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Clinical significance of ossification of the cartilages of the front feet based on nuclear bone scintigraphy, radiography and lameness examinations in 21 Finnhorses

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Summary

Reasons for performing study: **Research on the clinical significance of ossification of the cartilages of the foot has been limited, despite the common nature of the condition and conflicting reports in previous literature.**

Hypothesis: **Some radiographic features in the ossification of the cartilages, such as incomplete fusion lines between separate centres of ossification and the ossified base, are of clinical significance.**

Methods: **The relationships between radiopharmaceutical uptake in bone phase nuclear scintigraphy at the heels (palmar processes of the distal phalanx, including ossification of the cartilages of the foot), radiographic extent and type of ossification of the cartilages and clinical lameness were evaluated retrospectively in 21 Finnhorses (age ≥4 years) in a total of 36 front feet.**

Results: **No significant relationship between height of the ossifications and radiopharmaceutical uptake at the ipsilateral heels existed. Clearly separate centres of ossification were not associated with increased uptake. Moderately increased uptake was suspected to be associated with ossification of the adjacent cartilage in only one foot. Intense uptake was present unilaterally in 4 horses, at one medial and 3 lateral heels. In 2 of these horses, a unilateral palmar digital nerve block relieved the mild lameness; 2 horses had no obvious lameness but had a history of being stiff or having locomotion problems during high speed trot. At 2 of the lateral heels, an incomplete fusion line was present between a large separate centre of ossification and the base, and the third horse had a high sidebone with bony protrusions, suggestive of chronic entheseopathy in a narrow foot. At the medial heel, an oblique radiograph revealed a faint radiolucent line at the base of the ossification. In all cartilages with intense radiopharmaceutical uptake at the heel and/or lameness, the ossified part of the cartilage was wider and more irregular compared to other ossifications of the front feet of the individual.**

Conclusions: **Increased radiopharmaceutical uptake, associated with a different radiographic appearance from that of other ossifications of the front feet, was a conclusive sign of clinical significance. Obscure locomotion problems were more commonly associated with ossification of the cartilages than true lameness.**

Potential relevance: **This information is useful in lameness and prepurchase examinations and is likely also to be applicable to other coldblooded breeds used for athletic purposes.**

Introduction

Ossification of the cartilages of the foot (sidebones) is common in the front feet of coldblooded but rare in warmblooded horses (Verschooten *et al.* 1996). About 80% of Finnhorses have radiographic signs of ossification in one or more of the cartilages, but less than 20% have ossification extending above the level of the navicular bone and/or separate centres of ossification (Ruohoniemi 1997). The clinical significance of ossification has not been clarified completely and may vary between breeds. According to Verschooten *et al.* (1996), ossification itself is not painful and has never been the cause of lameness, whereas another investigator (Körber 1991) considers it to be a more frequent cause of lameness than generally believed. Sensory nerves have been found on axial and abaxial surfaces of the cartilages (Bowker *et al.* 1998). Ossification is usually considered to be an incidental radiographic finding, but may occasionally have clinically significant features (Reid 1980; Schneider and Stickle 1987; Reeves *et al.* 1989; Hunt *et al.* 1995; Ruohoniemi *et al.* 1997a; Butler *et al.* 2000). Clinical signs associated with ossification include shortening of the stride or a slight lameness, which is more evident on a hard surface and when the horse turns in the direction of the affected foot (Colles 1986). Sidebones are a source of lameness if they are fractured and, occasionally, extremely large sidebones may cause mechanical interference with the distal limb action (Schneider and Stickle 1987; Hunt *et al.* 1995). Diagnosing an ossified cartilage as a source of lameness remains difficult, as no specific local anaesthesia is available. A palmar digital nerve block above the cartilage on the affected side should relieve the lameness (Schneider and Stickle 1987; Reeves *et al.* 1989; Hunt *et al.* 1995; Stashak 2002).

Nuclear bone scintigraphy is a useful means of evaluating traumatic, inflammatory and degenerative skeletal diseases in horses (Lamb *et al.* 1988; Chambers 1996). The uptake of

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TABLE 1: Radiopharmaceutical uptake in bone scintigraphy, ossification type of the cartilages of the foot and classification of lameness in 21 Finnhorses in a total of 36 front feet

Horse	Limb	Bone uptake/medial aspect of the heel	Ossification grade/medial cartilage: base + SCO	Bone uptake/lateral aspect of the heel	Ossification grade/lateral cartilage: base + SCO	Lameness
1	RF	1	NS	1	4 + small	B
	LF	2	NS	2	NS	
2	RF	1	NS	1	NS	A (LF)
	LF	1	NS	1	NS	
3	RF	2	NS	1	NS	A (RF)
	LF	1	NS	1	NS	
4	RF	1	NS	1	4	D
	LF	1	5	3	5	
5	RF	1	NS	2	NS	A (LF medial side)
	LF	3	4 (x)	1	NS	
6	RF	2	NS	1	NS	A (LF)
	LF	1	NS	1	NS	
7	LF	1	NS	1	NS	B
8	LF	1	NS	1	NS	B
9	RF	2	NS	1	2 + small	C
10	LF	1	NS	1	NS	C
11	RF	1	0 + small	1	1 + large	C
	LF	1	1 + small	1	2 + small	
12	RF	2	NS	1	NS	B
	LF	2	NS	2	NS	
13	RF	2	NS	1	NS	C
	LF	1	NS	1	NS	
14	RF	2	NS	1	NS	C
	LF	1	NS	1	NS	
15	RF	1	NS	1	NS	D
	LF	1	NS	1	NS	
16	LF	1	NS	1	1 + small	A (LF)
17	RF	1	NS	1	NS	B
	LF	1	NS	1	NS	
18	LF	1	NS	1	NS	A (LF)
19	RF	1	NS	1	NS	B
	LF	1	NS	2	NS (3*)	
20	RF	1	NS	1	2+small	D
	LF	1	2 + small	3	2 + large (xx)	
21	RF	1	2	1	2	A (LF lateral side)
	LF	1	2	3	2 + large (xx)	

RF = right fore; LF = left fore. Bone uptake: 1 = normal; 2 = moderately increased in the solar view; 3 = moderately to intensely increased in the solar view, visible also in lateral and dorsal views. SCO = separate centre of ossification; NS = no significant ossification (*grade ≤3*, no separate centres of ossification). (x) = radiolucent line in the ossification; (xx) = incomplete fusion between SCO and the ossified base of the cartilage; *indistinct appearance. A = lameness alleviated by a palmar digital nerve block; B = lameness localised outside the foot area; C = lameness not localised using nerve blocks, a site other than the foot considered to be the source of pain; D = no lameness but a history of stiffness or locomotion problems at high speed.

diphosphonate salt pharmaceuticals is dependent on both bone activity and blood flow. Scintigraphy is more sensitive than radiography in detecting acute injuries and developing bone lesions and has also been found valuable in evaluating chronic sclerotic bone lesions and screening cases of obscure or occult lameness (Chambers 1996; Lamb and O'Callaghan 1996; Hoskinson 2001). In the foot area, scintigraphy has been used mainly for detecting and assessing fractures of the distal phalanx, navicular syndrome and pedal osteitis (Lamb *et al.* 1988; Steckel 1991; Trout *et al.* 1991; Keegan *et al.* 1993, 1996; Chambers 1996; Lamb and O'Callaghan 1996). Ueltschi (1990) detected a fractured sidebone using nuclear scintigraphy.

The purpose of the present study was to evaluate whether some radiographic features in the ossification of the cartilages of the foot are associated with increased radiopharmaceutical uptake and/or clinical lameness and could be suggestive of clinical significance. The hypothesis was that, in addition to fractures, incomplete fusion lines between separate centres of ossification and the ossified base of the cartilages, and possibly also extremely large sidebones, could be such changes.

Materials and methods

Horses

This retrospective study consisted of Finnhorses which had had their front feet examined with nuclear bone scintigraphy at the Helsinki University Veterinary Hospital between November 1996 and December 2002. Horses examined for lameness at the hospital and having a dorsopalmar (DPa) radiograph taken of the front feet within a week from the scintigraphic examination were included. A total of 36 feet (16 right and 20 left) in 21 horses fulfilled these criteria (Table 1). Horses were age 4–10 years (mean 6.6 years) and included 10 mares, 9 stallions and 2 geldings. *Horses 4* and *21* were riding horses, *Horse 6* was a broodmare used as a pleasure horse and all the other 18 horses were trotters. The exact exercise history of the horses had not been systematically recorded.

Nuclear scintigraphy

Phase III, bone phase scintigraphy, was performed 2.5 h after i.v.

TABLE 2: The radiographic grade of ossification at the base of the cartilages of the foot, presence of separate centres of ossification and radiopharmaceutical uptake in bone scintigraphy in a total of 36 front feet (72 cartilages) of 21 Finnhorses

Bone uptake	Ossification grade at the base of the cartilage 0	1	2	3	4	5	Total
1	8^{S}	$11^{S,S,L}$	$27^{S,S,S,S}$	7	2^{S}	1	56 (77.8%)
2	1	5	5	1	0	0	12 (16.7%)
3	0	0	2^{L}	0	1	1	4 (5.5%)
Total	9 (12.5%)	16 (22.2%)	34 (47.2%)	8 (11.1%)	3 (4.2%)	2 (2.8%)	72 (100.0%)

Ossification grades of the cartilages: 0 = none; 1 = minimal ; 2 = mild ; 3 = moderate; 4 = advanced; 5 = extensive. Bone uptake: 1 = normal; 2 = moderately increased in the solar view; 3 = moderately/intensely increased in the solar view, visible also in the lateral and dorsal views. ^{S} = small, ^{L} = large separate centres of ossification.

injection of 1 GBq/100 kg bwt (5.0–5.5 GBq/horse) ^{99m}Tc-hydroxymethylene diphosphonate (TechneScan HDP)[1]. Waterproof adhesive taping protected the hooves from urine contamination. For the examination, the horses were sedated with i.v. detomidine (Domosedan[2]) 10–20 µg/kg bwt. Scintigraphy was performed bilaterally in all horses. A routine scintigraphic examination included lateral and solar views and, in all cases with increased activity in the heel area in the solar view, a dorsal view was also included. The solar view was obtained by placing the weightbearing surface of the limb directly on the collimator of the gamma camera. For the lateral view, the contralateral limb was shielded from view with a lead plate. Static lateral images were acquired for 150,000–250,000 counts, solar images for 75,000–100,000 counts, which required 60–120 secs acquisition time, and dorsal images for 150,000 counts. No motion correction was used.

The scintigraphic findings at both aspects of the heels (palmar processes of the distal phalanx, including ossification of the cartilages of the foot) were graded separately from the digital image on the computer screen in the following way: 1 = uptake in the heel area equal to or less than that in the adjacent bone; 2 = moderately increased focal uptake in the medial or lateral aspect of the heel in the solar view, not visible in the lateral and dorsal views; 3 = moderately or intensely increased focal uptake in the medial or lateral aspect of the heel in the solar view, clearly visible also in the lateral and dorsal views.

The scintigraphic images were evaluated by one clinician (O.M.) on 3 separate occasions, without prior knowledge of the radiographic findings or the lameness of the horses.

Radiography

The DPa radiographs had been taken using a horizontal x-ray beam and the horse standing weightbearing. Additional views of the front feet were variably available and had been taken according to the clinical and scintigraphic findings.

Ossification at the base of the cartilages extending in the proximal/palmaroproximal direction was graded 0–5 according to the most proximal point of ossification (Ruohoniemi *et al.* 1993). All radiographs were assessed by 2 clinicians (M.R. and T.E.) until agreement. At *grade 0*, there was no visible ossification. At *grade 1* ossification was minimal to the level of the medial/lateral joint margins of the distal phalanx, and at *grade 2* mild ossification to the palmar level of the distal interphalangeal joint was present. *Grade 3* indicated moderate ossification, to the level of the proximal border of the navicular bone and, at *grade 4*, ossification extended above the navicular bone but remained at the level of the distal half of the middle phalanx. *Grade 5* indicated extensive ossification to the level of the proximal half of the middle phalanx. The presence and height of the separate centres of ossification were also recorded. Separate centres of ossification were considered small if their height was <1 cm. The appearance of any radiolucent gap between the separate centre of ossification and the base of the cartilage was assessed.

Lameness examination

Most of the horses were referral cases for scintigraphy but all horses were subjected to a lameness examination at the hospital, performed on a hard surface according to a standard protocol including the use of hoof testers and local anaesthesia. Trotters were generally examined in straight lines only.

Statistical analyses

The difference in bone uptake between the lateral and medial aspects of the heels was tested for significance using a Sign test. The relationship between uptake at the heel and grade of ossification of the ipsilateral cartilages was analysed with Spearman's correlation test. P value <0.05 was considered significant.

Results

No significant difference was present between uptake at the lateral and medial aspects of the heels. The lateral cartilages had more ossification and more separate centres of ossification than the medial (Table 1). Usually, there was some space between the ossified base and separate centre of ossification, or the smooth and rounded margins indicated that these ossifications were not in contact with each other. In the left lateral cartilage of *Horses 20* (Fig 1) and *21*, a large separate centre of ossification appeared to be partly fused or in close contact with the base. No significant relationship was found between scintigraphic uptake at the heels and ossification grade of the ipsilateral cartilages. None of the clearly separate centres of ossification was associated with increased uptake.

Nearly all heels with *grade 2* uptake (11/12) had an ossification grade of the ipsilateral cartilage ≤2 (Table 2). The only exception was the left lateral cartilage of *Horse 19*, which had *grade 3* ossification of the cartilage with a widened and slightly irregular appearance (Fig 2), while all the other cartilages of this individual had *grade 2* ossification with an inactive appearance. This horse had a history of longstanding gait asymmetry during high speed trot. In the clinic, the horse showed mild right forelimb lameness (*grade 1/5*), which was localised to the metacarpophalangeal joint. No pain could be elicted using hoof testers.

Grade 3 uptake was present in one medial heel (*Horse 5*; Figs 3a,b) and 3 lateral heels (*Horses 4*, *20* and *21*). None of these feet showed pain on hoof tester examination. In *Horse 5*, a slightly oblique radiolucent line was found in an oblique view at the base of the *grade 4* ossification in the left medial cartilage (Fig 3c). *Horse 4* had *grade 3–5* ossification in all 4 cartilages, but only the left lateral cartilage had increased uptake (Table 1) and an outline suggestive of chronic entheseopathy (Fig 4). *Horse 4* also had narrow feet. Lateral and/or oblique views revealed that in the left front foot of *Horse 4* and, to a lesser extent, in the left medial heel

Fig 1: The DPa radiograph of the left front foot of Horse 20 *(5-year-old Finnhorse mare) revealed a small separate centre of ossification (white arrow) in the medial cartilage and a large separate centre of ossification separated by a radiolucent line (black arrow) from the ossified base of the lateral cartilage. Flaring of the margins of the incomplete fusion line has made the ossified lateral cartilage relatively wide. Intensely increased bone uptake was present in the lateral heel area. M = medial.*

Fig 2: DPa radiograph of the left front foot of Horse 19 *(5-year-old Finnhorse stallion) with increased bone uptake (*grade 2*) at the lateral aspect of the heel. Ossification of the lateral cartilage extends to the level of the proximal margin of the navicular bone and appears to be laterally widened and slightly indistinct. M = medial.*

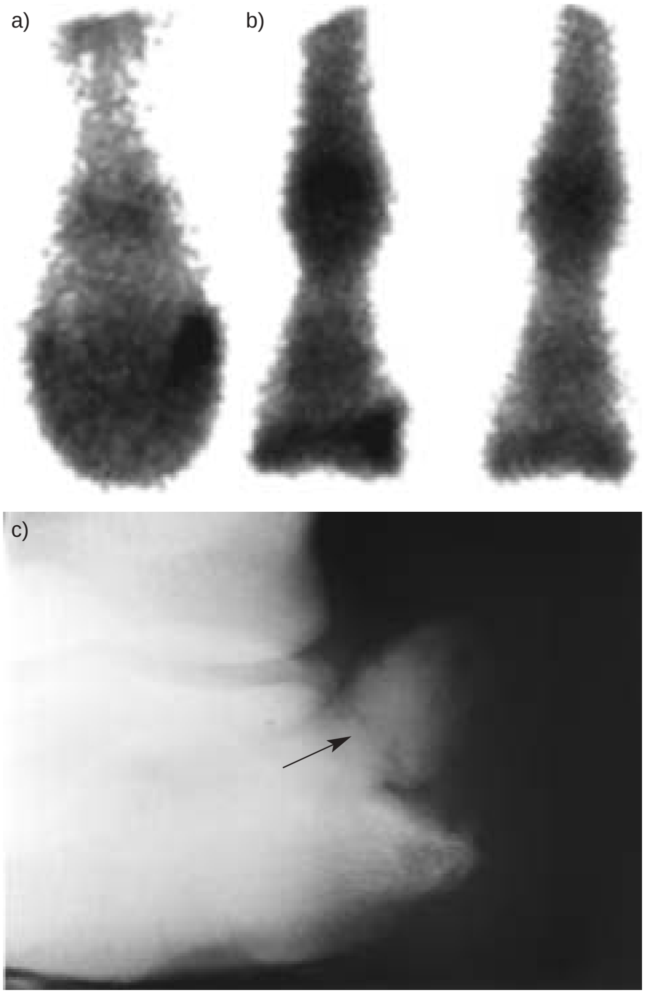

*Fig 3: a) Intensely increased focal uptake (*grade 3*) in the solar scintigraphic view at the medial aspect of the heel of the left front foot of* Horse 5 *(5-year-old Finnhorse mare). b) In the dorsal scintigraphic view of the same horse, the increased uptake is evident on the medial side of the left front foot. c) The dorsomedial-palmarolateral oblique radiograph of the left front foot of* Horse 5 *reveals the slightly irregular appearance of the* grade 4 *ossification in the medial cartilage and a faint radiolucent line (arrow) is visible at the base of the ossification. Some ossification is present also in the distal palmar process.*

of *Horse 5*, ossification was present also at the distal palmar process, causing elongation of the bone (Figs 3c and 4). The lateral sidebones with an incomplete fusion line between the large separate centre of ossification and the ossified base in *Horses 20* (Fig 1) and *21* were associated with *grade 3* uptake. *Horse 20* also had distal interphalangeal joint distension in the same foot. In all heels with *grade 3* uptake, the radiographic appearance of the ossified cartilage in the DPa view differed from that of other cartilages of the front feet of the individual. All these cartilages had ossification extending above the proximal border of the navicular bone which was wider and more irregular in the DPa views than in the other cartilages of the individual.

Eighteen of the 21 horses showed lameness when examined at the clinic. In 7 horses, lameness was present in ≥2 limbs. Three horses had no lameness but had a history of longstanding locomotion problems: gait asymmetry during high speed trot had been noted in *Horses 15* and *20* and stiffness and behavioural problems, such as headshaking and biting of the front limbs, during riding in *Horse 4*. *Horse 21* had been variably unsound, especially on circles, and tended to carry the head and neck slightly tilted to the right during riding.

In 7 horses (*Horses 2*, *3*, *5*, *6*, *16*, *18* and *21*), lameness was relieved with a uni- or bilateral palmar digital nerve block (Table 1). In 2 of these horses *(Horses 5* and *21*), the radiographic and scintigraphic findings in the ossified cartilage could be associated with the lameness. *Horse 16* had a small separate centre of ossification in the lateral cartilage of the lame limb, with no increased bone uptake, and a subchondral lucency in the proximal interphalangeal joint was considered to be a more likely source of pain. In the remaining 4 horses with foot pain, the diagnoses included navicular or distal interphalangeal joint syndrome, associated with carpitis or carpal canal syndrome in 2 horses. In 6 horses, lameness was blocked out at sites other than the foot (fetlock, carpus, stifle or distal tarsus). Five lame horses had no local anaesthesia performed or local anaesthesia failed to localise the source of pain but, based on the bone scintigram and/or clinical and ultrasonographic findings, the problem was considered to be related to sites other than the foot (fetlock or proximal suspensory ligament).

Fig 4: A slightly oblique lateral view of the left front foot of Horse 4*, a 9-year-old Finnhorse gelding. The palmar aspect of the high lateral sidebone appears spiculated. Ossification is present not only in the palmaroproximal direction but also in the distal palmar process, causing palmar elongation of the distal phalanx.*

Discussion

The solar and lateral scintigraphic views allowed assessment of uptake in the foot area as reported previously (Trout *et al.* 1991; Keegan *et al.* 1996), but a dorsal view helped to distinguish the uptake at separate aspects of the heels and allowed more accurate localisation of the increased uptake in the proximodistal direction. Additionally, a focal area of increased uptake on the medial side of the foot may not always be visible on a lateral image, due to the distance and shielding effect of the bone between the lesion and the camera (Ross and Stacy 2003).

Bone scintigraphic uptake patterns have been reported to vary between breeds and occupation of horses (Ehrlich *et al.* 1998, 1999; Twardock 2001). Nearly all Finnhorses in the present study were trotters. In racing Standardbred horses, the distal phalanx is an uncommon site for increased uptake (Ehrlich *et al.* 1999). Increased bone uptake may be associated with stress-related bone remodelling or trauma (Ross 1998) or hoof imbalance (Lamb *et al.* 1988; Steckel 1991; Lamb and O'Callaghan 1996) and may also be an incidental finding (Dyson 2003). The palmar processes have not been considered to be an ideal area for quantitative analysis of uptake (Dyson 2002). In the present study, a subjective analysis was considered adequate for grading of the scintigraphic findings, as the scoring was relatively coarse and the final grade was determined with use of more than one view.

Despite the limited number of horses, all grades of ossification were represented and their distribution was in agreement with previous studies in Finnhorses (Ruohoniemi 1997). All horses examined were mature (≥4 years) and the most active ossification process in the cartilages was probably over. In Finnhorses, the extent of ossification increases rapidly during the second and third year of life and relatively slowly in older subjects (Ruohoniemi *et al.* 1997b). The DPa view is a standard view for the grading of ossification of the cartilages of the foot, even though it has some limitations. Small separate centres of ossification, as well as radiolucent lines suggestive of previous separate ossification centres or fractures, are not always visible in this view, as was also found in the present study. In mature Finnhorses, ossification grades ≤3 at the base of the cartilages have been considered to be normal variations, especially when the ossifications have a smooth appearance (Ruohoniemi 1997). Ossification of the cartilages is usually bilaterally symmetrical and the lateral cartilages show more ossification and more separate centres of ossification than the medial (Ruohoniemi *et al.* 1993). Females are more commonly affected than males (Ruohoniemi *et al.* 1993).

Bone uptake in nuclear scintigraphy had no significant relationship with ossification grade of the cartilages, supporting the previous opinion that the height of ossification is not a direct measurement of the clinical significance of the condition (Ruohoniemi 1997). None of the clearly separate centres of ossification seen in the DPa view were associated with an increased uptake or lameness and these are not likely to be clinically significant findings. Large and rapidly growing ossification centres are mostly seen in young horses (Verschooten *et al.* 1996).

Horse 5, suspected to have lameness associated with ossification of the medial cartilage, had a radiolucent line at the base of the ossification, involving the proximal palmar process of the distal phalanx. This location is more suggestive for a fracture than an incomplete fusion line. The most common type of fracture associated with trauma to the sidebone has been reported to be a medial or lateral sagittal (articular) distal phalanx fracture (Reeves *et al.* 1989; Hunt *et al.* 1995). Fractures of the ossified cartilage occur rarely and may be difficult to differentiate radiographically from incomplete fusion lines between the separate centre of ossification and ossification at the base of the cartilage (Reid 1980; Schneider and Stickle 1987; Butler *et al.* 2000).

Incomplete fusion lines with a reactive appearance, seen in 2 lateral cartilages (*Horses 20* and *21*), have been suggested to be a possible source of pain (Ruohoniemi *et al.* 1997a). In Finnhorses, the incomplete fusion lines are generally located in the distal or middle part of the cartilage (Ruohoniemi *et al.* 1993), frequently at the level where the horny hoof becomes narrower (Ruohoniemi *et al.* 1997a). Continuous movement of the separate centre of ossification relative to the base has been considered one possible cause for an appearance resembling hypertrophic nonunion fracture healing (Ruohoniemi *et al.* 1997a). In addition to the flared margins of the ossification, associated soft tissue changes may have caused irritation of the distal interphalangeal joint in *Horse 20*. Although no lameness could be demonstrated in a routine lameness examination, this trotter with intense uptake in the cartilage area had a history of locomotion problems during high speed trot. One limitation in the present study was that horses were not examined at high speed. Even subtle musculoskeletal abnormalities may cause gait abnormality at high speed, or poor performance (Morris and Seeherman 1991).

The extensively ossified lateral cartilage with *grade 3* uptake in *Horse 4* had an outline suggestive of chronic entheseopathy. Increased radiopharmaceutical uptake occurs in areas with bone remodelling or dystrophic mineralisation (Martinelli and Chambers 1995; Chambers 1996; Lamb and O'Callaghan 1996) and active remodelling may be present amid more chronic-appearing radiographic changes (Chambers 1996). The cartilages are joined to surrounding tissues, e.g. the extensor process of the distal phalanx, middle phalanx, distal aspect of the proximal phalanx and collateral sesamoidean ligaments, by numerous small ligaments and their axial surfaces merge tightly with the digital cushion (Ruohoniemi *et al.* 1997a). The association between the cartilages and digital cushion is extensive and is important for energy dissipation within the foot (Bowker *et al.* 1998). Strain by the ligaments attaching to the cartilage has been considered important in the ossification process (Körber 1991). The main complaint in *Horse 4* was a stiff gait and behavioural problems at work. The horse had narrow feet, which may increase the likelihood of sidebones being a space-occupying lesion. In horses with broad feet, even extensive ossification may not be clinically significant (Reid 1980). Finnhorses tend to have broad feet and general conformational adaptations of the front feet are not commonly related to ossification of the cartilages in this breed (Ruohoniemi *et al.* 1997c). However, local conformational adaptations and fibrosis have been reported around extensively ossified cartilages (Ruohoniemi *et al.* 1997a).

Two of the horses with intense bone uptake at the heel also showed elongation of the distal palmar process in the lateral and/or oblique radiographs. Increased bone uptake has been reported in horses with low, collapsed heels and radiographic evidence of modelling and elongation of the palmar process of the distal phalanx (Butler *et al.* 2000; Dyson 2003). Ossification in the palmar aspect of the distal palmar processes, causing elongation of the distal phalanx, has been reported in Finnhorses (Ruohoniemi *et al.* 1997a,c), but the variability of radiographic projections available did not allow systematic evaluation of this finding in the present study.

In the assessment of the clinical significance of ossification of cartilage, it was found that increased radiopharmaceutical uptake, associated with different radiographic appearance to the other cartilages of the front feet, were conclusive signs of significance. Asymmetrical ossification has been considered to be an indicator of an improperly balanced foot that concentrates stresses to one side of the foot (Reid 1980), but the nature of the stress inducing ossification needs to be clarified further. In a study of Finnhorses, no significant relationship was found between signs of increased weightbearing and ossification of the cartilages (Ruohoniemi *et al.* 1997c) and the question was raised as to whether greater tension could be a more important factor in the ossification process than increased weightbearing or concussion. Our results suggest that clinically significant ossification of the cartilages of the foot may cause subtle gait abnormalities, possibly at high speeds only, rather than overt lameness.

Manufacturers' addresses

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References

Bowker, R.M., van Wulfen, K.K., Springer, S.E. and Linder, K.E. (1998) Functional anatomy of the cartilage of the distal phalanx and digital cushion in the equine foot and a hemodynamic flow hypothesis of energy dissipation. *Am. J. vet. Res.* **59**, 961-968.

Butler, J.A., Colles, C.M., Dyson, S.J., Kold, S.E. and Poulos, P.W. (2000) Distal phalanx. In: *Clinical Radiology of the Horse*, 2nd edn., Blackwell Science Ltd., Oxford. pp 27-63.

Colles, C.M. (1986) Diseases and injuries of the horse's foot. Sidebone. In: *Equine Surgery and Medicine,* Vol. 2, Ed: J. Hickman, Academic Press Inc., London. pp 221-223.

Chambers, M.D. (1996) Bone imaging: the diphosphonates. In: *The Handbook of Veterinary Nuclear Medicine*, Eds: C.R. Berry and G.B. Daniel, North Carolina State University, North Carolina. pp 49-59.

Dyson, S. (2002) Subjective and quantitative scintigraphic assessment of the equine foot and its relationship with foot pain. *Equine vet. J.* **34**, 164-170.

Dyson, S. (2003) Osteitis of the palmar processes of the distal phalanx. Disease of the cartilages of the foot. In: *Diagnosis and Management of Lameness in the Horse*, Eds: M.W. Ross and S.J. Dyson, W.B. Saunders Co., St. Louis. pp 322-325.

Ehrlich, P.J., Dohoo, I.R. and O'Callaghan, M.W. (1999) Results of bone scintigraphy in racing Standardbred horses; 64 cases (1992-1994). *J. Am. vet. med. Ass.* **215**, 982-991.

Ehrlich, P.J., Seeherman, H.J., O'Callaghan, M.W., Dohoo, I.R. and Brimacombe, M. (1998) Results of bone scintigraphy in horses used for show jumping, hunting, or eventing: 141 cases (1988-1994). *J. Am. vet. med. Ass.* **213**, 1460-1467.

Hoskinson, J.J. (2001) Equine nuclear scintigraphy. Indications, uses and techniques. *Vet. Clin. N. Am.: Equine Pract.* **17**, 63-74.

Hunt, R.J., Kobluk, C.N. and Steckel, R.R. (1995) Diseases of the foot. In: *The Horse: Diseases and Clinical Management,* Eds: C.N. Kobluk, T.R. Amer and R.J. Geor, W.B. Saunders Co., Philadelphia. pp 659-705.

Keegan, K.G., Twardock, A.R., Losonsky, J.M. and Baker, G.J. (1993) Scintigraphic evaluation of fractures of the distal phalanx in horses: 27 cases (1979-1988). *J. Am. vet. med. Ass.* **202**, 1993-1997.

Keegan, K.G., Wilson, D.A., Lattimer, J.C., Twardock, A.R. and Ellersieck, M.R. (1996) Scintigraphic evaluation of ^{99m}Tc-methylene diphosponate uptake in the navicular area of horses with lameness isolated to the foot by anaesthesia of the palmar digital nerves. *Am. J. vet. Res.* **57**, 415-421.

Körber, H.-D. (1991) Röntgenologische Untersuchung der Hufknorpelverknöcherung des Pferdes und ihre klinische Beurteilung. *Berl. Münch. Tierärztl. Wschr.* **104**, 334-340.

Lamb, C.R. and O'Callaghan, M.W. (1996) Combined modality imaging of the equine musculoskeletal system. In: *The Handbook of Veterinary Nuclear Medicine,* Eds: C.R. Berry and G.B. Daniel, North Carolina State University, North Carolina. pp 60-70.

Lamb, C.R., Koblik, P.D., O'Callaghan, M.W. and Mariner, J.C. (1988) Comparison of bone scintigraphy and radiography as aids in the evaluation of equine lameness: retrospective analysis of 275 cases. *Proc. Am. Ass. equine Practnrs.* **34**, 359-368.

Martinelli, M.J. and Chambers, M.D. (1995) Equine nuclear bone scintigraphy: physiological principles and clinical application. *Equine vet. Educ.* **7**, 281-287.

Morris, E.A. and Seeherman, H.J. (1991) Clinical evaluation of poor performance in the racehorse: the results of 275 evaluations. *Equine vet. J.* **23**, 169-174.

Reeves, M.J., Yovich, J.V. and Turner, A.S. (1989) Miscellaneous conditions of the equine foot. *Vet. Clin. N. Am.: Equine Pract.* **5**, 221-242.

Reid, C.F. (1980) Radiography and the purchase examination in the horse. *Vet. Clin. N. Am.: Large Anim. Pract.* **2**, 151-202.

Ross, M.W. (1998) Observations in horses with lameness abolished by palmar digital analgesia. *Proc. Am. Ass. equine Practnrs.* **44**, 230-232.

Ross, M.W. and Stacy, V.S. (2003) Nuclear medicine. In: *Diagnosis and Management of Lameness in the Horse*, Eds: M.W. Ross and S.J. Dyson, W.B. Saunders Co., St. Louis. pp 198-212.

Ruohoniemi, M. (1997) *Ossification of the Collateral Cartilages of the Distal Phalanx in the Front Feet of Finnhorses.* Doctoral Thesis. pp 1-48.

Ruohoniemi, M., Tulamo, R.-M. and Hackzell, M. (1993) Radiographic evaluation of ossification of the collateral cartilages of the third phalanx in Finnhorses. *Equine vet. J.* **25**, 453-455.

Ruohoniemi, M., Kärkkäinen, M. and Tervahartiala, P. (1997a) Evaluation of the variably ossified collateral cartilages of the distal phalanx and adjacent anatomic structures in the Finnhorse with computed tomography and magnetic resonance imaging. *Vet. Radiol. Ultrasound* **38**, 344-351.

Ruohoniemi, M., Laukkanen, H., Ojala, M., Kangasniemi, A. and Tulamo, R.-M. (1997b) Effects of sex and age on the ossification of the collateral cartilages of the Finnhorse and the relationships between ossification and body size and type of horse. *Res. vet. Sci.* **62**, 34-38.

Ruohoniemi, M., Raekallio, M., Tulamo, R.-M. and Salonius, K. (1997c) Relationship between ossification of the cartilages of the foot and conformation and radiographic measurements of the front feet in Finnhorses. *Equine vet. J.* **29**, 44-48.

Schneider, R.K. and Stickle, R.L. (1987) Orthopedic problems of the foot. In: *Current Therapy in Equine Medicine 2*, Ed: N.E. Robinson, W.B. Saunders Co., Philadelphia. pp 282-289.

Stashak T.S. (2002) Ossification of the collateral cartilages of the distal phalanx (sidebones). In: *Adams' Lameness in Horses,* Ed: T.S. Stashak, Lippincott Williams & Wilkins, Philadelphia. pp 715-717.

Steckel, R.R. (1991) The role of scintigraphy in the lameness evaluation. *Vet. Clin. N. Am.: Equine Pract.* **7**, 207-239.

Trout, D.R., Hornof, W.J. and O'Brien, T.R. (1991) Soft tissue- and bone-phase scintigraphy for diagnosis of navicular disease in horses. *J. Am. vet. med. Ass.* **198**, 73-77.

Twardock, A.R. (2001) Equine bone scintigraphic uptake patterns related to age, breed and occupation. *Vet. Clin. N. Am.: Equine Pract.* **17**, 75-94.

Ueltschi, G. (1990) Die Untersuchung des Hufes aus radiologischer und szintigraphischer Sicht. *Collegium Veterinarium* **21**, 85-87.

Verschooten, F., van Waerebeek, B. and Verbeeck, J. (1996) The ossification of cartilages of the distal phalanx in the horse: an anatomical, experimental, radiographic and clinical study. *J. equine vet. Sci.* **16**, 291-305.