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Sclerosis of the Third Carpal Bone. A Prospective Study of its Significance in a Group of Young Standardbred Trotters

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Uhlhorn H, Eksell P, Sandgren B, Carlsten J: Sclerosis of the third carpal Bone. A prospective study of its significance in a group of young standardbred trotters. Acta vet. scand. 2000, 41, 51-61. – To assess the significance of radiographic signs of sclerosis of the third carpal bone (C3) in young Standardbred trotters in relation to performance, lameness and bone turnover both carpi in 14 Standardbred trotters were radiographically and scintigraphically examined 6 times, from the beginning of speed training until the beginning of racing, between the mean ages of 20 and 42 months. At the end of the study 8 horses had raced in official qualifying races and 14 limbs in 11 horses had been diagnosed with carpal lameness. All horses but 2 developed sclerosis and all but one had increased bone turnover in the C3 area by scintigraphy. C3 sclerosis increased continuously over time and with increased performance. Carpal lameness was significantly associated with progression of sclerosis but in most cases sclerosis developed without concomitant signs of carpal lameness. No association between carpal lameness and increased scintigraphic uptake was found, but horses that had qualified for racing had significantly higher C3 to carpus ratio of radiopharmaceutical uptake. We conclude that there is a continuous increase in C3 radiographic sclerosis with time in young Standardbred trotters in professional training, but radiographic sclerosis appears to be of limited value as an indicator of clinical carpal disease or level of performance in Standardbred trotters.

equine; subchondral bone; degenerative joint disease; lameness; radiography; scintigraphy.

Introduction

Radiographic sclerosis of the third carpal bone (C3) is recognised in Thoroughbred and Standardbred racehorses (*Butler et al.* 1993). Published investigations into the clinical importance of radiographic C3 sclerosis have primarily been made in Thoroughbred racehorses (*O'Brien et al.* 1985, *De Haan et al.* 1987). Sclerosis of the C3 has been indicated as a predisposing factor for ischaemic degenerative changes in the subchondral bone (*Young et al.* 1988) and dorsal slab fractures (*Young et al.* 1991).

Under experimental conditions reorientation of trabecular architecture (*Radin et al.* 1982) and decreased subchondral bone porosity (*Radin et al.* 1984) have been shown to result from repetitive impulse loading of joints. This process is generally believed to be the cause of radiographic signs of sclerosis of the radial fossa of the C3 in racing horses (*Bramlage et al.* 1988,

Table 1. No of horses available for each examination.

Examination / mean age (SD) months		No of horses examined	Horses lost from study since prev. examination
I	20.3 (1.2)	22	
II	23.1 (1.1)	22 *	
III	25.9 (1.2)	21 **	1 horse transferred to other trainer (later qualified for racing)
IV	30.3 (1.4)	20	1 horse died (lymphoma)
V	33.7 (1.1)	17	1 horse transferred to other trainer (qualified for racing) 1 horse sold abroad (no follow up) 1 horse transferred to other trainer (not qualified for racing at age 4)
VI	42.3 (2.1)	14	2 horses transferred to other trainers (both qualified for racing) 1 horse taken out of training (not qualified for racing at age 4)

* One horse, scint. examination lost due to computer failure
** One horse not available for scint. examination due to temporary change of ownership.

Blevins & Widmer 1990, *Young et al.* 1991, *Pool* 1996). Based on post mortem material, a higher prevalence and severity of radiographic signs of subchondral bone sclerosis have been reported in C3 from racing compared to training and non-athletic Thoroughbreds (*Young et al.* 1988). Subchondral bone porosity has been reported to be lower in C3 from trained compared to untrained Thoroughbreds (*Young et al.* 1991, *Firth et al.* 1999), and to decrease with age in untrained horses (*Young et al.* 1991).

The clinical relevance of sclerosis of the C3 has been debated. Radiographically identified sclerosis of the C3 is currently described as a sign of degenerative joint disease by some authors (*Blevins & Widmer* 1990, *Park et al.* 1996, *Boring* 1998) but a lesser degree of sclerosis (*Butler et al.* 1993) or sclerosis (*Pool & Meagher* 1990, *Pool* 1996) have also been claimed to represent a normal adaptive response to exercise in the third carpal bone of conditioned racehorses.

Retrospective evaluation of clinical radiographs from racing Thoroughbreds with carpal lameness has indicated a high prevalence of sclerosis of the C3 (*O'Brien et al.* 1985). In the same study radiographic sclerosis of the C3 was also found in a group of Thoroughbred racehorses without lameness. It is likely that radiographic signs of subchondral sclerosis would persist after an initiating overload and the cessation of possible accompanying lameness. The aim of the present study was to investigate the association between the development of radiographic C3 sclerosis and clinical signs of carpal disease and level of exercise in a group of Standardbred trotters during their first 2 years of training and racing.

Materials and methods

Horses

A group of one-year-old Standardbred trotters (11 colts and 11 fillies) which started training at a professional training camp during 2 consecutive years was monitored in this study. All horses were trained according to the same protocol. All horses were free from lameness when entering the study and none of them had been lame during the previous 4 months of breaking and slow trotting and walking. The horses were examined on 3 occasions 3 months apart and then twice at 4-month intervals, during a

14-month period from the beginning of speed training (mean age 20.0 months). A 6th examination was performed 6-12 months after the 5th examination (Table 1). Eight horses (3 colts and 5 fillies) were lost from the study before the sixth examination (Table 1). The 14 horses remaining at examination 6 were included in the longitudinal study of the radiographic and scintigraphic appearance of the C3.

Training protocol and performance

The training protocol consisted of trotting at slow speed for 6000 to 7000 meters with intermittent fast trotting for 200 to 300 meters, 5 days a week from 20 months of age. In addition the horses trotted 2 x 1000 m at near maximal speed once a week and from 25 months of age, twice a week. The training regime was maintained with increasing speeds through the study. Training was interrupted in case of lameness and reduced in actively racing horses.

Level of performance was graded as training, qualified for racing and racing. To qualify for racing, the Swedish Trotting Association (STC) requires unstarted 2-year-old Standardbreds to race in official qualifying races over 2140 m at speeds exceeding 11.4 m/s. Racing records, including date when qualified for racing, number of races and racing results were obtained from the Swedish Trotting Association (STC, Stockholm, Sweden).

Lameness evaluation

Horses observed by the trainer to have gait asymmetries were examined and evaluated for lameness by the stable veterinarian followed by weekly reevaluations. Lameness was evaluated by trotting the horse in hand on a hard surface 25-30 meters straight away from and towards the examiner. Lameness at presentation and lameness after one min of flexion of the carpus was graded subjectively on a scale from 0 to 5, where grade 0 was not lame and grade 5 was not weight bearing. The diagnosis of carpal lameness was based on absence of lameness after anaesthesia of the intercarpal joint. In one case carpal lameness was not confirmed with intra-articular anaesthesia due to limitations imposed by the owners. This horse had a moderate distention of the left intercarpal joint and a mild (grade 1) left front limb lameness at presentation that increased after flexion of the carpus.

Radiographic examination and evaluation

The initial radiographic examination included dorso-palmar (DPa), latero-medial (LM) and dorsolateral-palmaromedial oblique (DL-PaMO) views of both carpi using regular screens and high latitude films with exposure factors of 73 kV and 3.2 mAs at a focus-film distance of 125 cm. The distal row of carpal bones were radiographed in the dorsoproximal-dorsodistal oblique (DPr-DDiO) or "skyline" view using high detail intensifying screens and mammography film. Exposure factors were 81 kV and 10 mAs at a focus-film distance of 75 cm. At the following examinations both carpi were routinely radiographed in the DL-PaMO and DPr-DDiO projections.

All DPr-DDiO radiographs were coded and randomly evaluated for grade of sclerosis by the same radiologist. Sclerosis was defined by changes in radioopacity and trabecular structure and classified into 4 different grades (Table 2).

Scintigraphic examination and evaluation

At each examination, bone phase skeletal scintigraphy was performed 2 h after i.v. administration of 8-10 MBq/kg ^{99}Tc-HDP (Mallinckrodt Medical B.V. Petten, Holland). Static 150k (lateral) and 200k (dorsal) count images were acquired of the carpi, using a gamma camera with a low energy all purpose collimator (Picker SX 300 gamma camera, Picker International Inc., Cleveland, Ohio 44143, USA). Care

Table 2. The 4 grades of sclerosis

Grade:	Description
0 - No sclerosis:	Trabecular bone of uniform opacity, no loss of trabecular structure or definition between radiopaque margin and trabecular bone.
1 - Mild sclerosis:	Distinct focal increase in trabecular opacity with focal thickening of trabeculation but no loss of trabecular structure or definition between radiopaque margin and trabecular bone.
2 - Moderate sclerosis:	Focal loss of trabecular structure, indistinct delineation between radiopaque margin and trabecular bone.
3 - Marked sclerosis:	Loss of trabecular structure and definition between radiopaque margin and trabecular bone.

was taken to place the limbs as close as possible to the collimator surface. Dorsal images included both carpi. Lead aprons were used to shield gamma radiation from areas other than the carpus, or carpi, in view.

Scintigrams were evaluated using a Hermes software package (Nuclear Diagnostics, Stockholm, Sweden). In dorsal images subjective grading and ranking of increased radiopharmaceutical uptake (IRU) in the C3 area was performed in a red-green-blue colour scale after filtering the scintigrams with a Metz filter. Scintigrams were considered normal if the C3 area had the same intensity as the rest of the carpus region. Increased C3 uptakes were subjectively classified as mild, moderate or severe. Objective evaluation of IRU was performed using region-of-interest (ROI) analysis assessing the ratio of C3 to carpus uptake. The carpus region was defined as the area between the radius and the metacarpus and the C3 region was defined as the medial 2 thirds of the distal half of the carpus region. The C3 region was subtracted from the carpus region before average pixel counts ratios were calculated. Regions were anatomically confirmed by comparison on the monitor with digitized dorsoplantar radiographs of the carpus. ROIs were drawn in filtered images and pixel counts calculated in original images. For 2 horses, scintigraphic data was missing from one occasion (Table 1).

Statistical analysis

Radiographic and scintigraphic data were ranked and compared over time in a Friedman 2-way analysis of variance by ranks test, using a formula suitable for the occurrence of tied ranks (*Lehman & D'Abrera* 1975). When overall significance was found the location of significant differences was determined through a multiple comparison procedure suggested by Sprent (1993). In the Friedman analysis, the 2 missing scintigraphic values were substituted by the mean of the previous and subsequent recordings.

Contingency table analysis was used to compare subjectively evaluated scintigraphic data, and a Wilcoxon rank sum test to compare scintigraphic ratios with radiographic data, with level of performance (training, qualified for racing or racing) and carpal lameness (yes/no) data.

Results

With the exception of signs of mild joint distension, radiographs in the DPa, LM and DLPMO projections in the 22 horses were without signs of degenerative joint disease. At examinations 1

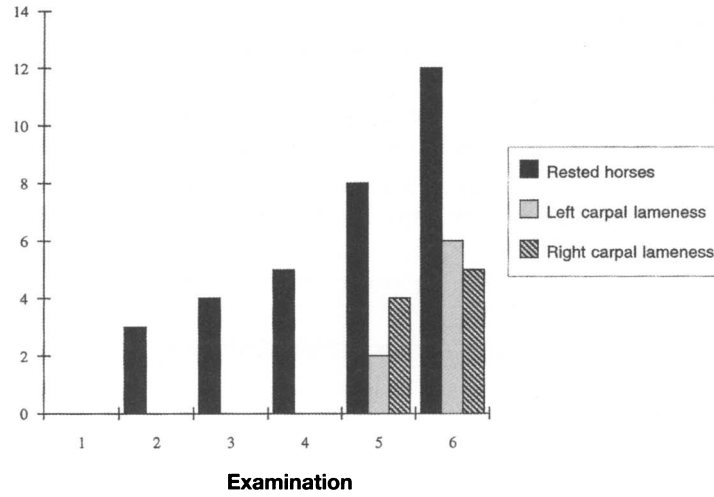

Figure 1. Number of horses rested from training and number of limbs diagnosed with carpal lameness since previous examination in 14 Standardbred trotters, at 6 examinations between the mean ages of 20 and 42 months.

to 5, the 8 horses which did not complete the longitudinal study (Table 1) did not differ significantly from the remaining 14 horses in frequency of C3 sclerosis and IRU. Follow up information was available for 7 of the 8 horses. Of these, 4 horses had qualified for racing at 4 years of age (Table 1).

Longitudinal study of 14 horses

Speed training intensity gradually increased so that 2 horses at examination 3 and 12 horses at examination 4 were doing near maximal speed training twice a week. At the fifth examination 13 of 14 horses were doing near maximal speed training twice a week and 8 horses had qualified for racing (as 2-year-olds). At the sixth examination (as 3-year-olds), 6 of the 8 horses that had qualified for racing had raced.

All horses were in active use at the times of examination 1 to 4. At the 5th examination, 1 horse was lame from both carpi and 2 horses were resting due to other conditions. At the 6th examination, 3 horses were resting because of previous carpal lameness and 2 horses were resting due to other conditions.

The number of horses that were rested from training ≥5 days and horses diagnosed with carpal lameness are presented in Fig. 1. In the course of the study, carpal lameness was diagnosed on 16 occasions, in 14 limbs (7 left carpi, 7 right carpi) in 11 horses (Table 3). Carpal lameness scores ranged from 1 to 2. Intercarpal joint distension was mild to moderate and the response to carpal flexion was positive in all lame horses.

The radiographic examination revealed sclerosis of the dorsomedial C3 in 19 of 28 carpi (Table 3). The distribution of sclerosis over time is shown in Fig. 2. Gradings of C3 sclerosis increased significantly ($p<0.001$) over time for both left and right carpi and there was a continuous increase in rank sums with time after the first 2 examinations. Grades of sclerosis did not differ significantly between left and right carpi on any occasion.

Subjectively graded scintigraphic uptake in the C3 varied significantly ($p<0.05$) over time for left carpi (Fig. 3). Rank sums at the first 2 ex-

Table 3. Distribution of grades of sclerosis (Scl.) and subjectively graded, increased radiopharmaceutical uptake (IRU) in the third carpal bone at 6 examinations between the mean ages of 20 and 42 months in 14 Standardbred trotters (A to N). Indices indicate performance and lameness status.

		Examination number											
		Left limb						Right limb					
Horse		1	2	3	4	5	6	1	2	3	4	5	6
A	Scl.				1	1^{Q}	2^{R}				1	1^{Q}	2^{R}
	IRU			1	1	1	2^{L}		1		1		1
B	Scl.					1^{Q}	1^{R}					Q	R
	IRU		m						m				
C	Scl.					Q	2^{R}					Q	R
	IRU		1		1	3	3^{L}		1		1	1	1
D	Scl.												
	IRU				1	2	1			1			L
E	Scl.			1	1	1^{Q}	1				1	1^{Q}	2
	IRU				1		1^{L}	1	1	1	1	1	1^{L}
F	Scl.	3	3	3	3	3^{Q}	3^{R}	3	3	3	3	3^{Q}	3^{R}
	IRU	1	1	m	1	2	2	1	1	m	1	1	2
G	Scl.					Q						1^{Q}	2
	IRU						1^{L}		1	1	1	2	3^{L}
H	Scl.					Q	R					Q	1^{R}
	IRU			1									
I	Scl.	1	1	1	1	1	2			1	1	1	1
	IRU	1				1	1^{L}				1		1
J	Scl.												
	IRU				1	L	L			1		L	1^{L}
K	Scl.			1	1	1	1		2	2	2	3	3
	IRU			1	1	1		1	1	2	2	1^{L}	L
L	Scl.	1	1	1	1	1^{Q}	1^{R}	1	1	1	1	1^{Q}	1^{R}
	IRU		1	1		1	1	1		1	1	2^{L}	1
M	Scl.			1	1	1	1						
	IRU	1		1	1					1	1	1^{L}	1
N	Scl.			1	1	1	1		1	1	1	1	1
	IRU			1		L		1		1	1	2	

Grades of sclerosis and increased radiopharmaceutical uptake (IRU):
1 = mild, 2 = moderate, 3 = severe, m = data missing.
Indices: Q = qualified for racing, R = racing, L = carpal lameness diagnosed since previous examination.

aminations were significantly lower ($p<0.05$) compared to examinations 4, 5 and 6. In right carpi, rank sums at the first 2 examinations were lower than the rank sums of the last 4, but differences were not significant ($p>0.1$). Objective scintigraphic C3/carpus ratios ranged between 0.92 and 1.72 (mean 1.14). Variance increased with time but for ranked scintigraphic

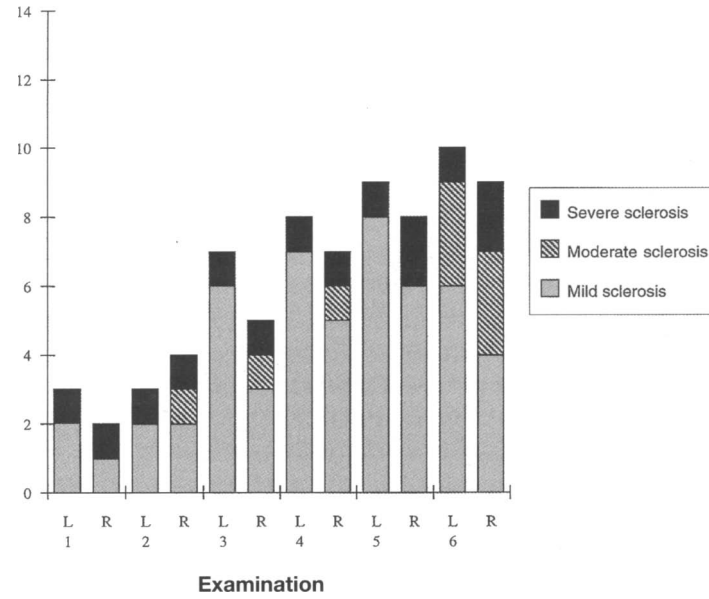

Figure 2. Distribution of grades of third carpal bone sclerosis over time for left (L) and right (R) carpi in 14 Standardbred trotters, at 6 examinations between the mean ages of 20 and 42 months.

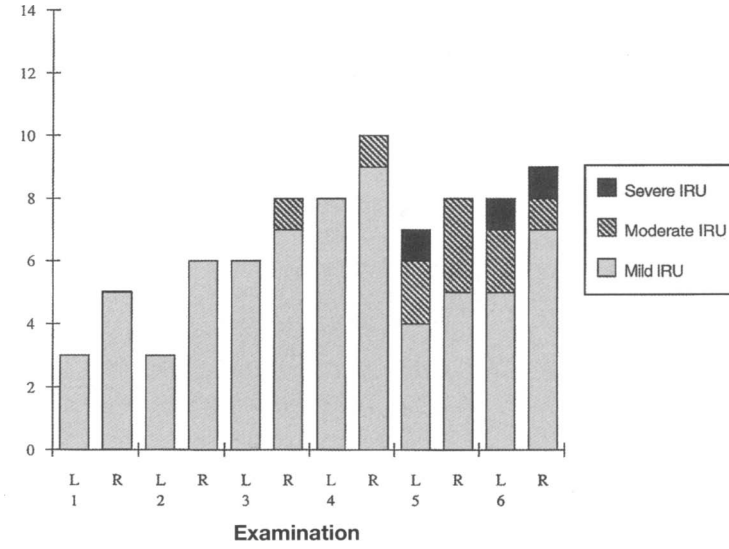

Figure 3. Distribution of increased radiopharmaceutical uptake (IRU) in the third carpal bone area over time for left (L) and right (R) carpi in 14 Standardbred trotters, at 6 examinations between the mean ages of 20 and 42 months. Data is missing for one horse at examination 2 and for another horse at examination 3.

ratios, rank sums did not show any significant variation over time ($p>0.8$). Mean objective scintigraphic ratios and prevalence of subjective IRU was higher in right limbs at every examination, but differences were only significant ($p<0.03$) for objective scintigraphic ratios at examinations 1, 2 and 3.

At the fifth examination both horses with as well as without C3 sclerosis had qualified for racing (Table 3). The number of carpi that had been lame at the fifth examination was small (Fig. 1) and there was no apparent association between lameness and grade of sclerosis. At the sixth examination, increased grade of sclerosis, compared to previous examination, did not show any significant association with having qualified for racing, having raced, or number of starts but increased grade of sclerosis related significantly to carpal lameness between examinations 5 and 6 ($p = 0.045$). Carpal lameness had been diagnosed in 5/7 limbs where C3-sclerosis had increased compared to 6/21 limbs with unchanged grade of sclerosis (Table 3).

Having started or qualified for racing was not found to be significantly associated with presence of subjectively evaluated IRU at examinations 5 and 6, but limbs from horses that had qualified for racing had higher mean scintigraphic ratios at examinations 5 and 6 (1.19 compared to 1.09 and 1.22 compared to 1.08 respectively). The differences were significant at examination 6 ($p = 0.04$) but not at examination 5 ($p = 0.054$). Horses that had started did not have significantly higher scintigraphic ratios at examination 6 ($p = 0.42$). At the sixth examination, there was no significant difference ($p = 0.29$) in frequency of IRU between limbs that had been diagnosed with carpal lameness (8/11) and limbs where lameness had not been diagnosed (9/17). Severe IRU was found on 3 occasions in 2 limbs (Table 3). Mean scintigraphic ratios did not show any significant association with previous carpal lameness ($p = 0.12$). Scintigraphic uptake was similar between horses that were resting from training at the time of the sixth examination ($N = 5$) and others, and the only horse that was lame from its carpi at the time of examination did not have IRU of the C3.

Presence of C3 sclerosis was not significantly related to frequency of IRU except at the first and sixth examinations. At the first examination 4/5 sclerotic carpi had IRU compared to 4/23 non-sclerotic carpi ($p = 0.005$). At the sixth examination, moderately sclerotic C3 had significantly higher frequency of IRU compared to other C3 ($p = 0.03$). Limbs where C3-sclerosis had increased since previous examination had significantly higher mean scintigraphic ratios ($p = 0.03$) at examination 6 (1.3 compared to 1.1).

Discussion

The present study investigated the gradual development of C3 sclerosis in a group of Standardbred trotters under authentic training conditions. This made it possible to relate the development of sclerosis to performance and lameness parameters relevant to the racing Standardbred population. However, frequent changes of ownership and the need for minimal interference with the racing career of the horses resulted in varying intervals between examinations 5 and 6 and a loss of horses from the study (Table 1). Recorded radiographic, scintigraphic and performance data indicated no significant differences between horses lost from the study and the remaining 14 horses and there was no indication that the material was biased through the loss of horses.

The training protocol described in the present study was typical of Swedish Standardbred trotters in professional training and the proportion of horses racing as 3-year-olds (43%) was similar to the 42% recorded for the general population in the same years (STC 1996, STC 1997).

Since 12 of 14 previously untrained Standardbred trotters had developed C3 sclerosis at the end of the study it is reasonable to infer that a majority of racing Swedish Standardbred trotters develop radiographic signs of C3 sclerosis. Eleven of 14 horses were free from radiographic signs of C3 sclerosis at the beginning of speed training, indicating that the early period of breaking and low intensity exercise had a limited impact on the build up of bone. Walking exercise for 18 months has been shown to be an insufficient stimulus for increased C3 bone density in Thoroughbreds (*Firth et al.* 1999). Progression of sclerosis since previous examination was significantly associated with IRU and the strong association between IRU and presence of sclerosis at the first examination confirmed that most of the sclerosis represented active processes and may have developed with the beginning of speed training.

After the beginning of speed training the level of sclerosis increased with age and increasing exercise load (Fig. 2). There was a significant association between having qualified for racing and IRU, but no trends relating level of sclerosis to the investigated performance parameters were found. This could be due to the relative insensitivity of the method, the small number of horses and that the variation in training intensities within the group was too small.

Sclerosis has been suggested to represent a normal adaptive response in young racehorses (*Butler et al.* 1993, *Pool* 1996). It is possible that an equilibrium between mechanical demands and sclerosis is reached in a population of competing horses, but this was not seen in the present investigation as sclerosis and IRU appeared to continue to increase at the end of the study (Fig. 2, Fig. 3) even if differences between examinations 4, 5 and 6 were not significant.

The present results show that radiographic sclerosis, at least sclerosis graded mild or moderate, may develop without concomitant clinical signs of lameness even when increasing from none to moderate in 3 months (horse K, Table 3). The present study also shows that severe C3 sclerosis does not prevent successful training and racing as has been suggested for Thoroughbred racehorses (*Ferraro* 1990).

It was tempting to interpret the development of radiographic sclerosis as a physiological adaptation of the third carpal bone, necessary for the bone to withstand loading at high speeds according to the mechanisms described by Bramlage et al. (1988). This hypothesis was inconsistent with the fact that at the sixth examination, 3/6 racing horses and 4/8 horses qualified for racing had at least 1 front limb free of C3 sclerosis (Table 3). The finding of appositional growth of woven bone in sclerotic areas of C3 from training and racing Thoroughbreds (*Young* 1987) would also, according to the mechanostate theory of bone adaptation (*Frost* 1992), indicate that radiographic signs of C3 sclerosis often represent a reparative response following pathological overload rather than physiological adaptation.

The severe sclerosis and mild scintigraphic uptake seen in 1 horse (horse F, Table 3) at the first examination may represent unusually drastic effects of the early, light exercise, but could also be the result of some unknown event during the pretraining period that was not possible to document from interviews with the owners.

Carpal lameness increased the likelihood of discovering progression of sclerosis at the following radiographic examination but did not appear to influence the level of scintigraphic uptake. Increased radiopharmaceutical uptake for periods of 4 months has been reported from induced osteochondral defects in the radiocarpal bone in ponies (*Todhunter et al.* 1993), but little is known about the duration of exercise-induced and pain-related IRU in the C3 of young equine athletes. A correlation between disap-

pearance of pain and normalised scintigraphic appearance has been shown in humans (Chisin et al. 1987). Since only 1 horse was examined when actually lame it is possible that C3 IRU of short duration was missed in the present study.
A predominance of subjectively and objectively assessed C3 IRU in the right fore limb was seen throughout the study, on most occasions without concurrent differences in grades of sclerosis or incidence of carpal lameness between left and right limbs. This may have been related to predominantly unidirectional training and racing similar to what has been reported for the incidence of C3 fracture in Thoroughbred racehorses (Schneider et al. 1988, *Stephens et al.* 1988, *Martin et al.* 1988).
Objective scintigraphic ratios, representing the whole dorsal C3 did not show any trend of increase or decrease over time while subjective scintigraphic grades increased with time. This indicates that the subjective and objective evaluation of third carpal bone IRU were not completely comparable and that the subjective evaluation of IRU may have been more sensitive to focal increased uptakes, information that was lost from the averaging effect when objective scintigraphic ratios were calculated.

Conclusions

In Standardbred trotters, radiographic signs of sclerosis of the third carpal bone may develop without clinical signs of lameness but carpal lameness increases the likelihood of development and progression of sclerosis. This indicates that third carpal bone sclerosis should not exclusively be regarded as adaptation to exercise. The present study also indicates that in young Standardbred trotters in professional training there is a continuous increase in radiographic sclerosis of the third carpal bone and that a majority of the horses have developed unilateral or bilateral sclerosis by the time they start racing.

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Sammanfattning

Tolkning av radiologisk skleros i tredje karpalbenet. En prospektiv studie av en grupp unga varmblodiga travhästar.

För att klargöra betydelsen av radiologisk skleros i tredje karpalbenet utvärderades bägge karpallederna hos 14 varmblodiga travhästar radiologiskt och scintigrafiskt i relation till hälta och prestation. Hästarna undersöktes 6 gånger mellan 20 och 42 månaders ålder, från hastighetsträningens inledning till början av tävlingsperioden. Mot slutet av studien hade 8 hästar kvalificerat sig för tävling, och hälta lokaliserad till mellersta karpalleden hade diagnosticerats i 14 ben på 11 hästar. Alla hästar utom 2 utvecklade radiologiska tecken till skleros och alla hästar utom en uppvisade ökat scintigrafiskt upptag i området för tredje karpalbenet. Under studien sågs en kontinuerlig ökning av skleros över tid och med ökande prestation. Ett signifikant samband sågs mellan hälta lokaliserad till mellersta karpalleden och tilltagande skleros, men i de flesta fall utvecklades skleros utan medföljande hälta. Inget samband mellan ökat scintigrafiskt upptag och hälta sågs, men hästar som kvalificerat sig för tävling hade signifikant högre scintigrafiskt upptag i området för tredje karpalbenet. Hos varmblodiga travhästar i professionell träning ses tilltagande skleros i tredje karpalbenet över tid, men studien visar att radiologisk skleros är av begränsat värde som indikator för tidigare karpalhälta eller prestation.

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