Prevalence in the other sites is slightly lower in the Roman period compared to the Iron Age, but the difference is very small. Prevalence in Iron Age Houten-Castellum is much higher than in the Iron Age sample from the other sites. This could be due to variation between sites or to a difference in date; the Houten-Castellum data are dominated by the Middle Iron Age sample, while the other sites are dominated by the Geldermalsen-Hondsgemet Late Iron Age sample.

Prevalence of a reduced hypoconulid in the third lower molar is great in Iron Age Houten-Castellum and decreases in the Roman period (Fig. 12). The other sites show the opposite: a greater prevalence in the Roman period. The difference between prevalence in Houten-Castellum and the other sites is greatest in the Iron Age; as mentioned above, this may be related to a difference in date or a genetic difference in cattle populations.

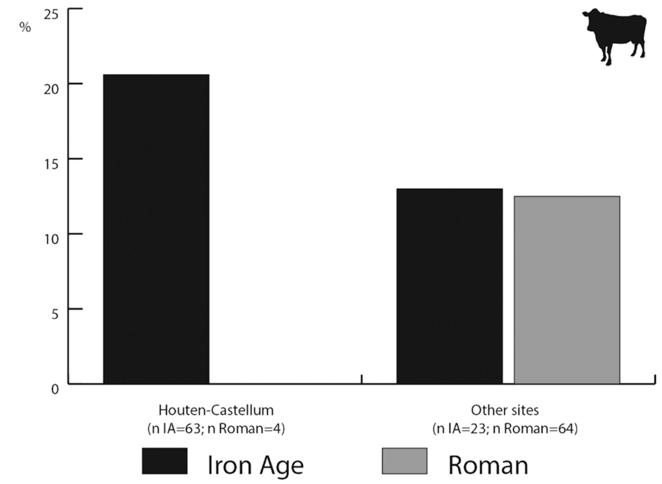

Fig. 11. Prevalence of missing lower second premolar in cattle in the central region, Iron Age compared to the Roman period. Data from Houten-Castellum, Geldermalsen-Hondsgemet, Tiel-Passewaaijse Hogeweg, Wijk bij Duurstede-De Geer, Utrecht-Leidse Rijn 46 and Utrecht-Leidse Rijn 78.

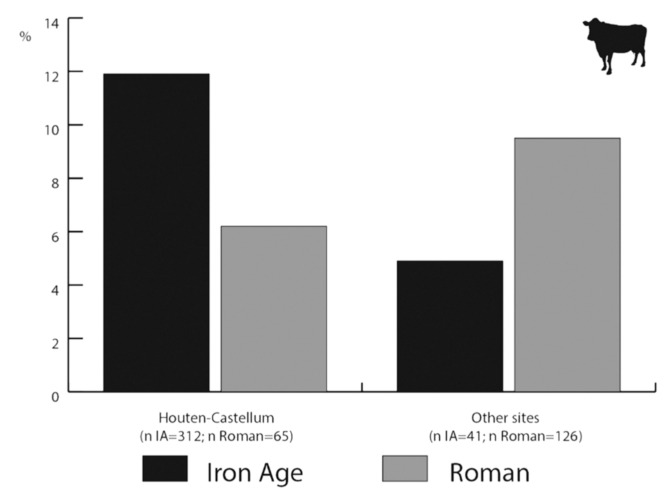

Fig. 12. Prevalence of a reduced hypoconulid in the third lower molar in cattle in the central region, Iron Age compared to the Roman period. Data from Houten-Castellum, Geldermalsen-Hondsgemet, Tiel-Passewaaijse Hogeweg, Wijk bij Duurstede-De Geer, Utrecht-Leidse Rijn 46 and Utrecht-Leidse Rijn 78.

4. Discussion

Adopting a regional review of animal pathology leads to a loss of detail, but is outweighed by having larger sample sizes. This study seeks a compromise by investigating larger multi-period sites, as well as smaller sites. The occurrence of lesions in archaeological animal bones is influenced by many factors, including sample size, taxonomic representation, taphonomy, the nature of the animal bone assemblage, and the age profile of the animals represented (Bartosiewicz, 2021). The animal bone assemblages included in this study are all from settlement sites and share a similar taphonomic history (mainly food refuse but include some animal burials). Paradoxically, the occurrence of pathology in animal bones can interpreted as a sign of fitness, since the animal survived long enough for the disease to become visible in its bones (Bartosiewicz and Gál 2018). Hence, we cannot simply equate a low percentage of lesions with good health and vice versa.

4.1. Frequencies of pathology

Several studies provide data on the frequency of pathological conditions from different regions and periods (Table 2). Grimm's (2008) calculation of the presence of pathological lesions for medieval Emden is the lowest with 0.08%, but she emphasises that only the obvious cases of pathology have been recorded. The greatest frequency of pathological conditions is found among animal bone assemblages from 13th-to-17th-century Estonian towns, where 1.25% of identified fragments show pathological changes (Maldre, 2008). The calculations for the Iron Age and Roman Netherlands (0.69% for both the four main domesticates combined and for cattle separately) are relatively similar to those noted in other studies.

The frequencies of different types of pathology for cattle in the Iron Age and Roman can be compared to those published in other studies (Fig. 13). These show high percentages of joint pathology, while Siegel's (1976) study yielded similar joint and dental pathology frequencies to this study. Murphy's (2005) and Grimm's (2008) data show a lower frequency of dental pathology and a higher frequency of trauma. Cattle pathologies in Sirmium and Vranj, Serbia, were also dominated by joint pathology (Marković et al., 2014).

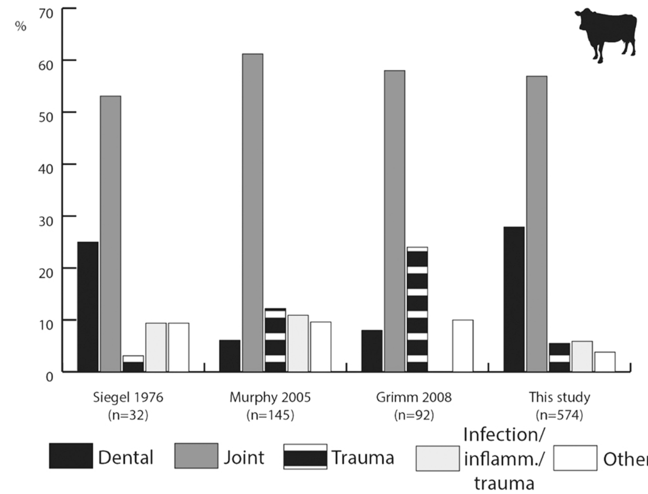

Fig. 13. Frequency of recorded pathological lesions in cattle in this study compared to Britain (Siegel, 1976), Ireland (Murphy, 2005) and medieval Emden (Grimm, 2008).

4.2. Diachronic and regional developments in cattle pathology

The percentage of lesions – both for the four main domesticates combined and cattle separately – fluctuates over time. The overall percentage of pathology for cattle increases from the Middle to the Late Iron Age, and then decreases in the Early Roman period. It is hard to say what could have caused this. No clear changes in cattle exploitation have been recognised during the Iron Age (Groot and Albarella, 2022), although this could be related to a lack of data. One change in animal husbandry that has been observed is a decrease in the proportion of cattle in the Early Roman period, linked to an increase in sheep and goats. Milk use or consumption seems to have declined from the Iron Age to the Roman period, and the exploitation of cattle for traction does not increase until the Middle Roman period (Groot and Albarella, 2022). Perhaps cattle were generally slaughtered at a younger age in the Early Roman period compared to the periods before and after. In Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet, slaughter ages of cattle increase during the Roman period (Groot, 2016: 97–99). What can be said is that size changes do not seem to be a factor. A size increase in cattle has been noted for the central region in the Late Iron Age (potentially leading to a higher prevalence of joint pathologies), but this increase continues even more in the Early Roman period, when the percentage of pathology drops again.

Cattle show an increased frequency of pathological lesions from the Late Iron Age/Early Roman period to the Late Roman period. If the overall percentage of pathology is related to intensification of animal husbandry, then it is interesting that pathology continues to increase in the Late Roman period. It was previously believed that the most drastic changes in animal husbandry occurred in the Middle Roman period in response to population growth, urban and military markets, and tax requirements (Groot, 2016; Groot and Albarella, 2022), and that the Late Roman period saw a collapse of surplus production, at least in the central part of the Netherlands. Biometric analyses suggested that Late Roman Nijmegen-Valkhof was supplied at least partially with cattle from outside the region (Groot, 2016: 208). However, in the central region, cattle continued to increase in size, if not in all sites; the proportion of male cattle also increased further and many cattle reached advanced ages (Groot and Albarella, 2022; Groot, 2016). The decline in cattle frequencies suggests that the economy may have been more self-sufficient at this time, but the other evidence shows that cattle remained important for arable farming and urban meat supply (see also Grau-Sologestoa et al., 2022). With population decline and a low settlement density, compared to the Middle Roman period, the demand for food would have declined, resulting in a reduced scale of production. However, with fewer farmers to produce food, surplus production remained important.

A comparison of pathology frequencies for cattle in the Iron Age and Roman period per region shows contradictory results. In the central

Table 2
Number and percentage of pathological lesions noted at different sites, regions, and periods.

Region	Period	Species	(n) pathology	NISP	(%) pathology	Reference
Emden, Germany	Medieval	All	156	195,000	0.08	Grimm (2008)
Europe + Southwest Asia	All	All /Cattle	1348 / 549	1294,625 / 591,222	0.10 / 0.09	Bartosiewicz (2021)
Britain	Neolithic – Medieval	All	114	47,300	0.24	Siegel (1976)
Ireland	Late Bronze Age - Postmedieval	All	227	71,663	0.32	Murphy (2005)
Israel	Neolithic - postmedieval	All	58	14,540	0.40	Sapir-Hen et al. (2008)
Vranj, Serbia	Roman	All /Cattle	7 /6	1434 / 507	0.49 / 1.18	Marković et al. (2014)
Sirmium, Serbia	Roman	All /Cattle	65 / 30	12,165 / 4423	0.53 / 0.68	Marković et al. (2014)
Netherlands	Iron Age - Roman	Cattle,Sheep/Goat,Horse,Pig / Cattle	881 /572	127,373 / 82,310	0.69 / 0.69	This study
Justiniana Prima / Caričin Grad	Roman	All	96	11,807	0.81	Marković et al. (2018)
Estonia	13th-17th century	All	266	21,302	1.25	Maldre (2008)

region, the frequency of pathology decreases slightly in the Roman period, while in the western region there is a marked increase. Combining the periods may increase sample size but hides trends within the periods. When the periods are considered in more detail, the central region shows a steady increase during the Roman period, from the Late Iron Age/Early Roman period to the Late Roman period. The western region also shows an increase from the Middle Iron Age to the Late Roman period, but less pronounced than that in the central region. Some individual multi-period sites also show an increase in cattle pathology during the Roman period.

There is little change in the occurrence of different types of cattle pathology between Iron Age and Roman period; only a slight increase in dental pathology and a decrease in infection/trauma. However, just as for the overall percentage of pathology for cattle, combining phases within periods may hide trends.

4.3. Cattle pathology and traction

The use of cattle for traction puts strain on the body, especially on the hind limbs (Bartosiewicz, 2013: 154). Certain joint pathologies in the metapodials and phalanges have been related to cattle traction (Bartosiewicz et al., 1997). Bartosiewicz et al. (1997) developed a system to score these pathological changes based on lesions in modern Rumanian draught cattle. This system has been applied to archaeological material in several studies (see De Cupere et al., 2000; Dietmeier, 2018; Gaastra et al., 2018; Johannsen, 2005, 2006; Telldahl, 2005; Thomas, 2008), but not yet in the Netherlands.

Problematic is that there are many causes for foot lesions, including age, sex, castration, body weight, genetic predisposition, substrate, nutritional health, nature and intensity of traction, form of harnessing, and type of plough or wagon (Thomas, 2008; Bartosiewicz, 2013: 150). Ideally, all these factors should be considered when assessing the aetiology of foot pathologies. For medieval Dudley Castle, Thomas (2008) concluded that a larger size and increased slaughter age are the most likely factors for an increase in the Pathological Index in the mid-14th century, while an increased emphasis on meat (with younger slaughter ages) and decreased emphasis on traction are likely factors for a decrease in the Pathological Index in the later 14th century. In his study on cattle feet from Neolithic Denmark, Johannsen (2005, 2006) argues that while distal exostoses in the proximal phalanx (also found in aurochs) are likely to be related to age, an extension of the articular surface is more likely to be related to traction. Telldahl (2005) found an increase in the frequency of pathology in phalanges from the Viking to medieval period in Eketorp, Sweden; this increase may be related to the introduction of a heavier plough. In prehistory and early history, before the introduction of heavy ploughs, 'light' traction, the occasional pulling of light loads or a low intensity of traction, may not result in severe pathology or influence management decisions such as slaughter age and therefore be harder to recognise archaeologically (Bartosiewicz, 2013: 150, 153; Gaastra et al., 2018). Like Johannsen, Gaastra et al. (2018) found that while exostoses occurred in aurochs as well as domestic cattle, extension of the articular surface was only found in domestic cattle. More recently, Lin et al. (2016) developed a traction index osteometric system, which uses biometry to describe the degree of remodelling in distal metapodia. Bartosiewicz et al.'s Pathological Index has recently been applied to semi-feral cattle of various ages and sexes and modified to account for characteristics that are strongly correlated with age (Thomas et al., 2021).

Bartosiewicz saw a shift in the anatomical location of joint pathology in cattle from prehistoric to Roman/medieval times from the axial column and proximal phalanges to the pelvic region and hock joint/metatarsals, but no change in the overall percentage of pathology (Bartosiewicz, 2013: 151). This shift is caused by the higher strain traction puts on the hind limbs.

A note of caution regarding too readily associating pathological changes with traction was recently provided by the observation of pathological changes in modern non-draught cattle in southern Russia, where minor lipping and exostoses of metapodials and phalanges, ankylosis and eburnation in the hip joint are common (Rassadnikov, 2021). However, the uneven terrain in this region is mentioned as a contributing factor; cattle in less demanding landscapes may be less likely to develop lesions.

For this study, it was not possible to apply Bartosiewicz et al.'s or Lin et al.'s methods, since no new material was recorded. Even the anatomical distribution of joint pathology could not be investigated. We can only look at the percentage of joint pathology in cattle over time and compare this to known changes in animal husbandry. The overall percentage of cattle joint pathology shows no change from the Iron Age to Roman period. Increases in the percentage of cattle joint pathology occur in both Geldermalsen-Hondsgemet and Tiel-Passewaaijse Hogeweg in the Middle Roman period, but while the percentage increases even further in the Late Roman period in the latter site, it decreases in the former. The Roman period saw changes in cattle husbandry, including an increase in size (possibly associated with genetic change), older slaughter ages and an increase in the proportion of male animals. These changes have been related to an increased emphasis on traction (Groot, 2016; Groot and Albarella, 2022). However, even if the changes are not related to traction, these factors could have led to an increase in joint pathology. It is not clear why we do not find an increase in the overall percentage of joint pathology. Other zooarchaeological indicators clearly point at an increased emphasis on traction, but perhaps this was still relatively low in intensity compared to later periods. A more systematic study, for instance using the Pathological Index, may recognise this in the future. The approach used in this study, using brief descriptions of the presence of pathological lesions derived from archaeozoological reports, may not be specific enough to identify intensification.

It is also possible that combining data from different periods and regions has hidden differences between them. While it is tempting to link the increases in joint pathology in the individual sites to intensification of traction, we have to keep in mind that other factors, such as an increase in size – which certainly occurred in these sites – may also have played a role. In fact, this may explain the different developments in joint pathology in the Late Roman period. In Geldermalsen-Hondsgemet, size decreases in the Late Roman period, while it continues to increase in Tiel-Passewaaijse Hogeweg.

The percentage of trauma in cattle increases from the Iron Age to Roman period from 0% to 6.7%. It has been noted that trauma in lower limbs and ribs in cattle is more common when cattle are kept in overcrowded conditions (Murphy, 2005:15). The increase in trauma in the Roman period may reflect intensification of cattle husbandry.

4.4. Dental pathology and cattle husbandry

Periodontal disease can be related to many factors, including genetics, abnormal tooth eruption and wear, saliva production, impacted food between the tooth and gingiva, overgrazing, and malnutrition (Holmes et al., 2021; Bartosiewicz,2008). Differences in exploitation, resulting in different age profiles of herds, can have an effect on the prevalence of periodontal disease, since older animals are more likely to display calculus and alveolar recession (Holmes et al., 2021). Another aspect of animal management that plays a role is diet.

If we see diachronic changes in prevalence of dental pathology, and when other factors remain the same, diet may be the cause. In the Netherlands, we see a slight increase in dental pathology in the Roman period. Within the individual sites, only Geldermalsen-Hondsgemet shows a peak in dental pathology in the Middle Roman period; no clear pattern is observed in the other two sites. While a change in diet – linked to efforts to increase cattle size – is possible, there was probably also a change in genetic composition of herds and certainly an increase in older animals during the Roman period. This means that it is not possible to associate the increase in dental pathology with a change in cattle diet. Importantly, one limitation to this study is that all dental pathology is lumped together, including pathologies that may not be related to diet. Unfortunately, the scale of the approach, as well as the lack of detailed descriptions and photographs in most reports, did not allow for a more detailed analysis.

4.5. Dental anatomical variations and genetic change

The two dental variations in cattle show a change in prevalence from the Iron Age to the Roman period, but the results differ between Houten-Castellum and several other combined sites. This could reflect genetic differences between cattle herds already in the Iron Age and/or differences in the acquisition of imported animals and breeding strategies in the Roman period. We need more information on the variability of cattle populations in the Iron Age and larger samples to establish prevalence of these two variations more accurately. Furthermore, both presence and absence of these variations need to be recorded. At this time, usually only the presence is noted, which does not allow the calculation of prevalence rates.

5. Conclusion

Sample size in paleopathological studies is critical. The starting point for this study was a total number of reported pathological cases (n = 881, NISP) noted in main domesticates; cattle, sheep/goats, horses, and pigs. However, when we focus on the dominant species -cattle- and divide data into regions, periods, sites, and types of pathology, we greatly reduce the sample size. This was particularly evident in analyses of pathological conditions in species other than cattle. To overcome this limitation, this study sought to aggregate data at chronological and regional levels. Multi-period sites with large animal bone samples, investigated by the same researcher, hold great potential when seeking to track changes over time.

One essential question posed in this study was whether reported cattle pathology could be associated with the intensification of cattle husbandry. Indeed, an increase in the percentage of cattle pathology during the Roman period was noted, culminating in a peak in the Late Roman period. Unexpectedly, no overall increase in joint pathology in the Roman period was noted. A potential increase in joint pathology (whether due to size increase, older ages at slaughter or traction) may have been obscured by higher mortality from acute illness due to higher livestock densities. The increase in trauma in the Roman period could be related to higher stocking densities. A slight increase in dental pathology may be related to changes in cattle diet and management but could also be related to increased slaughter ages. Investigating the potential intensification of animal husbandry is complicated by the multi-causal origin of pathological conditions that can be related to intensification, i.e., joint pathology and traction, and dental pathology and diet.

Despite the limitations of this study, some insight into cattle husbandry and health was achieved. Two individual sites show increases in joint pathology in the Middle Roman period and in one, a further increase in the Late Roman period, correlated to size increases (which may reflect increased emphasis on traction). The increase in trauma in the Roman period may also reflect intensification. It is hoped that study will stimulate detailed and systematic paleopathological research in the Netherlands and globally, as we seek to understand the complex relationships between humans and domesticates over time.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijpp.2023.02.003.

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