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General Articles

Patterns of scintigraphic uptake in the fetlock joint of Thoroughbred racehorses and the effect of increased radiopharmaceutical uptake in the distal metacarpal/tarsal condyle on performance

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Keywords: horse; lameness; scintigraphy; fetlock joint; palmar osteochondral disease; condylar fracture; performance

Summary

Reasons for performing study: **The effect of palmar osteochondral disease lesions on performance of Thoroughbred (TB) racehorses is unclear. There is a need to describe patterns of radiopharmaceutical uptake (IRU) in fetlock joints of TB racehorses and to evaluate post scintigraphy performance.**

Hypotheses: **IRU in the metacarpal (MC) and metatarsal (MT) condyles is more common than IRU in the parasagittal grooves and is associated with poorer post diagnosis performance than controls.**

Methods: **Location of IRU within the fetlock region was identified and graded subjectively in TB racehorses. Performance variables were determined from race records for horses with moderate/marked MC/MT condylar IRU (cases), other horses undergoing scintigraphy (scintigraphy controls) and age/sex matched controls from the last race in which a case participated (controls). Statistical analyses included quantile regression, Fisher's exact test, Kaplan-Meier survival curves, log-rank test and Cox regression.**

Results: **Metacarpal/MT condylar IRU was identified in 103/220 horses with only 3/220 having parasagittal IRU. Moderate/marked IRU was identified in the MC and MT condylar regions in 62 and 39 horses, respectively, with palmaromedial and plantarolateral IRU most common. Fore- and hindlimb cases had fewer starts, reduced earnings ($P<0.001$) and reduced earnings/start than controls respectively. Cases were more likely to return to racing later than controls following a rest period. Cases were older than scintigraphy controls.**

Conclusions: **In TB racehorses presenting for lameness MC/MT condylar IRU is the most common abnormality identified within the fetlock joint. Racehorses with moderate/marked condylar IRU have a shortened racing career, are less successful than age/sex matched controls and are older than other racehorses presented for scintigraphy.**

Potential relevance: **Overload of the MC/MT condyles is a common and significant problem in TB racehorses that is readily identified with scintigraphy. Scintigraphy of horses that are lame or performing poorly is less useful for screening for potential condylar fractures.**

Introduction

Repeated high stresses on the distal metacarpus (MC)/metatarsus (MT) at mid stance during locomotion (Merritt *et al*. 2008) are thought to contribute to fatigue injury of subchondral bone (Kawcak *et al*. 2000). Two subchondral bone injuries are common at this site; condylar fractures and palmar osteochondral disease (POD) (Parkin *et al*. 2004; Barr *et al*. 2009). The lateral MC/MT condyle has been identified in Thoroughbred (TB) racehorses as the most common site of fatal fracture in the UK and second most common site in the USA (Johnson *et al*. 1994a,b; Parkin *et al*. 2004, 2006). The overall prevalence of condylar fracture in the UK was 2.8% per year in 1300 TB horses in training (Bathe 1994), whereas the prevalence during racing has been reported as 0.024% (Parkin *et al*. 2006). Palmar osteochondral disease, previously termed traumatic osteochondrosis (Pool and Meagher 1990), has been identified in 67% of TB racehorses at *post mortem* (Barr *et al*. 2009) and the distal palmar/plantar MC/MT condyles are the most common sites of increased radiopharmaceutical uptake (IRU) (Arthur and Constantinide 1995).

Condylar fractures propagate from the distal MC articular surface developing from the lengthening of a dominant crack usually within the parasagittal groove and are associated with pre-existing pathology (Radtke *et al*. 2003; Parkin *et al*. 2006). These findings are consistent with bone fatigue being a primary cause (Stover *et al*. 1994; Parkin *et al*. 2006). Palmar osteochondral disease lesions are also considered to be fatigue injuries, a result of high magnitude cyclical loading at the proximal sesamoid and MC/MT articulation (Norrdin *et al*. 1998).

Diagnosis of POD is difficult using routine imaging methods; only advanced lesions can be identified radiographically (Hornof

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et al. 1981) or, in selected cases, arthroscopically (Byron and Goetz 2007). Nuclear scintigraphy has been used extensively in racehorses for the diagnosis of stress fractures and has been shown to have a high sensitivity for the detection of stress-induced bone injuries (Pleasant *et al*. 1992; Davidson and Ross 2003). Stress reactions in the palmar/plantar MC/MT condyles have been identified as focal areas of IRU in TB racehorses (Martinelli *et al*. 1994; Shepherd and Pilsworth 1997).

Despite the relative frequency of condylar fractures in racing Thoroughbreds, reports of focal linear IRU within the parasagittal grooves are rare. In contrast, IRU of the palmar/plantar condyles has been reported in Thoroughbreds and is commonly observed in Standardbred (SB) racehorses (Martinelli *et al*. 1994; Shepherd and Pilsworth 1997; Ross 1998; Tull and Bramlage 2009). No large study in TB racehorses has examined the distribution of IRU in the fetlock joint and distal MC/MT of horses presented for scintigraphy.

The effect of POD lesions on performance of TB racehorses is unclear despite their high prevalence, but is likely to be detrimental as the palmar/plantar aspect of the distal MC/MT is a significant load bearing site (Merritt *et al*. 2008). Identification of IRU in the plantarolateral MT condyle in SB racehorses resulted in only 50% returning to their previous level of performance (Ross 1998), whereas 62% of TB racehorses with a diagnosis of cumulative stress-induced injury of the distal third metacarpal/metatarsal bones returned to racing at the same or improved class (Tull and Bramlage 2009).

Our aims were to describe patterns of IRU in the fetlock joints of TB racehorses and to evaluate the post diagnosis performance of horses with IRU in the distal third MC/MT condyles. We hypothesised that IRU in the distal medial MC and distal lateral MT condyles is most common, whereas IRU in the parasagittal groove is rare, and that increased condylar uptake in the distal MC/MT results in poorer post diagnosis performance when compared with age and sex matched controls as well as horses with scintigraphic uptake in other locations.

Materials and methods

Thoroughbred racehorses presenting for lameness examination that underwent scintigraphic examination from March 2004–March 2008 (n = 220) were included. A standard scintigraphic protocol was used for each horse. An 18 gauge catheter was placed in the left jugular vein and 12.7–15 MBq/kg bwt of ^{99}Tc-HDP administered. Static delayed phase standing lateral and dorsal (forelimbs) or plantar (hindlimbs) images were obtained 3 h after radiopharmaceutical injection and images acquired with a large field of view gamma camera (Phillips Argus Epic)[1] using a 256 × 256 matrix and transferred to a workstation for processing (Sun Ultra Workstation)[2].

The location of the increased radiopharmaceutical uptake (IRU) was identified and the severity graded subjectively: *grade 0* = normal, *grade 1* = mild, *grade 2* = moderate, *grade 3* = marked. Horses were grouped into 3 categories: 1) cases = horses with at least one distal MC/MT condyle with *grade 2* or *grade 3* IRU (n = 83); 2) scintigraphy controls = all distal MC/MT condyles less than *grade 2* IRU (n = 137) and 3) controls = age/sex/race matched horses selected from the last race in which a case horse competed prior to presentation for scintigraphy (n = 333). The number of controls per case ranged from 0–14 with a mean of 4.

Data collected following scintigraphic examination included: scan date, sex, age, limbs examined, location of fetlock IRU and other sites of moderate/marked IRU in case horses, location of condylar IRU (forelimbs and hindlimbs) unilateral or bilateral condylar IRU (forelimbs and hindlimbs), and results of any diagnostic analgesic techniques. Radiographic examination of the fetlock joint was performed in 59 of 83 cases (71.1%). Views obtained included latero-medial, flexed latero-medial, dorso-palmar, dorso45°proximo45°latero-palmarodistomedial oblique and dorso45°proximo45°medio-palmarodistolateral oblique views (Butler *et al*. 2000; Richard and Alexander 2007). In addition, a flexed dorsopalmar radiographic projection of the distal metacarpus was obtained in horses with parasagittal IRU to identify condylar fractures (Pilsworth *et al*. 1988). Race records were obtained on 10th August 2009 (http://sirius.racingvictoria.net.au) for horses in all 3 groups and performance data collected after scintigraphy included: return to racing; time to return to racing; number of starts; prize money; prize money/start; number of places; whether the horse was still racing, retired or dead and the date of retirement or death. A performance index (PI) was calculated (Woodie *et al*. 2005). The PI was calculated by assigning a point value for the place of finish: first = 3 points, second = 2 points and third = 1 point. The PI was the mean of the points earned after diagnosis. A minimum follow-up period of 16 months was obtained for all horses in this study. A minimum of 3 months paddock rest from racing exercise was recommended for all case horses following diagnosis. A period of ≥90 days between races was defined as a spell or rest period. The race records of control horses were examined and a spell period identified. The length of time taken to return to racing following scintigraphy for cases and scintigraphy controls and following the identified spell period for controls was compared.

Statistical analysis

Quantile regression (Koenker 2005) was used to compare medians of race performance variables between cases and controls and between cases and scintigraphy controls, except for performance variables expressed as proportions where a conditional logistic regression or Fisher's exact test was used. Fixed effects of case/control status and matched set were included in the quantile regression when comparing cases and controls. Age and sex were not considered when comparing cases and controls as these factors had already been matched (Vandenbroucke *et al*. 2007). Kaplan-Meier survival curves, the log-rank test and Cox proportional hazards regression were used to compare time to return to racing following scintigraphy of cases and scintigraphy controls. The Cox model included case/scintigraphy control status, age group at scan (age ≥4 years vs. <4 years) and gender (male vs. female). Kaplan-Meier survival curves and the log-rank test were used to compare the time taken to return to racing following a rest period between cases and controls. A censored observation occurred when the horse had not raced by the end of the study period or had not raced when the horse retired, died or was transferred. A 2-sided P value ≤0.05 was regarded as significant. Stata version 11.1 for Windows[3] performed the statistical analyses.

Results

Fetlock radiopharmaceutical uptake

Increased radiopharmaceutical uptake in the fetlock region of mild, moderate or marked severity was identified in 113/220 horses. The

most common sites of fetlock IRU were found to be the palmar/plantar MC/MT condyles; 103 horses had mild, moderate or marked condylar IRU, and 83 had moderate/marked MC/MT condylar IRU (cases). In only 3 horses was distinct parasagittal IRU observed (Fig 1) and in each case a fracture was not identified radiographically. Other sites of IRU included the proximal phalanx (13 horses) and the sesamoid bones (9 horses). Nine horses were identified as having moderate/marked IRU in multiple sites within the fetlock region, i.e. concurrent IRU in the condyle, sesamoids and/or proximal phalanx (Table 1). Of the 83 cases, 50 (60.2%) had moderate/marked IRU identified in locations distant from the fetlock. The most common of these included the carpus (n = 19), pedal and navicular bone (n = 10), sacroiliac region (n = 6) and distal tarsal joints (n = 5). In 44 of 83 cases (53.0%) local anaesthetic techniques were performed. In 39 of 44 cases (88.6%) lameness was localised to the condylar region following anaesthesia of the palmar/plantar metacarpal/tarsal nerves (at the level of the 'button' of the second and fourth metacarpal/tarsal bones). Twenty-three of these horses (59.0%) had other sites of moderate/marked IRU identified. Five of 44 cases (11.4%) had perineural anaesthesia performed and lameness was not localised to the fetlock region. Of the 39 cases that did not have nerve blocks performed, 18 horses (46.2%) had no other sites of moderate/marked IRU identified. No osseous abnormalities were identified in 46 of 59 cases (78.0%) that had radiographs performed, with only 6 cases (10.1%) having radiographic evidence of palmar/plantar condylar lysis and the remaining 7 cases (11.9%) showing evidence of periarticular modelling of the fetlock joint.

Condylar uptake

Seventy-nine horses had mild, moderate or marked forelimb condylar IRU with 62 of these horses having moderate or marked IRU (Fig 2). Medial (28/62) or biaxial (26/62) palmar condylar IRU were seen with almost equal frequency. Lateral condylar uptake was observed in 8 horses, 6 of which had marked lateral condylar IRU and 2 moderate IRU. Of the 6 horses with marked IRU, 3 had parasagittal IRU, and one of these 3 had lateral parasagittal IRU only, while the other 2 had a combination of parasagittal and palmar condylar IRU. Of cases, 37/62 horses had bilateral condylar IRU (Table 2).

Forty-eight horses had mild, moderate or marked hindlimb condylar IRU of which 39 horses had moderate or marked IRU in the plantar condyles. Plantarolateral condylar IRU was observed in 36/39 horses with biaxial IRU in the remaining horses. Of the cases with MT condylar IRU, 20/39 had bilateral condylar IRU (Table 2).

Moderate/marked IRU in at least one forelimb and one hindlimb was identified in 18/83 horses. Of these 18 horses, 14 were found to have IRU in >2 limbs.

Performance data

Unadjusted descriptive statistics of mean, median and range are reported in Table 3. The following results report the decrease of

TABLE 1: Location of increased radiopharmaceutical uptake within the fetlock region of Thoroughbred racehorses undergoing scintigraphic examination

	Parasagittal IRU (n)	MC/MT condyle (n)	Sesamoid (n)	Proximal phalanx (n)
Grade 1	0	20	4	2
Grade 2	0	63	4	10
Grade 3	3	20	1	1

Note: In some horses multiple areas of IRU were identified within the fetlock region IRU = Increased radiopharmaceutical uptake; MC = metacarpus; MT = metatarsus; n = number of horses.

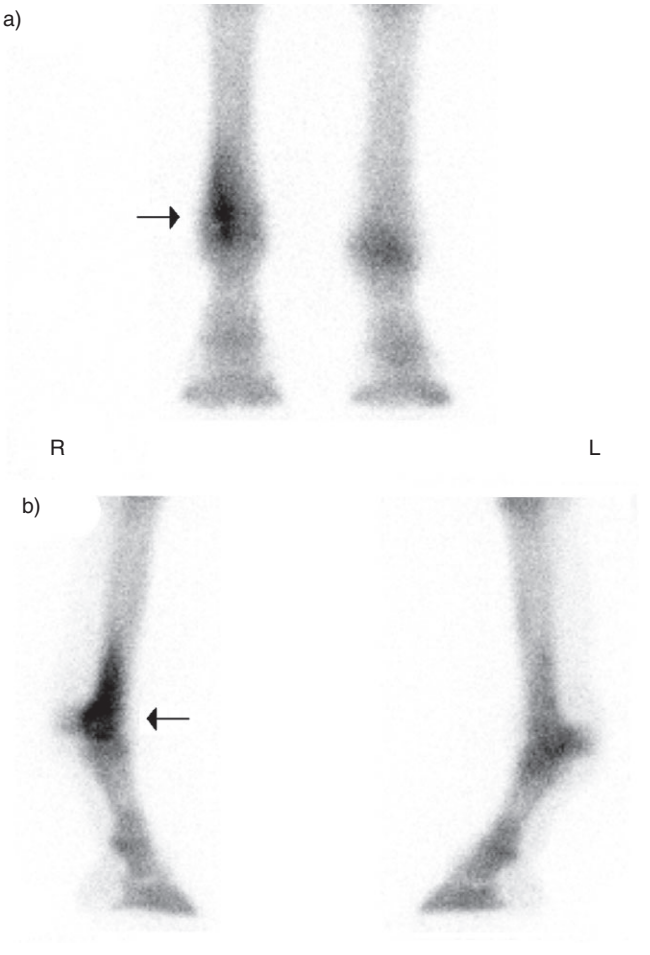

Fig 1: Dorsal (a) and lateral (b) scintigraphic image of the distal limbs showing focal linear intense parasagittal IRU (→) associated with the right fore distal metacarpus.

TABLE 2: Location of moderate/marked radiopharmaceutical uptake (IRU) within the MC/MT condyles of case horses

Condylar IRU	Lateral n (%)	Medial n (%)	Biaxial n (%)	Unilateral n (%)	Bilateral n (%)
Forelimbs	8/62 (12.9%)	28/62 (45.2%)	26/62 (41.9%)	25/62 (40.3%)	37/62 (59.7%)
Hindlimbs	36/39 (92.3%)	0/39 (0%)	3/39 (7.7%)	19/39 (48.7%)	20/39 (51.3%)

n = number of horses. Note: 18 horses were found to have condylar IRU in both forelimbs and hindlimbs.

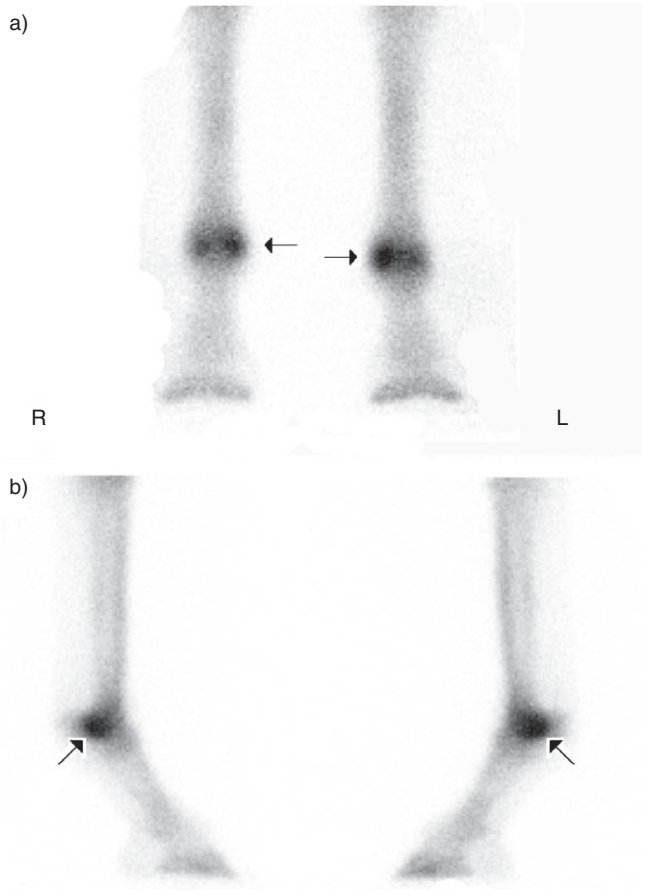

Fig 2: Dorsal (a) and lateral (b) scintigraphic image of the distal forelimbs showing focal intense palmar metacarpal condylar IRU (→) in both forelimbs.

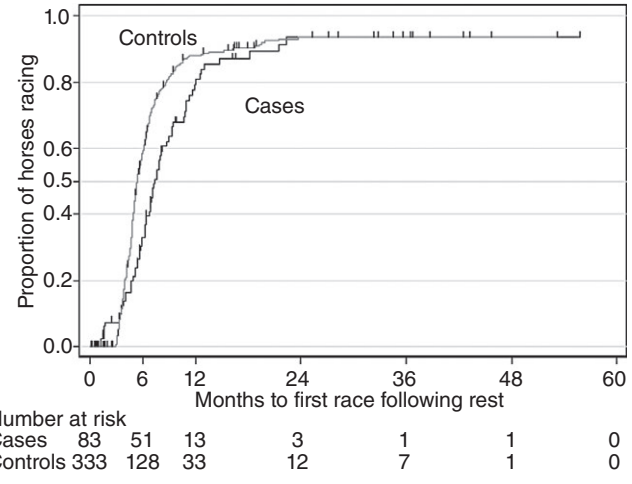

Fig 3: Kaplan-Meier plot of the proportion of horses starting a race according to time from scintigraphy for cases and time from the beginning of a 90 day rest period for control horses. The small vertical lines are the times when a censored observation occurred. A significant difference between the survival curves was observed (Log-rank test P = 0.003). Cases = horses with at least one distal MC/MT condyle with Grade 2 *or* 3 *IRU (n = 83); Controls = age/sex/race matched horses selected from the last race in which a case horse competed prior to presentation for scintigraphy (n = 333).*

cases compared with controls for adjusted differences in medians. Cases had fewer median starts (4; 95%CI 2–6; P<0.001), won less median prize money (AU$9358; 95%CI AU$8765–9951; P<0.001) and less median prize money/start (AU$302; 95%CI AU$260–345; P<0.001) following diagnosis than controls (Table 3).

Cases with forelimb condylar IRU had fewer median starts (4; 95%CI 1–7; P = 0.003), won less median prize money (AU$10,200; 95%CI AU$8789–11,611; P<0.001) and less median prize money/start (AU$450; 95%CI AU$328–572; P<0.001) after scintigraphic diagnosis when compared with controls (Table 3).

Cases with hindlimb condylar IRU had fewer median starts (7; 95%CI 1–13; P = 0.017), won less median prize money (AU$7675; 95%CI AU$7093–8257; P<0.001) and earned less median prize money/start (AU$450; 95%CI AU$231–669; P<0.001) than controls following diagnosis. No other significant differences were observed between these groups.

No statistical differences were observed between performance of cases and scintigraphy controls (Table 3).

The median rest period after diagnosis in cases was longer than the rest period identified for controls (log-rank test P = 0.003, hazard ratio 0.66, 95%CI 0.51–0.87) (7.3 months, 95% CI 6.4–8.7, and 5.3 months, 95% CI 5.1–5.7, respectively) (Fig 3). There were 6 case horses that returned to racing within 3 months of diagnosis and these were the reason for the crossover of survival curves at about 3 months. However, a test of the proportional hazards assumption on the natural log time scale indicated that this assumption was satisfied (P = 0.22). A Cox regression, stratified on matching sets, gave a hazard ratio of 0.69 (95%CI 0.49–0.98, P = 0.037). There was no difference in the proportion of horses returning from a rest period between cases (66/83; 79%) and controls (283/333; 85%) (P = 0.24). Conditional logistic regression removed 39 sets (172 observations) where all horses raced or did not race within a matched set and reported an odds ratio of 0.79 (95%CI 0.40–1.53, P = 0.48).

No difference in time to return to racing between cases and scintigraphy controls was identified (log-rank test P = 0.17, hazard ratio 1.24; 95%CI 0.91–1.68) with a median time to first race following scintigraphy of 7.3 months (95%CI 6.4–8.7) and 8.2 months (95%CI 6.7–9.6), respectively (Fig 4). Adjustment for age group and gender with a Cox proportional hazards model also indicated that the cases vs. scintigraphy controls were similar in their time to first race following scintigraphy (hazard ratio 1.20, 95%CI 0.88–1.65, P = 0.24). The proportional hazards assumption was satisfied (P = 0.49). No difference in the proportion of horses returning to racing following scintigraphy was observed between cases (66/83; 79%) and scintigraphy controls (107/137; 78%) (P = 0.87).

For horses with IRU of the metacarpal/tarsal condyles, no significant differences were observed in race performance variables and survival curves between those where lameness was localised to the fetlock by diagnostic analgesia (n = 39) and those where diagnostic analgesia was not performed (n = 39, P>0.22).

Descriptive statistics

Cases (mean ± s.d. 3.8 ± 1.1 years) and controls (3.7 ± 1.0 years) were significantly older than scintigraphy controls (3.3 ± 1.1 years; P<0.001) (Table 4). The median time from scan to the end of the study was similar for all 3 groups being 1391, 1358 and 1391 days for cases, scintigraphy controls and controls, respectively.

TABLE 3: Performance data analysis

Performance variables post diagnosis	Cases Mean [median (range)]	Scintigraphy controls Mean [median (range)]	Controls Mean [median (range)]	P value (Cases vs. scintigraphy controls)	P value (Cases vs. controls)
All cases	n = 83	n = 137	n = 333		
Number of starts	11.3 (7 [0–43])	10.8 (7 [0–52])	17.8 (14 [0–67])	>0.99	<0.001*
Earnings (AU$)	116,601 (6880 [0–3,320,750])	41,583 (4400 [0–1,143,000])	85,659 (26,090 [0–2,440,000])	0.60	<0.001*
Earnings (AU$)/start (n = 66; 107; 325)	8088 (1144 [0–195,338])	3347 (1138 [0–103,909])	5514 (1400 [0–221,818])	0.87	<0.001*
Number of firsts	1.5 (0 [0–11])	1.2 (0 [0–7])	1.9 (1 [0–11])	>0.99	nc
Number of places	4.2 (2 [0–22])	3.5 (1 [0–20])	5.6 (4 [0–26])	0.35	0.35
PI average (n = 66; 107; 325)	0.59 (0.64 [0–1.67])	0.56 (0.60 [0–2.25])	0.58 (0.57 [0–3])	0.72	0.12
FL IRU	n = 62	n = 137	n = 239		
Number of starts	10.5 (7 [0–43])	10.8 (7 [0–52])	16.9 (12 [0–67])	>0.99	0.003*
Earnings	98,253 (4649 [0–3,320,750])	41,583 (4400 [0–1,143,000])	93,024 (26,090 [0–2,440,000])	0.93	<0.001*
Earnings/start (n = 46; 107; 232)	9024 (949 [0–195,338])	3347 (1138 [0–103,909])	6550 (1450 [0–221,818])	0.77	<0.001*
Number of firsts	1.3 (0 [0–6])	1.2 (0 [0–7])	1.7 (1 [0–10])	>0.99	nc
Number of places	3.5 (1 [0–18])	3.5 (1 [0–20])	5.4 (3 [0–23])	>0.99	0.47
PI average (n = 46; 107; 232)	0.53 (0.60 [0–1.47])	0.56 (0.60 [0–2.25])	0.59 (0.56 [0–3])	>0.99	0.23
HL IRU	n = 39	n = 137	n = 178		
Number of starts	12.9 (5 [0–43])	10.8 (7 [0–52])	18.8 (16 [0–67])	0.43	0.017*
Earnings	105,969 (8100 [0–2,256,495])	41,583 (4400 [0–1,143,000])	80,050 (26,825 [0–2,440,000])	0.56	<0.001*
Earnings/start (n = 33; 107; 174)	4433 (1309 [0–68,379])	3347 (1138 [0–103,909])	4548 (1423 [0–221,818])	0.77	<0.001*
Number of firsts	1.9 (0 [0–11])	1.2 (0 [0–7])	2.1 (2 [0–11])	>0.99	nc
Number of places	5.3 (2 [0–22])	3.5 (1 [0–20])	6.1 (5 [0–26])	0.42	0.73
PI average (n = 33; 107; 174)	0.63 (0.72 [0–1.67])	0.56 (0.60 [0–2.25])	0.60 (0.62 [0–2])	0.31	>0.99

*denotes significance with P<0.05; IRU = Increased radiopharmaceutical uptake; Cases = horses with at least one distal MC/MT condyle with *grade 2* or *3* IRU (n = 83); Scintigraphy controls = all distal MC/MT condyles less than *grade 2* IRU (n = 137); Controls = age/sex/race matched horses selected from the last race in which a case horse competed prior to presentation for scintigraphy (n = 333); FL = forelimb; HL = hindlimb ; nc = no convergence.

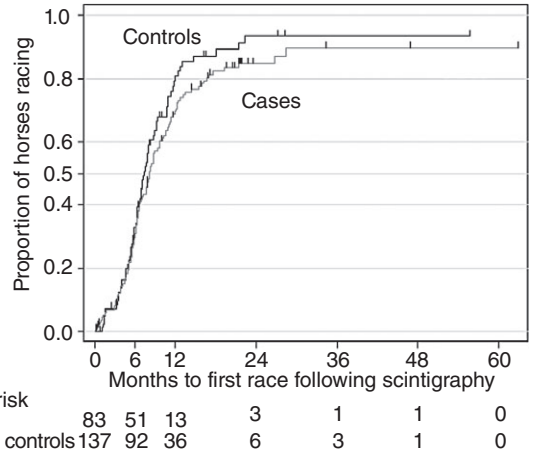

Fig 4: Kaplan-Meier plot of the proportion of horses starting in a race according to time from scintigraphy for cases and scintigraphy controls. The small vertical lines are the times when a censored observation occurred. There was no difference between the survival curves (Log-rank test P = 0.17). Cases = horses with at least one distal MC/MT condyle with Grade 2 *or* 3 *IRU (n = 83); 2. Scintigraphy controls = all distal MC/MT condyles less than* Grade 2 *IRU (n = 137).*

Discussion

We demonstrated that palmar/plantar MC/MT condylar IRU is the most common finding in the fetlock region of TB racehorses presenting for scintigraphy, whereas parasagittal IRU is rare. The most common distribution of forelimb condylar IRU was either medially or biaxially, and laterally in the hindlimb. Horses with moderate to marked increased palmar MC condylar uptake had fewer starts, earned less prize money and less prize money/start, whilst horses with moderate to marked increased plantar MT condylar uptake also had fewer starts, earned less prize money and prize money/start than controls. Horses with increased MC/MT uptake were also older than horses with IRU at other sites.

The observed distribution and prevalence of IRU in the fetlock region is consistent with that of POD lesions identified at *post mortem* (Pool 1996; Barr *et al*. 2009). Increased parasagittal radiopharmaceutical uptake, consistent with lateral condylar fracture, was a rare finding in this and previous reports (Martinelli *et al*. 1994; Ross 1998). Nuclear scintigraphy is very sensitive for detecting osteoblastic activity (Francis *et al*. 1980; Kanishi 1993) and has been used extensively in the diagnosis of stress fractures and subchondral bone injury in horses (Mackey *et al*. 1987; Pilsworth *et al*. 1994; Ruggles *et al*. 1996; Davidson and Ross 2003; O'Sullivan and Lumsden 2003; Davidson and Martin 2004). Current evidence indicates that lateral condylar fractures are fatigue fractures that propagate from the distal metacarpal articular surface following microcrack coalescence, and that pre-existing pathology is often present (Radtke *et al*. 2003; Stepnik *et al*. 2004; Parkin *et al*. 2006). Therefore, parasagittal groove IRU should be observed prior to fracture. However, extrapolation of published prevalence data for condylar fracture and POD (Bathe 1994; Barr *et al*. 2009) to the population of Thoroughbred racehorses serviced by our hospital (Australian Racing Fact Book 2008–09) suggests that we detected

TABLE 4: Descriptive statistics for each group

			Sex			Limbs scanned		
	n	Age (mean ± s.d.)	Male	Female	Gelding	Forelimb	Hindlimb	Both
Cases	83	3.8 ± 1.1	7 (8.4%)	34 (41.0%)	42 (50.6%)	24 (28.9%)	15 (18.1%)	44 (53.0%)
Scintigraphy controls	137	3.3 ± 1.1	10 (7.3%)	62 (42.3%)	65 (47.4%)	38 (27.7%)	53 (38.7%)	46 (33.6%)
Controls	333	3.7 ± 1.0	2 (0.6%)	130 (39.0%)	201 (60.4%)	NA	NA	NA

NA = not applicable.

approximately 11% of POD cases compared with only 1% of condylar fractures. It is possible that current scintigraphic techniques are not able to differentiate condylar and parasagittal uptake well or the subchondral bone response to both POD and fracture are similar. Additional scintigraphic views, for example flexed dorsal views, may be able to better differentiate parasagittal IRU from condylar IRU. Also, bone fatigue associated with condylar fracture may develop rapidly resulting in fracture prior to an osteoblastic response or the development of lameness. If lameness is not observed then horses are unlikely to be presented for scintigraphic examination.

The distribution of forelimb condylar uptake was most commonly medial or biaxial. Others have reported the medial condyle as most common (Davidson and Ross 2003). Hindlimb condylar uptake was predominantly in the lateral condyle, which is consistent with the findings of others (Ross 1995, 1998; Shepherd and Pilsworth 1997). Interestingly, the distribution of gross condylar lesions at *post mortem* was somewhat different (Barr *et al*. 2009); in the forelimbs there was no significant difference between medial and lateral condyles although a trend towards increased frequency of medial condylar lesions was identified and in the hindlimbs gross lesions were equally distributed between medial and lateral condyles (Barr *et al*. 2009). Greater hindlimb lateral condylar IRU could be explained by the typical toe-out stance of horses resulting in the lateral aspect of the joint being closer to the camera, or different training and racing environments influencing lesion distribution. Also, IRU is a measure of blood flow and osteoblastic activity and, therefore, not a direct indicator of pathology.

Horses with moderate/marked condylar IRU were less successful and had shorter racing careers following diagnosis than controls and the effect is similar for fore- and hindlimbs. This suggests that moderate/marked condylar IRU has a long-term effect on performance and the ability of subchondral bone to repair is limited. In a previous study of 15 TB racehorses, 40% returned to an equal or greater level of performance following diagnosis of MC/MT condylar IRU (Martinelli *et al*. 1994), but because performance of racehorses declines with age (Martinelli *et al*. 1996a) comparison with an age matched control population is appropriate. The mechanism for the observed effect on performance is unclear. The site of POD subchondral bone injury is subject to high loads during locomotion (Merritt *et al*. 2008) and therefore injury is likely to result in pain when performing. Also, the severity of POD lesions is correlated with severity of fetlock osteoarthritic changes i.e. wear lines, articular cartilage erosion and dorsal synovial pad proliferation (Pool 1996; Martinelli *et al*. 1996b; Barr *et al*. 2009). However, it is possible that bone activity at this site is a more general marker of bone stress throughout the skeleton. Approximately 50% of Standardbred racehorses returned to racing at the same or greater racing class following diagnosis of IRU in the plantarolateral MT condyle (Ross 1998) and 62% of TB racehorses returned to racing at the same or greater racing class following a diagnosis of cumulative stress-induced injury of the distal MC/MT condyle (Tull and Bramlage 2009). A direct comparison with our results is difficult as horses were not permitted to drop in racing class in Australia during the study period. Control horses returned to racing following a rest period sooner than cases but this is probably due to a treatment recommendation of a minimum 3 months rest following diagnosis.

Fatigue of subchondral bone has been proposed as the cause of POD lesions (Norrdin *et al*. 1998; Norrdin and Stover 2006). Our finding of IRU in the palmar/plantar MC/MT condyles in older horses compared with horses with IRU in other locations is consistent with this as older horses will have accumulated more distance at high speed. Therefore, management of training regimens and simpler methods of monitoring subchondral bone may be important in the prevention of these injuries.

There are a number of limitations in this study. Firstly, racehorses presented for scintigraphic investigation results in a bias towards lameness that is difficult to localise and/or that develops soon after high speed exercise and is therefore not a random selection of lame horses. Secondly, the scintigraphic images were graded subjectively. Objective grading of nuclear scintigraphic images by the use of region of interest (ROI) analysis may have provided a more robust grading system (Valdes-Martinez *et al*. 2008), although identifying a 'normal' ROI in the distal MC of racehorses can be challenging. Thirdly, lameness was not localised to the fetlock region in all horses with IRU using local analgesic techniques; however, it was not the purpose of the study to differentiate IRU causing lameness and IRU not associated with lameness. Palmar metacarpal/metatarsal IRU may be observed in association with other causes of lameness in the same or contralateral limbs and it is not always possible to perform diagnostic analgesia.

In conclusion, palmar/plantar MC/MT condylar IRU is the most common abnormality observed in fetlock joints of TB racehorses presented for scintigraphic examination, whereas lateral parasagittal IRU is observed infrequently. Scintigraphy of horses that are lame or performing poorly does not appear to be an effective screening technique for condylar fractures. Although it may not have been the cause of lameness in all cases, IRU of the palmar/plantar metacarpal/tarsal condyles is associated with reduced future performance in TB racehorses.

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Manufacturers' addresses

[1]Phillips Argus Epic, ADAC systems Pty Ltd, Melbourne, Victoria, Australia.
[2]Sun Ultra Workstation, Augus ADAC Systems Pty Ltd, Melbourne, Victoria, Australia.
[3]Stata version 11.1 for Windows, StataCorp, College Station, Texas, USA.

References

Arthur, R.M. and Constantinide, D. (1995) Results of 428 nuclear scintigraphic examinations of the musculoskeletal system at a thoroughbred racetrack. *Proc. Am. Ass. equine Practnrs.* **41**, 84-87.

Barr, E.D., Pinchbeck, G.L., Clegg, P.D., Boyde, A. and Riggs, C.M. (2009) *Post mortem* evaluation of palmar osteochondral disease (traumatic osteochondrosis) of the metacarpo/metatarsophalangeal joint in Thoroughbred racehorses. *Equine vet. J.* **41**, 366-371.

Bathe, A.P. (1994) 245 Fractures in Thoroughbred racehorses: Results of a 2-year prospective study in Newmarket. *Proc. Am. Ass. equine Practnrs.* **40**, 175-176.

Butler, J.A., Colles, C.M., Dyson, S.J., Kold, S.E. and Poulos, P.W. (2000) The foot, pastern and fetlock. In: *Clinical Radiology of the Horse*, 2nd edn., Blackwell Scientific Publications, Oxford. pp 27-32.

Byron, C.R. and Goetz, T.E. (2007) Arthroscopic debridement of a palmar third metacarpal condyle subchondral bone injury in a Standardbred. *Equine vet. Educ.* **19**, 344-347.

Davidson, E.J. and Martin, B.B. (2004) Stress fracture of the scapula in two horses. *Vet. Radiol. Ultrasound* **45**, 407-410.

Davidson, E.J. and Ross, M.W. (2003) Clinical recognition of stress-related bone injury in racehorses. *Clin. Tech. Equine Pract.* **2**, 296-311.

Francis, M.D., Ferguson, D.L., Tofe, A.J., Bevan, J.A. and Michaels, S.E. (1980) Comparative evaluation of three diphosphonates - *in vitro* adsorption (C-14 labelled) and *in vivo* osteogenic uptake (Tc-99m complexed). *J. Nucl. Med.* **21**, 1185-1189.

Hornof, W., O'Brien, T. and Pool, R. (1981) Osteochondritis dissecans of the distal metacarpus in the adult racing thoroughbred horse. *Vet. Radiol. Ultrasound* **22**, 98-106.

Johnson, B., Ardans, A., Stover, S.M., Daft, B.M., Kinde, H., Read, D.H., Barr, B.C., Moore, J., Woods, L., Anderson, M., Stoltz, J. and Blanchard, P. (1994a) California racehorse postmortem program: a 4-year overview. *Proc. Am. Ass. equine Practnrs.* **40**, 167-169.

Johnson, B.J., Stover, S.M., Daft, B.M., Kinde, H., Read, D.H., Barr, B.C., Anderson, M., Moore, J., Woods, L., Stoltz, J. and Blanchard, P. (1994b) Causes of death in racehorses over a 2 year period. *Equine vet. J.* **26**, 327-330.

Kanishi, D. (1993) Tc-99m-MDP accumulation mechanisms in bone. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* **75**, 239-246.

Kawcak, C.E., Park, R.D., Steyn, P.S., McIlwraith, C.W. and Norrdin, R.W. (2000) Clinical effects of exercise on subchondral bone of carpal and metacarpophalangeal joints in horses. *Am. J. vet. Res.* **61**, 1252-1258.

Koenker, R. (2005) *Quantile Regression*, Cambridge University Press, New York.

Mackey, V.S., Trout, D.R., Meagher, D.M. and Hornof, W.J. (1987) Stress-fractures of the humerus, radius and tibia in hores – Clinical features and radiographic and or scintigraphic appearance. *Vet. Radiol.* **28**, 26-31.

Martinelli, M.J., Freeman, D.E. and Reid, S.J. (1996a) Analysis of performance parameters in the population of Standardbred racehorses in the US (1984-1993). *Proc. Am. Ass. equine Practnrs.* **42**, 174-175.

Martinelli, M.J., Baker, G.J., Clarkson, R.B., Eurell, J.C., Pijanowski, G.J., Kuriashkin, I.V. and Carragher, B.O. (1996b) Correlation between anatomic features and low-field magnetic resonance imaging of the equine metacarpophalangeal joint. *Am. J. vet. Res.* **57**, 1421-1426.

Martinelli, M.J., Chambers, M.D., Baker, G.J. and Semevolos, S.A. (1994) A retrospective study of increased bone scintigraphic uptake in the palmar-plantar fetlock and its relationship to performance: 50 horses (1989-1993). *Proc. Am. Ass. equine Practnrs.* **40**, 53-54.

Merritt, J.S., Davies, H.M., Burvill, C. and Pandy, M.G. (2008) Influence of muscle-tendon wrapping on calculations of joint reaction forces in the equine distal forelimb. *J. Biomed. Biotechnol.* **2008**, 165730.

Norrdin, R.W. and Stover, S.M. (2006) Subchondral bone failure in overload arthrosis: A scanning electron microscopic study in horses. *J. Musculoskelet. Neuronal. Interact.* **6**, 251-257.

Norrdin, R.W., Kawcak, C.E., Capwell, B.A. and McIlwraith, C.W. (1998) Subchondral bone failure in an equine model of overload arthrosis. *Bone* **22**, 133-139.

O'Sullivan, C.B. and Lumsden, J.M. (2003) Stress fractures of the tibia and humerus in Thoroughbred racehorses: 99 cases (1992-2000). *J. Am. vet. med. Ass.* **222**, 491-498.

Parkin, T.D., Clegg, P.D., French, N.P., Proudman, C.J., Riggs, C.M., Singer, E.R., Webbon, P.M. and Morgan, K.L. (2004) Risk of fatal distal limb fractures among Thoroughbreds involved in the five types of racing in the United Kingdom. *Vet. Rec.* **154**, 493-497.

Parkin, T.D., Clegg, P.D., French, N.P., Proudman, C.J., Riggs, C.M., Singer, E.R., Webbon, P.M. and Morgan, K.L. (2006) Catastrophic fracture of the lateral condyle of the third metacarpus/metatarsus in UK racehorses - fracture descriptions and pre-existing pathology. *Vet. J.* **171**, 157-165.

Pilsworth, R.C., Hopes, R. and Greet, T.R. (1988) A flexed dorso-palmar projection of the equine fetlock in demonstrating lesions of the distal third metacarpus. *Vet. Rec.* **122**, 332-333.

Pilsworth, R.C., Shepherd, M.C., Herinckx, B.M.B. and Holmes, M.A. (1994) Fracture of the wing of the ilium, adjacent to the sacroiliac joint, in Thoroughbred racehorses. *Equine vet. J.* **26**, 94-99.

Pleasant, R.S., Baker, G.J., Muhlbauer, M.C., Foreman, J.H. and Boero, M.J. (1992) Stress reactions and stress fractures of the proximal palmar aspect of the 3rd metacarpal bone in horses – 58 cases (1980-1990). *J. Am. vet. med. Ass.* **201**, 1918-1923.

Pool, R.R. (1996) Pathologic manifestations of joint disease in the athletic horse. In: *Joint Disease in the Horse*, 1st edn., Eds: C.W. McIlwraith and G.W. Trotter, W.B. Saunders Co, Philadelphia. pp 87-104.

Pool, R.R. and Meagher, D.M. (1990) Pathologic findings and pathogenesis of racetrack injuries. *Vet. Clin. N. Am.: Equine Pract.* **6**, 1-30.

Radtke, C.L., Danova, N.A., Scollay, M.C., Santschi, E.M., Markel, M.D., Da Costa Gomez, T. and Muir, P. (2003) Macroscopic changes in the distal ends of the third metacarpal and metatarsal bones of Thoroughbred racehorses with condylar fractures. *Am. J. vet. Res.* **64**, 1110-1116.

Richard, E. and Alexander, K. (2007) Nonconventional radiographic projections in the equine orthopaedic examination. *Equine vet. Educ.* **19**, 551-559.

Ross, M.W. (1995) Classification of scintigraphic findings in the metatarsophalangeal joint in Standardbreds – Correlation with clinical and radiographic characteristics: 114 horses (1993-1995). *Proc. Am. Ass. equine Practnrs.* **41**, 88-90.

Ross, M.W. (1998) Scintigraphic and clinical findings in the Standardbred metatarsophalangeal joint: 114 cases (1993-1995). *Equine vet. J.* **30**, 131-138.

Ruggles, A.J., Moore, R.M., Bertone, A.L., Schneider, R.K. and Bailey, M.Q. (1996) Tibial stress fractures in racing Standardbreds: 13 cases (1989-1993). *J. Am. vet. med. Ass.* **209**, 634-637.

Shepherd, M.C. and Pilsworth, R.C. (1997) Stress reactions to the plantarolateral condyles of MtIII in UK Thoroughbreds: 26 cases. *Proc. Am. Ass. equine Practnrs.* **43**, 128-131.

Stepnik, M.W., Radtke, C.L., Scollay, M.C., Oshel, P.E., Albrecht, R.M., Santschi, E.M., Markel, M.D. and Muir, P. (2004) Scanning electron microscopic examination of third metacarpal/third metatarsal bone failure surfaces in thoroughbred racehorses with condylar fracture. *Vet. Surg.* **33**, 2-10.

Stover, S.M., Read, D., Johnson, B., Harrington, T., Ardans, A., Anderson, A., Barr, M.L., Daft, B.C., Kinde, H., Moore, J., Stolz, J. and Woods, L. (1994) Lateral condylar fracture histomorphology in racehorses. *Proc. Am. Ass. equine Practnrs.* **40**, 173.

Tull, T.M. and Bramlage, L.R. (2009) Cumulative stress-induced injury of the distal third metacarpal/metatarsal bone in Thoroughbred racehorses: 55 cases (2000-2009). *Proc. Am. Ass. equine Practnrs.* **55**, 198.

Valdes-Martinez, A., Seiler, G., Mai, W., Bolt, D.M., Mudge, M., Dukti, S.A. and Hubert, J.D. (2008) Quantitative analysis of scintigraphic findings in tibial stress fractures in Thoroughbred racehorses. *Am. J. vet. Res.* **69**, 886-890.

Vandenbroucke, J.P., von Elm, E., Altman, D.G., Gotzsche, P.C., Mulrow, C.D., Pocock, S.J., Poole, C., Schlesselman, J.J. and Egger, M. (2007) Strengthening the reporting of observational studies in epidemiology (STROBE): Explanation and elaboration. *Epidemiol.* **18**, 805-835.

Woodie, J.B., Ducharme, N.G., Kanter, P., Hackett, R.P. and Erb, H.N. (2005) Surgical advancement of the larynx (laryngeal tie-forward) as a treatment for dorsal displacement of the soft palate in horses: A prospective study 2001-2004. *Equine vet. J.* **37**, 418-423.