International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. **17**: 207–213 (2007)
Published online 26 October 2006 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/oa.875

Ossification of the Interosseous Ligaments Between the Metapodials in Horses: A New Recording Methodology and Preliminary Study

R. BENDREY*

Department of Archaeology, University of Winchester, Sparkford Road, Winchester, Hampshire SO22 4NR, UK

ABSTRACT This article presents a methodology for recording and quantifying the ossification of the interosseous ligaments between the metapodials in horses, including a scoring system for defining stages in the development of this lesion. The method is applied to a sample of ten Przewalski's horse skeletons from the National Museum, Prague. This case study demonstrates the nature of this lesion in a sample of unworked animals and presents a preliminary sample for comparison with archaeological assemblages. The results show that the condition can occur in animals that are not worked. They also indicate that age is an important factor in the development of the lesion. The expression of the pathology in this sample appears to be linked to how the weight of the animal acts through the legs, in that it occurs earliest, and is generally more advanced, in the areas that support a greater burden. Copyright © 2006 John Wiley & Sons, Ltd.

Key words: horse metapodials; interosseous ligaments; work-related changes; age-related changes; horse use

Introduction

In a recently reported study of some 280 horse skeletons from Lithuania, Daugnora and Thomas (2005) note that ossification of the ligaments between the metapodials was the most frequently recorded pathology. However, in the absence of previously published prevalences of this condition in populations that have, or have not, been worked, the authors were unable to assess the extent to which the manifestation of this condition in their sample reflects natural processes (Daugnora & Thomas, 2005, 71–3).

This paper proposes a new methodology for recording and quantifying this pathology. It demonstrates the methodology on a sample of ten Przewalski's horse skeletons. These animals all derive from an unworked population and present a preliminary case study for the consideration of this pathology as a naturally occurring condition, and for comparison with archaeological samples.

Anatomy

Three metapodials are present in each limb of the horse: the metacarpals in the forelimbs and the metatarsals in the hindlimbs (e.g. Figure 1). In the forelimb the metacarpal iii, also known as the cannon bone, is well developed and carries the

* Correspondence to: Department of Archaeology, University of Winchester, Sparkford Road, Winchester, Hampshire SO22 4NR, UK.
e-mail: robin.bendrey@winchester.ac.uk

Received 15 August 2005
Revised 27 April 2006
Accepted 2 May 2006

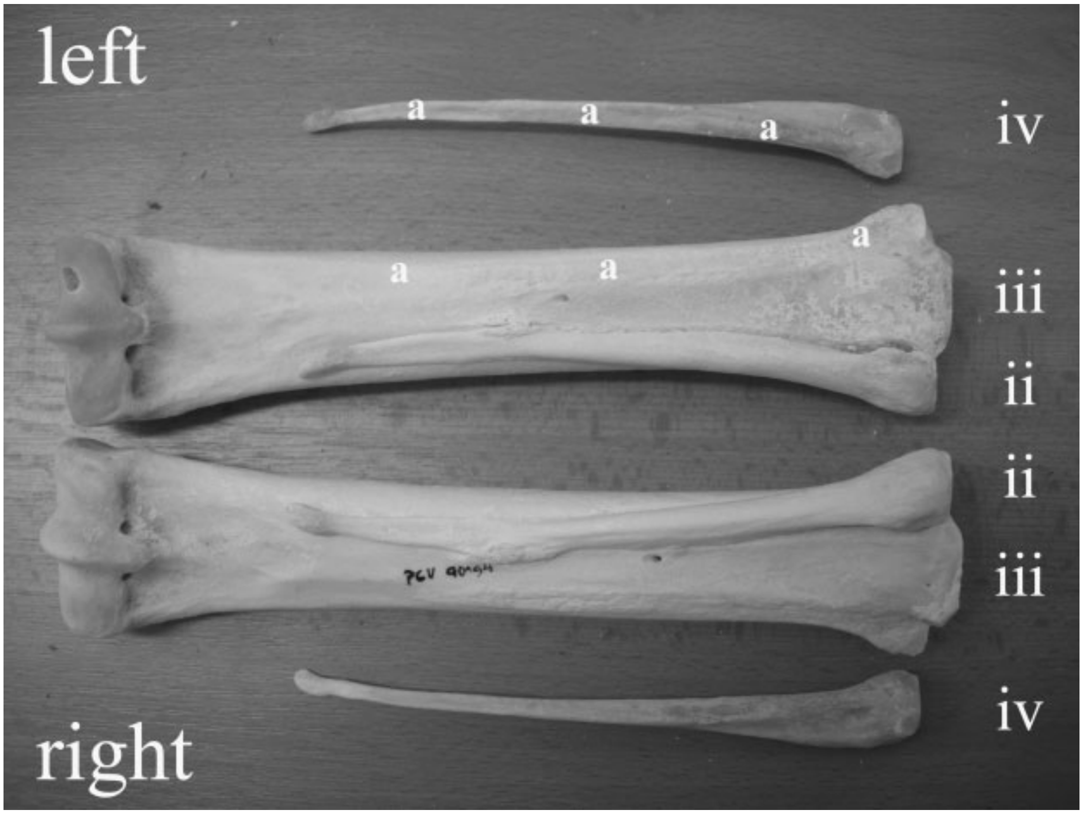

Figure 1. Left and right horse metacarpals: metacarpal ii is the medial splint bone, metacarpal iii is the cannon bone and metacarpal iv is the lateral splint bone (horse P6V 90194). In this individual the metacarpal ii on both sides are attached to the metacarpal iii, and the metacarpal iv on both sides are not. The interosseous metacarpal ligament is situated between the opposing surfaces of the metacarpal shafts, as indicated for the left metacarpal iii and iv by the lines of 'a's (see also Ashdown & Done, 1987, Fig. 7.46).

entire weight of the limb, and the metacarpals ii and iv, the medial and lateral splint bones respectively, consist of a proximal articulation and a shaft that tapers towards its distal end some two-thirds of the way down the metacarpal iii (Sisson & Grossman, 1966: 96–7; Budras *et al.*, 2003, 2). The cannon bone is firmly united by connective tissue, called the interosseous ligament, to the opposing surface of each splint bone (see Figure 1) (Sisson & Grossman, 1966: 225; Budras *et al.*, 2003, 106).

The anatomy of the metatarsals follows the same general arrangement as the metacarpals.

Ossification of the interosseous ligaments

The pathological condition *desmoiditis ossificans ligamentum interosseum* describes the ossification of the ligament situated between the metapodial shafts (Daugnora & Thomas, 2005: 69), and is more commonly known as 'splints' (Cresswell & Smythe, 1963; Budras *et al.*, 2003, 106; Kahn, 2003).

A number of possible causes have been suggested for this pathology. It is thought that it is caused by trauma or concussion from working a horse on a hard surface, resulting in movement between the metapodials and periosteal tearing (Cresswell & Smythe, 1963). Budras *et al.* (2003: 106) suggest that hard exercise causes additional and repeated force to be placed on the proximal ends of the metapodials ii and iv, disturbing and irritating the interosseous ligament, and causing periostitis and new bone growth, which connects the separate bones. They also suggest that excessive exercise that overextends the fetlock joint and stretches the interosseous ligament, pulling the splint bone axially and causing

DOI: 10.1002/oa

repeated movement between the splint bone and the cannon bone, may cause the condition by stressing the interosseous ligament (Budras *et al.*, 2003: 106). Contributory factors may include trauma from concussion or injury, strain from excess training, faulty conformation, or improper shoeing (Kahn, 2003).

Kahn (2003) also describes the lesion as a periostitis with production of new bone along the involved splint bone; it may, however, be more appropriate to describe it as an enthesopathy. Enthesopathies are skeletal manifestations resulting from osteon remodelling stimulated by increased blood flow when muscle/tendon/ligament-bone junctions are regularly subjected to minor stress, and hypertrophy of bone is the direct result of this increased, repetitive, stress (Hawkey & Merbs, 1995: 324; Jurmain, 1999: 142). The lesion may thus be viewed as a response to the repeated movements of the bones, causing repetitive stress on the connecting ligaments ultimately leading to their ossification.

Figure 2. Medial view of right horse metatarsal iii from Iron Age Danebury, Hampshire, England, showing no evidence for ossification of the ligaments between the metapodials, in particular no new bone formation (indicated by arrow) along the edges of the area where the two bones join (score = 0). The horse was 3 years old at death.

Proposed scoring system

The following scoring system divides the severity of expression of ligament ossification for the interosseous border between metapodials into five descriptive stages:

0. No apparent evidence for ossification of the ligaments between the metapodials (see Figure 2)
1a. Metapodials attached, but no visible signs of new bone formation. In museum specimens this stage could include specimens in which connective tissue still remains in the joint following the preparatory process of the skeleton, or specimens that might have been glued e.g. for display (not illustrated).
1b. Metapodials unattached, but evidence for new bone formation between the skeletal elements, in particular along the edges of the area where the two bones join (see Figures 3 and 4).
1c. Metapodials attached with visible signs of new bone formation, but this new bone has not yet bridged the interosseous border between the two skeletal elements (see Figure 5).
2. Metapodials attached and new bone deposition clearly bridges the interosseous border (see Figures 6 and 7).

It is proposed that a single score be awarded for each of the joints between the metapodials (i.e. left metacarpal ii–iii, left metacarpal iii–iv, etc). These scores can then be tabulated together in the analysis of complete skeletons (e.g. Table 1), or presented as a cross-tabulated scores (e.g. Table 2), and compared between different populations.

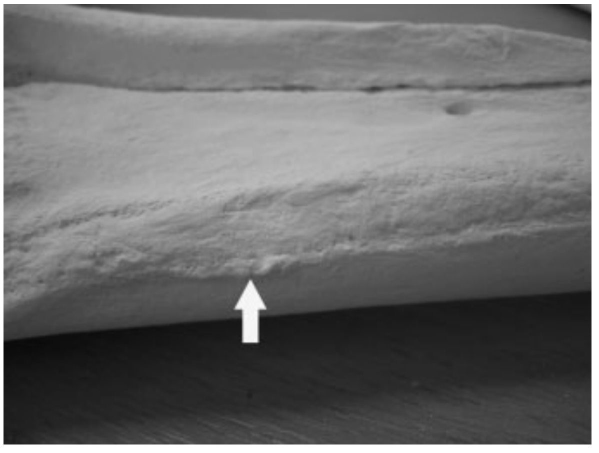

Figure 3. Lateral view of left metacarpal iii (horse P6V 22772). Metapodials unattached, with evidence for new bone formation (indicated by arrow) along the edges of the area where the two bones join (score = 1b).

DOI: 10.1002/oa

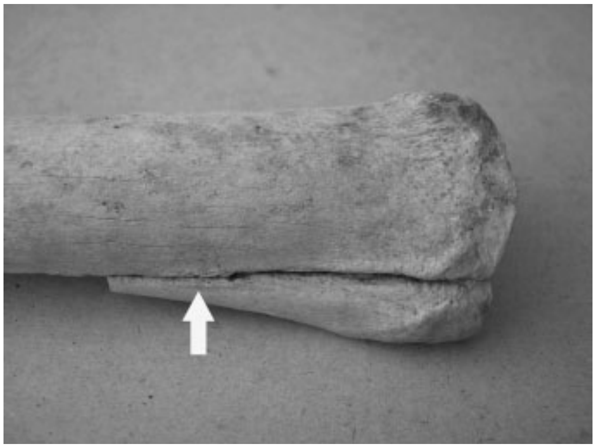

Figure 4. Lateral view of left horse metacarpals iii and iv from Iron Age Danebury, Hampshire, England. Metapodials unattached, with evidence for new bone formation along the edges of the area where the two bones join (score = 1b). The horse was 16–18 years old at death.

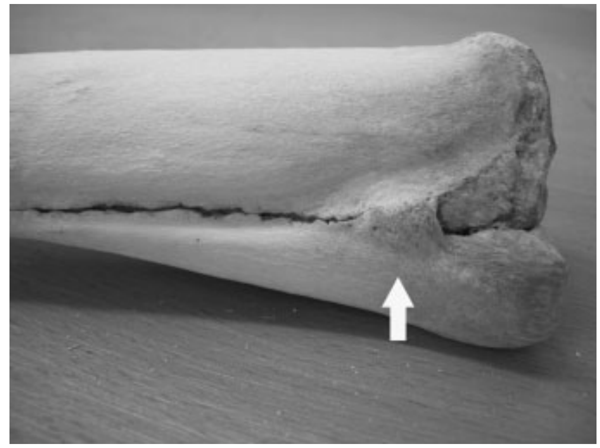

Figure 6. Lateral view of left metatarsals iii and iv (horse P6V 90194). The arrow indicates the area where new bone formation has bridged the interosseous border (score = 2).

Preliminary case study

This case study examines the expression of this lesion in ten disarticulated Przewalski's horse (*Equus ferus przewalskii* Poliakof 1881) skeletons held at the National Museum, Prague using the recording methodology set out above. The animals have not been worked. They derive from the breeding population at Prague Zoo, and ages and sexes are known.

Figure 5. Medial view of left metacarpals ii and iii (horse P6V 22772). Metapodials attached with visible signs of new bone formation, but this new bone has not yet bridged the interosseous border between the two skeletal elements (score = 1c).

Table 1 compares the recorded expression of the ossification of the ligaments between the metapodials in the Przewalski's horses against the age and sex of the animals. The results of this study show that the condition can occur in horses that have not been worked.

Division of the horses into groups of similar age indicates that the development of the lesion is linked with age (Table 1): scores of 1(a–c) can be seen to be most common in age groups 1 and 2, whereas scores of 2 dominate in age group 3.

Comparing the results for metacarpals and metatarsals indicates that, in each age group, the

Figure 7. Medial view of left metacarpals ii and iii (horse P6V 48351). Metacarpals attached and new bone deposition clearly bridges the interosseous border (score = 2).

DOI: 10.1002/oa

Table 1. Expression of ligament ossification for the interosseous border between metapodial splint and cannon bones recorded from Przewalski's horses at the National Museum, Prague—the animals have been divided into three age groups (ages given in years) based on a simple division of like ages in the sample

	Museum registration number	Sex	Age	Left metacarpal		Right metacarpal		Left metatarsal		right metatarsal	
				ii–iii	iii–iv	ii–iii	iii–iv	ii–iii	iii–iv	ii–iii	iii–iv
Age group 1	P6V 48278	M	6	1a	1a	1a	1a	0	0	0	0
	P6V 46585	F	7	1b	1b	2	1b	1c	1c	1c	1b
	P6V 49009	M	8	1c	1b	1b	0	0	0	0	0
Age group 2	zvl 48/50 HM	M	14	2	1b	2	1b	0	1b	—	—
	P6V 90194	M	16	1c	0	1c	0	1a	0	1a	0
	P6V 48918	F	16	1c	1b	1b	1b	1b	1b	1b	1b
Age group 3	P6V 48351	F	29	2	2	2	2	1c	1c	1c	1c
	P6V 48756	F	29	2	2	2	2	2	2	2	2
	P6V 22772	F	29	2	2	2	2	2	1c	2	1c
	P6V 24688	M	30	1c	1a	2	1c	1c	0	2	1a

lesions are more severe in the metacarpals than the metatarsals (Tables 1 and 2). This is particularly apparent in age groups 1 and 3. In age group 1 there is a higher proportion of scores of 0 amongst the metatarsals (8/12) than seen in the metacarpals (0/12). In age group 3 there is a higher proportion of scores of 2 amongst the metacarpals (13/16) than seen in the metatarsals (7/16). This pattern would appear to suggest that the lesion occurs first in the forelimbs and later in the hindlimbs. Its earlier development and more severe expression in the forelimb is probably

Table 2. Cross-tabulation of scores for medial (ii-iii) and lateral (iii-iv) metapodial joints from individual limbs of the Przewalski's horses at the National Museum, Prague, divided by age groups (see Table 1)

Metapodials ii–iii	Metapodials iii–iv									
	Metacarpal					Metatarsal				
	0	1a	1b	1c	2	0	1a	1b	1c	2
Age group 1										
0	—	—	—	—	—	4	—	—	—	—
1a	—	2	—	—	—	—	—	—	—	—
1b	1	—	1	—	—	—	—	—	—	—
1c	—	—	1	—	—	—	—	1	1	—
2	—	—	1	—	—	—	—	—	—	—
Age group 2										
0	—	—	—	—	—	—	—	1	—	—
1a	—	—	—	—	—	2	—	—	—	—
1b	—	—	1	—	—	—	—	2	—	—
1c	2	—	1	—	—	—	—	—	—	—
2	—	—	2	—	—	—	—	—	—	—
Age group 3										
0	—	—	—	—	—	—	—	—	—	—
1a	—	—	—	—	—	—	—	—	—	—
1b	—	—	—	—	—	—	—	—	—	—
1c	—	1	—	—	—	1	—	—	2	—
2	—	—	—	1	6	—	1	—	2	2
Total										
0	—	—	—	—	—	4	—	1	—	—
1a	—	2	—	—	—	2	—	—	—	—
1b	1	—	2	—	—	—	—	2	—	—
1c	2	1	2	—	—	1	—	1	3	—
2	—	—	3	1	6	—	1	—	2	2

DOI: 10.1002/oa

linked to the greater strain placed on the interosseous ligaments in this region because of the greater weight-bearing load (Cresswell & Smythe, 1963: 449).

The cross-tabulation of the scores for the medial (ii–iii) and lateral (iii–iv) joints for both the metacarpal and metatarsal indicates that in most cases the lesion is more severe on the medial side (Table 2; e.g. see Figure 1). This is clear from the age group summaries, and in particular the totals, in Table 2, where the frequency distributions are predominantly on the medial side (ii–iii) of the tables. It is suggested that this is as a response to greater forces acting medially through the legs than laterally (Cresswell & Smythe, 1963: 450). From an evolutionary perspective, this can also be seen in larger measurements from the medial condylar element than that of the lateral side of horse metapodials (Hillson, 1992: 46).

Discussion

The methodology presented in this paper for recording the ossification of the interosseous ligaments between the metapodials in horse skeletons sets out a simple scoring system for stages in the development of this lesion. It is proposed that each of the joints between the metapodials is scored using the stages described (Figures 2–7). Simple tabulation of the results (e.g. Table 1) can then be used to demonstrate the expression of the lesion in a horse skeleton and compare it to other skeletons, and other variables, such as age. The expression of this lesion in a population can be explored by cross-tabulation of results to assess its distribution throughout the skeleton (e.g. Table 2). These results can then be compared between populations.

The preliminary case study has shown that the ossification of the ligaments between the metapodials can occur in horses that are not worked. The results, admittedly from a limited sample, suggest that the expression and progression of this pathology is linked to how the weight of the animal acts through the legs, in that it occurs earliest, and is generally more advanced, in the areas that support a greater burden. These areas are the forelimbs (relative to the hindlimbs) and the medial side of the limbs (relative to the lateral). Figure 1, for example, illustrates the latter state, with symmetrical expression in one individual of more advanced pathology on the medial side. The exception to this is horse zvl 48/50 HM (Table 1), in which the left metatarsal can be seen, in Table 2, to be the only specimen that shows greater lateral involvement than medial. This animal has a slightly different life history than the other animals, in that it was born in Washington rather than Prague, although the anomalous pathology in the left metatarsal could be linked to a trauma to this limb (unfortunately the right metatarsals were not available for study).

It is suggested, from the preliminary case study, that age is a major factor in the development of this pathology (Tables 1 and 2). Any analysis of the presence and prevalence of this lesion in archaeological material must be considered in relation to the age distribution of the animals—only then will its significance to the population be understood. There are many other variables that may have affected its manifestation in this population, such as sex, weight, conformation, genetics, and environmental factors. The sample was too small to explore the role of sex as a factor, and live-weights of the animals were not available to test individual weight as a variable. An environmental factor that may have affected the manifestation of the pathology in this sample is the substrate material in the Przewalski's horse enclosure at Prague Zoo, part of which is currently a hard man-made material (Figure 8). This may have caused a greater degree of

Figure 8. Przewalski's horse at Prague Zoo (July 2005).

DOI: 10.1002/oa

concussive damage than would be expected, for example, from grassland. Genetic and conformation differences between the Przewalski's horse (*Equus ferus przewalskii*) and the domestic horse (*Equus caballus*) may mean that prevalence comparisons between the sample considered here and archaeological horse samples may not be precisely comparable. The study, however, has provided a model of the development of this lesion in a population of modern caballine horses that have not been worked. Comparison of this model to the distribution of the pathology in the metapodials of archaeological skeletons and development in relation to age can be used to interpret possible patterns of use for the animals. The archaeological sample from Lithuania reported by Daugnora & Thomas (2005: 71–2) produced the same pattern as recorded here: the pathology was more common in the metacarpals than metatarsals, and was noted as starting on the medial side. The prevalence of the pathology between different age groups for the Lithuania sample, however, is not given.

In considering the effect of work on archaeological horse populations, analyses must consider the expression of the pathology against unworked samples. It will only be through the analysis of further aged and sexed samples of horses with known life histories—whether riding, driving, pack, or unworked—that interpretative patterns will be developed. The distribution of the pathology between the metacarpals and metatarsals, for example, may be significant in making interpretations, as this may vary according to use, due to riding and traction exerting different forces on the skeleton (Levine *et al.*, 2000).

Acknowledgements

I would like to thank Dr Petr Benda and Dr Zdenka Hodkova (National Museum, Prague) for their kind assistance and allowing me access to the skeletal collections.

References

Ashdown RR, Done SH. 1987. *The Horse: Colour Atlas of Veterinary Anatomy* (Vol. 2). Mosby-Wolfe: London.

Budras K-D, Sack WO, Röck S. 2003. *Anatomy of the Horse: An Illustrated Text* (4th edn). Schlütersche: Hannover.

Cresswell H, Smythe RH. 1963. Foot lameness. In *Equine Medicine and Surgery: a Text and Reference Work*, Bone JF, Catcott EJ, Gabel AA, Johnson LE, Riley WF (eds). American Veterinary Publications: Wheaton, IL; 427–470.

Daugnora L, Thomas R. 2005. Horse burials from Middle Lithuania: a palaeopathological investigation. In *Diet and Health in Past Animal Populations: Current Research and Future Directions*, Davies J, Fabis M, Mainland I, Richards M, Thomas R (eds). Oxbow Books: Oxford; 68–74.

Hawkey DE, Merbs CF. 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. *International Journal of Osteoarchaeology* **5**: 324–338.

Hillson S. 1992. *Mammal Bones and Teeth. An Introductory Guide to Methods of Identification*. Institute of Archaeology: London.

Jurmain R. 1999. *Stories from the Skeleton: Behavioral Reconstruction in Human Osteology*. Gordon and Breach Publishers: Amsterdam.

Kahn CM (ed.). 2003. *The Merck Veterinary Manual* (8th edn). Merck & Co., Inc.: Whitehouse Station, NJ. http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/110504.htm [accessed 20 July 2005].

Levine MA, Bailey GN, Whitwell KE, Jeffcott LB. 2000. Palaeopathology and horse domestication: the case of some Iron Age horses from the Altai Mountains, Siberia. In *Human Ecodynamics and Environmental Archaeology*, Bailey G, Charles R, Winder N (eds). Oxbow: Oxford; 123–133.

Sisson S, Grossman JD. 1966. *The Anatomy of Domestic Animals* (4th edn). W.B. Saunders Company: London.