

# A retrospective study of radiographic abnormalities in the repositories of 2-year-old Thoroughbred in-training sales in Japan

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*This study aimed to evaluate the influence of radiographic abnormalities of 2-year-old Thoroughbred horses that were listed at in-training sales in Japan, on whether they started to race or not at 2–3 years of age. Radiographs of 850 2-year-old Thoroughbreds in the in-training sales repository from 2007 to 2010 were reviewed, and 26 categories of radiographic abnormalities were found. Forty-three horses (5.1%, 43/850) did not start a race at 2–3 years of age. In accordance with the racing results for this age category, as determined by Fisher's exact test and multiple logistic regression analysis, none of the radiographic abnormalities were significantly related to failure to start a race. At 2 years of age, 198 horses (23.3%, 198/850) did not start a race. Horses with enlargement of the proximal sesamoid bones in the fore (9 of 19 horses) and hind limbs (5 of 9 horses) did not start a race at the age of 2 years, and fewer of these horses (fore,  $P=0.021$ ; hind,  $P=0.030$ ) started a race at the age of 2 years compared with the population of horses without these radiographic abnormalities. These results suggest that identification of radiographic enlargement of the proximal sesamoid bones during training sales could derail the racing debut of horses at the age of 2 years. However, this might not necessarily indicate a poor prognosis and resulting in retirement from racing at 2–3 years of age.*

**Key words:** prognosis, radiography, repository, sales, Thoroughbred

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A radiographic repository for limbs has been obligatory for 2-year-old Thoroughbreds listed at in-training sales in Japan since 2006. A radiographic repository is a set of radiographs of Thoroughbreds listed in sales that are submitted to sales companies before a sale. Sets of radiographs are submitted to the sales company and are available for viewing as a radiographic repository to potential buyers or their veterinarians. The radiographic repository provides important information to guide the selection of horses by potential buyers. Because radiographic abnormalities affect

the purchase price and the subsequent management of horses, analytical data on the prevalence, the prognosis, and the effects on future performance should be investigated. Recent studies on the radiographic abnormalities found in 2-year-old Thoroughbreds listed at in-training sales [11] as well as yearling sales [4, 7–9, 13] have been reported globally. Radiographic abnormalities at yearling sales, including moderate or extreme palmar supracondylar lysis of the third metacarpal bone (MC3), enthesophyte formation on the proximal sesamoid bones, dorsal medial intercarpal joint disease (defined as the radial carpal bone showing a rounded appearance and/or thickened dorsal cortex or as proliferative changes, enthesophytes, or fragments involving the radial carpal or the third carpal bones), proximal dorsal fragmentation of the first phalanx (P1) in the metatarsophalangeal joint [9], enlarged vascular canals in the proximal sesamoid bones [13], and a defect greater than 10 mm in length in the sagittal ridge of the metatarsus and sesamoid modeling

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(osteophytes and enthesophytes) in forelimbs [7], have been suggested to affect future racing performance. In a previous study of radiographic abnormalities in 2-year-old Thoroughbreds listed at in-training sales, proximal phalangeal dorsoproximal articular margin chip fracture, proximal sesamoid bone fracture or sesamoiditis, and wedge-shaped central or third tarsal bones were significant risk factors for failure to start racing, and these horses subsequently earned less money [11].

Although various investigators worldwide have provided controversial data and speculations regarding the influence of radiographic abnormalities in a repository at in-training sales on the future performance of horses, there has been no such study for Thoroughbreds in Japan. The present study aimed to determine the prevalence of radiographic abnormalities in the repository at in-training sales of 2-year-old Thoroughbreds in Japan and investigate the prospective effects on their future performance.

## Materials and Methods

### *Radiography and evaluation of radiographs*

Radiographs of 2-year-old Thoroughbred horses in a repository of in-training sales from 2007 to 2010 in Japan were reviewed for radiographic abnormalities in their 4 limbs (left and right, fore and hind limbs). The radiographic repository includes data for metacarpophalangeal joints, metatarsophalangeal joints, and carpi. The lateromedial, dorsal 45° lateral palmar medial oblique, and dorsal 35° medial-palmar lateral oblique views were used to examine the carpi. The dorsal 30° proximal-palmar distal oblique, lateromedial, dorsal 15° proximal 45° lateral-palmar distal medial oblique, and dorsal 15° proximal 45° medial-palmar distal lateral oblique views were used to examine the metacarpophalangeal or metatarsophalangeal joints. The radiographs were evaluated by 4 and 3 experienced veterinary equine practitioners for carpi joints and metacarpophalangeal and metatarsophalangeal joints, respectively. Difference in diagnoses between the different investigators was reevaluated and diagnosed by the first author. If nondiagnostic views in a joint series were present, then series was not included in the present analysis.

### *Categorization of radiographic abnormalities*

**Carpus:** Signs of dorsal medial intercarpal joint disease were recorded if the radial carpal bone had a rounded appearance and/or a thickened dorsal cortex or if there were proliferative changes, enthesophytes, or fragments involving the radial carpal or third carpal bones [8]. The locations of the fragments, osteophytes, and circular lucency at the carpal bones were recorded [8]. Accessory carpal bone fractures were recorded.

Metacarpophalangeal and metatarsophalangeal joints: Proximal dorsal and proximal palmar/plantar fragments of the P1 were recorded. Subchondral cystic lesions at the distal MC3/third metatarsal bone (MT3) or the proximal P1 were recorded. In the present study, subchondral cystic lesions were defined as any area of increased lucency that extended through subchondral bone [8]. Irregular lucency of the sagittal ridge of the distal MC3/MT3 was defined as a defect only if visible radiographic abnormalities of the midsagittal ridge of the MC3/MT3 were identified in the present study. The presence of a fragment on the distal aspect of the MC3/MT3 was defined as a fragment on the proximal aspect of the dorsal sagittal ridge of the MC3/MT3 and was recorded. Osteophytes at the dorsal aspect of the MC3 were defined in the present study as new periosteal bone formation at the proximal dorsal aspect of the MC3 and were recorded. Enthesophytes on the palmar/plantar surface of the P1 were defined in the present study as new bone observed at the palmar/plantar surface and were recorded. In the present study, enlargement of the proximal sesamoid bones was defined as proximal, distal, or abaxial enlargement of proximal sesamoid bones and was recorded. Fractures of the proximal sesamoid bones including apical, abaxial, basal, midbody, comminuted, and other fractures were recorded [8]. Modeling of the proximal sesamoid bones, defined as the presence of proliferative bone growth that changed the bone surface contour on any surface of the proximal sesamoid bones, was recorded [7].

### *Racing results*

Horse racing data were obtained from Japan Bloodstock Information System (JBIS, Japan Bloodhorse Breeders' Association, Tokyo, Japan). These data included sex, date of first race, and number of starts at 2 and 3 years of age.

### *Statistics*

Data in the present study were statistically analyzed using statistical analysis software (JMP version 7.0, SAS Institute Inc., Cary, NC, U.S.A.).

Based on the racing results of the horses at 2–3 years of age, the horses were divided into the “starters” group, consisting of horses that started at least one race and the “failure to start a race” group consisting of horses that did not start to a race at 2–3 years of age. Again, in accordance with their racing results at 2 years of age, the horses were divided into 2 groups, namely the “2 years old/starters” group with horses that started at least one race at the age of 2 years and the “2 years old/failure to start a race” group with horses that failed to start a race at the age of 2 years.

**Univariate analyses:** The prevalences of the radiographic abnormalities were compared between the 2 groups using Fisher's exact tests. A *P* value <0.05 was considered statisti-

cally significant.

Multivariable analyses: Correlations between the radiographic abnormalities and the racing results of the horses were statistically evaluated using multivariable analyses in individual joints, including the carpi, the metacarpophalangeal joints, and the metatarsophalangeal joints. First, we used a single logistic regression system to analyze the correlation of variables (=radiographic abnormalities) with the racing results. The *P* value was adjusted for maximum likelihood estimation in the chi-square test, and a *P* value <0.20 was used for the multiple logistic regression to correlate the variables with starting in a race. On the other hand, variables with *P*>0.20 in the multiple logistic regression system were excluded in decreasing order of their *P* values. The exclusion of variables was repeated until a *P* value of <0.2 was obtained in the multiple logistic regression system. The final multiple logistic analysis was applied when all variables had a *P* value <0.20. A *P* value <0.05 was considered statistically significant in the final multiple logistic regression.

## Results

### *The number of samples*

In total, 850 radiographic series of 2-year-old Thoroughbreds in the repository of in-training sales from 2007 to 2010 in Japan were examined.

There were 171, 304, 217, and 158 radiographic series of 2-year-old Thoroughbreds during 2007, 2008, 2009, and 2010, respectively.

In total, 636 complete carpi radiographic series were examined. Carpi radiographic series of 214 horses were removed from the total 850 radiographic series because of the presence of one or more nondiagnostic views.

There were 691 complete radiographic series examined for fore fetlocks. The fore fetlock radiographic series of 159 horses were removed from the 850 radiographic series because of the presence of one or more nondiagnostic views.

A total of 660 complete hind fetlock radiographic series were examined. The hind fetlock radiographic series of 190 horses were removed from the total 850 radiographic series because of the presence of one or more nondiagnostic views.

### *Prevalence of radiographic abnormalities*

Five categories of radiographic abnormalities were found in the carpus during the study (Tables 1 and 2). The presence of osteophytes at the carpal bone (5.5%, 35/636) was the most common radiographic abnormality found in the carpus. Fracture of the accessory carpal bone (0.3%, 2/636) was the least common radiographic abnormality found in the carpus. The other common radiographic abnormalities included dorsal medial intercarpal joint disease in 2.2%

(14/636) of the horses, fragments in 1.1% (7/636) of the horses, and circular lucencies at the carpal bone in 1.3% (8/636) of the horses.

Ten categories of radiographic abnormalities were found in the fore fetlock and 8 categories of radiographic abnormalities were found in the hind fetlock in the present study (Tables 3–6). Modeling in the proximal sesamoid bones was the most common radiographic abnormality found in the fore fetlock (5.4%, 37/691), and the prevalence of modeling in the proximal sesamoid bones in the fore fetlock was higher than that in the hind fetlock (3.3%, 22/660). Proximal palmar fragments at the P1 was the most common radiographic abnormality in the hind fetlock (6.1%, 40/660), and this prevalence was higher than that in the fore fetlock (0.4%, 3/691).

The prevalence of proximal dorsal fragments at the P1 in the fore fetlock (3.0%, 21/691) was similar to that in the hind fetlock (2.7%, 18/660). There were 3 horses with subchondral cystic lesions at the distal MC3 or the proximal P1 in the fore fetlock (0.4%, 3/691); however, there were no instances of horses with subchondral cystic lesions at the distal MT3 or the proximal P1 in the hind fetlock. The prevalence of a fragment on the distal aspect of the MC3/MT3 was 1.6% (11/691) in the fore fetlock and 0.6% (4/660) in the hind fetlock. The prevalence of irregular lucency of the sagittal ridge of the distal MC3 / MT3 was 0.3% (2/691) in the fore fetlock and 0.6% (4/660) in the hind fetlock. Osteophytes at the proximal dorsal aspect of the MC3 were found in the fore fetlock (3.6%, 25/691) but not found in the hind fetlock. Enthesophytes in the palmar/plantar surface of the P1 were identified in 2.5% (17/691) of the horses in the fore fetlock and 2.4% (16/660) of the horses in the hind fetlock. The prevalence of enlargement of the proximal sesamoid bones was 2.7% (19/691) for the fore fetlocks in the horses and 1.4% (9/660) for the hind fetlocks in the horses. The prevalences of fractures of the proximal sesamoid bones were 0.4% (3/691) and 1.2% (8/660) in the fore and hind limbs, respectively.

### *Statistics analyses*

Of the total 850 horses listed at the training sales from 2007 to 2010, 807 horses (94.9%, 807/850) were included in the “starters” group, whereas the remaining 43 horses (5.1%, 43/850) were included in the “failure to start a race” group. Radiographic abnormalities were found in the horses starting a race as well as the horses not starting a race. For example, osteophytes of carpal bones were most frequently found in 35 horses, 32 of which were in the “starters” group; the remaining 3 were in the “failure to start a race” group (Table 1). As indicated by the Fisher’s exact test, none of the radiographic abnormalities were significantly related to failure to start a race at 2–3 years of age (Tables 1, 3 and

**Table 1.** Prevalence of radiographic abnormalities in the carpus of “Starters” and “Failure to start a race”; 2–3 years of age (638)

Radiographic abnormalities	Category	Starters (605)		Failure to start a race (33)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Dorsal medial intercarpal lesions	Present	12	85.7	2	14.3	3.2	0.7–14.9	0.16
	Absent	593	95.0	31	5.0			
Fragments	Present	7	100	0	0	NA	NA	1.0
	Absent	598	94.8	33	5.2			
Osteophytes	Present	32	91.4	3	8.6	1.8	0.5–6.2	0.41
	Absent	573	95.0	30	5.0			
Circular lucencies at the carpal bone	Present	8	100	0	0	NA	NA	1.0
	Absent	597	94.8	33	5.2			
Fracture of the accessory carpal bone	Present	1	50.0	1	50.0	18.9	1.2–308.7	0.10
	Absent	604	95.0	32	5.0			

All P values are for Fisher’s exact test. NA: not applicable.

**Table 2.** Prevalence of radiographic abnormalities in the carpus of “Starters” and “Failure to start a race”; 2 years of age (638)

Radiographic abnormalities	Category	Starters (490)		Failure to start a race (148)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Dorsal medial intercarpal lesions	Present	11	78.6	3	21.4	0.9	0.3–4.0	1.0
	Absent	479	76.8	145	23.2			
Fragments	Present	7	100	0	0	NA	NA	0.36
	Absent	483	76.55	148	23.45			
Osteophytes	Present	25	71.4	10	28.6	1.3	0.6–2.9	0.41
	Absent	465	77.1	138	22.9			
Circular lucencies at the carpal bone	Present	8	100	0	0	NA	NA	0.21
	Absent	482	76.5	148	23.5			
Fracture of the accessory carpal bone	Present	1	50	1	50	3.3	0.2–53.5	0.41
	Absent	489	76.9	147	23.1			

All P values are for Fisher’s exact test. NA: not applicable.

5). In addition, none of the radiographic abnormalities were significantly related to failure to start a race at 2–3 years of age, as determined by multivariable logistic regression analysis.

In accordance with the racing results at 2 years of age, 652 horses (76.7%, 652/850) were included in the “2 years old/starters” group, whereas the remaining 198 horses (23.3%, 198/850) were placed in the “2 years old/failure to start a race” group (Tables 2, 4 and 6). As shown in Tables 4 and 6 and indicated by the Fisher’s exact test, the enlargement of the proximal sesamoid bones (Fig. 1) in the fore (9 of 19 horses with this lesion were 2 years old and failed to start a race) and hind limbs (5 of 9 horses with this lesion were 2 years old and failed to start a race) significantly (fore,  $P=0.021$ ; hind,  $P=0.030$ ) increased the number of horses in the “2 years old/failure to start a race” group. Enlargement of the proximal sesamoid bones was additionally a significant risk factor (fore,  $P=0.013$ ; hind,  $P=0.031$ ) for failure to start a race at 2 years of age, as determined by multivariable logistic regression analysis.

## Discussion

The present study made 2 important observations. First, 26 categories of radiographic abnormalities were found in the repository for the in-training sales of 2-year-old Thoroughbreds in Japan, and these radiographic abnormalities affected <7% of the population. Second, radiographic abnormalities at in-training sales were not statistical risk factors for a failure to start a race at 2–3 years of age.

We suggest that most of the radiographic abnormalities cannot affect the debut of the horses in a race at 2–3 years of age. In addition, 24 of the total 26 categories of radiographic abnormalities did not significantly increase the number of horses in the “2 years old/failure to start a race” group. Only enlargement of the proximal sesamoid bones in the fore and hind limbs was positively correlated with the increase in failure to start a race at 2 years of age.

### Carpus

Fewer radiographic abnormalities were found in the

**Table 3.** Prevalence of radiographic abnormalities in the fore fetlocks of “Starters” and “Failure to start a race”; 2–3 years of age (691)

Radiographic abnormalities	Category	Starters (660)		Failure to start a race (31)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Proximal dorsal fragments at the P1	Present	21	100	0	0	NA	NA	0.62
	Absent	639	95.4	31	4.5			
Proximal palmar fragments at the P1	Present	3	100	0	0	NA	NA	1.0
	Absent	657	95.5	31	4.5			
SCLs at the distal MC3 or proximal P1	Present	3	100	0	0	NA	NA	1.0
	Absent	657	95.5	31	0			
Fragments at the dorsal aspect of the distal MC3	Present	11	100	0	0	NA	NA	1.0
	Absent	649	95.4	31	4.6			
Irregular lucencies at the dorsal aspect of the distal MC3	Present	2	100	0	0	NA	NA	1.0
	Absent	658	95.5	31	4.5			
Osteophytes at proximal dorsal aspect of MC3	Present	25	100	0	0	NA	NA	0.62
	Absent	635	95.4	31	4.6			
Enthesophyte in palmar surface of P1	Present	17	100	0	0	NA	NA	1.0
	Absent	643	95.4	31	4.6			
Enlargement of sesamoid	Present	18	94.7	1	5.3	1.2	0.2–9.2	0.52
	Absent	642	95.5	30	4.5			
Fracture of sesamoid	Present	2	66.6	1	33.3	11.0	1.0–124.3	0.13
	Absent	658	95.6	30	4.4			
Modelling in sesamoid	Present	36	97.3	1	2.7	0.6	0.1–4.4	1.0
	Absent	624	95.4	30	4.6			

All P values are for Fisher’s exact test. NA: not applicable.

carpus in the present study than in the fore and hind fetlocks. This result is supported by previous studies [4, 7, 8]. In the present study, 14 horses were diagnosed with dorsal medial intercarpal joint disease (2.2%, 14/636). This prevalence was similar to that of a previous study of yearlings (2.7%) [8]. However, the previous study of yearlings found that the proportion of the horses starting a race was significantly lower for yearlings with dorsal medial intercarpal joint disease (63%, 19/30) compared with horses without this radiographic abnormality [9], and this was not similar to the result of the present study showing that this radiographic abnormality was not related with whether a horse started a race.

In the present study, 7 horses were diagnosed with fragments at the carpal bones (1.1%, 7/636) and all were “starters” and “2 years old/starters.” The result for the prevalence of fragments at the carpal bones in the present study was supported by previous studies of yearlings, with the prevalence being 0.8% in a study of Kane *et al.* [8] and 0.7% in a study of Jackson *et al.* [7]. Kane *et al.* also reported that fragments at the carpal bones were not associated with starting a race [9]. This result of the study of Kane *et al.* was similar to the result of the present study. The study of Jackson *et al.* did not report a relationship between fragments at the carpal bones and whether horses started a race [7].

In the present study, 33 horses were diagnosed with osteo-

phytes at the carpal bones (5.5%, 35/636). This prevalence was higher than that found in previous studies of yearlings, including those of Jackson *et al.* (3.3%) [7] and Kane *et al.* (1.7%) [8], and was similar to that found for 2-year-old horses by Meagher *et al.* (2.0%) [11]. The results of these previous studies showed that osteophytes at the carpal bones were not significantly related with whether a horse started a race, similar to the finding in the present study.

In the present study, 8 horses were diagnosed with circular lucencies at the carpal bone (1.3%, 8/636). This prevalence was higher than that reported in the study of Kane *et al.* of subchondral cysts at the carpal bones (0.3%) [8].

In the present study, 2 horses were diagnosed with a fracture of the accessory carpal bone (0.3%, 2/636). The prevalence of fracture of the accessory carpal bone was similar to that in the study of Kane *et al.* (0.4%) [8]. One of the horses with a fracture of the accessory carpal bone in the present study was in the “starter” group. However, all 4 horses with a fracture of the accessory carpal bone in the study of Kane *et al.* could start a race [9].

### Fetlocks

In the present study, 21 and 18 horses were diagnosed with proximal dorsal fragments at the P1 in the forelimbs (3.0%, 21/691) and hind limbs (2.7%, 18/660), respectively. The prevalence of proximal dorsal fragments at the P1 in

**Table 4.** Prevalence of radiographic abnormalities in the fore fetlocks of “Starters” and “Failure to start a race”; 2 years of age (691)

Radiographic abnormalities	Category	Starters (533)		Failure to start a race (158)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Proximal dorsal fragments at the P1	Present	16	76.2	5	23.8	1.1	0.4–2.9	1.0
	Absent	517	77.2	153	22.8			
Proximal palmar fragments at the P1	Present	2	66.7	1	33.3	1.7	0.2–18.8	0.54
	Absent	531	77.2	157	22.8			
SCLs at the distal MC3 or proximal P1	Present	3	100	0	0	NA	NA	1.0
	Absent	530	77.0	158	23.0			
Fragments at the dorsal aspect of the distal MC3	Present	7	63.6	4	36.4	2.0	0.7–6.8	0.28
	Absent	526	77.35	154	22.65			
Irregular lucencies at the dorsal aspect of the distal MC3	Present	2	100	0	0	NA	NA	1.0
	Absent	531	77.07	158	22.93			
Osteophytes at proximal dorsal aspect of MC3	Present	23	92.0	2	8.0	0.3	0.1–1.2	0.088
	Absent	510	76.58	156	23.42			
Enthesophyte in palmar surface of P1	Present	11	64.71	6	35.29	1.9	0.7–5.1	0.24
	Absent	522	77.45	152	22.55			
Enlargement of sesamoid	Present	10	52.63	9	47.37	3.2	1.3–7.9	0.021
	Absent	523	77.83	149	22.17			
Fracture of sesamoid	Present	2	66.67	1	33.33	1.7	0.2–18.8	0.54
	Absent	531	77.18	157	22.82			
Modelling in sesamoid	Present	24	64.86	13	35.14	1.9	0.9–3.8	0.072
	Absent	509	77.83	145	22.17			

All P values are for Fisher’s exact test. NA: not applicable.

**Table 5.** Prevalence of radiographic abnormalities in the hind fetlock of “Starters” and “Failure to start a race”; 2–3 years of age (660)

Radiographic abnormalities	Category	Starters (633)		Failure to start a race (27)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Proximal dorsal fragments at the P1	Present	17	94.4	1	5.6	1.4	0.2–10.9	0.53
	Absent	616	95.95	26	4.05			
Proximal palmar fragments at the P1	Present	37	92.5	3	11.1	2.0	0.6–7.0	0.22
	Absent	596	96.1	24	3.9			
SCLs at the distal MT3 or proximal P1	Present	0	0	0	0	NA	NA	NA
	Absent	633	95.9	27	4.1			
Fragments at the dorsal aspect of the distal MT3	Present	4	100	0	0	NA	NA	1.0
	Absent	629	95.9	27	4.1			
Irregular lucencies at the dorsal aspect of the distal MT3	Present	3	75.0	1	25.0	8.1	0.8–80.3	0.15
	Absent	630	96.0	26	4.0			
Enthesophytes in palmar surface of P1	Present	15	93.75	1	6.25	1.6	0.2–12.5	0.49
	Absent	618	96.0	26	4.0			
Enlargement of sesamoid	Present	9	100	0	0	NA	NA	1.0
	Absent	624	95.85	27	4.15			
Fracture of sesamoid	Present	8	100	0	0	NA	NA	1.0
	Absent	625	95.86	27	4.14			
Modelling in sesamoid	Present	20	90.9	2	9.1	2.5	0.5–11.1	0.23
	Absent	613	96.1	25	3.9			

All P values are for Fisher’s exact test. NA: not applicable.

the fore fetlocks in the present study was higher than those found in the studies of Jackson *et al.* (0.7%) [7], Kane *et al.* (1.6%) [8], and Meagher *et al.* of 2-year-old Thoroughbreds at in-training sales (0.8%) [11]. The results reported by Kane

*et al.* for yearling Thoroughbreds showed that the proximal dorsal fragments at the P1 in fore limb were not significantly associated with starting a race, similar to the result of the present study [9]. However, the study of Meagher *et al.*

**Table 6.** Prevalence of radiographic abnormalities in the hind fetlock of “Starters” and “Failure to start a race”; 2 years of age (660)

Radiographic abnormalities	Category	Starters (513)		Failure to start a race (147)		Odds ratio	95% confidence interval	P value
		Numbers	Prevalence	Numbers	Prevalence			
Proximal dorsal fragments at the P1	Present	15	83.3	3	16.7	0.7	0.2–2.4	0.78
	Absent	498	77.6	144	22.4			
Proximal palmar fragments at the P1	Present	29	72.5	11	27.5	1.3	0.7–2.8	0.43
	Absent	484	78.1	136	21.9			
SCLs at the distal MT3 or proximal P1	Present	0	0	0	0	NA	NA	NA
	Absent	513	77.7	147	22.3			
Fragments at the dorsal aspect of the distal MT3	Present	4	100	0	0	NA	NA	0.58
	Absent	509	77.6	147	22.4			
Irregular lucencies at the dorsal aspect of the distal MT3	Present	2	50.0	2	50.0	3.5	0.5–25.2	0.22
	Absent	511	77.9	145	22.1			
Enthesophytes in palmar surface of P1	Present	11	68.75	5	31.25	1.6	0.5–4.7	0.37
	Absent	502	77.95	142	22.05			
Enlargement of sesamoid	Present	4	44.4	5	55.6	4.5	1.2–16.9	0.030
	Absent	509	78.2	142	21.8			
Fracture of sesamoid	Present	4	50.0	4	50.0	3.6	0.9–14.4	0.078
	Absent	509	78.1	143	21.9			
Modelling in sesamoid	Present	18	81.8	4	18.2	0.8	0.3–2.3	0.80
	Absent	495	77.6	143	22.4			

All P values are for Fisher's exact test. NA: not applicable.

of 2-year-old Thoroughbreds at in-training sales found that the probability of starting a race was significantly lower for horses with a P1 dorsoproximal articular margin chip fracture (particularly when a front limb was affected) than for horses without this radiographic abnormality [11]. In the hind fetlock, the prevalence in the present study was not higher than that found in previous studies (3.3% by Kane *et al.* [8], 2.2% by Jackson *et al.* [7], and 2.0% by Cohen *et al.* [4]). Kane *et al.* found that 25 of 36 (69%) yearlings with proximal dorsal fragmentation of the P1 in the hind fetlock started a race, but that these yearlings were less likely to start a race as compared with yearlings without this radiographic abnormality [9]. This result for the hind limbs from the study of Kane *et al.* was not similar to the result of the present study. A follow-up study on 461 surgeries for the P1 fragmentation indicated that 89% of the Thoroughbred horses had higher activity grades than presurgical grades [5]. The results of the aforementioned study suggest that the prognosis of P1 fragmentation should improve after surgical correction, even if clinical signs have manifested [5].

In the present study, 3 and 40 horse were diagnosed with proximal palmar/plantar fragments of the P1 in the fore (0.4%, 3/691) and hind (6.1%, 40/660) limbs, respectively. Kane *et al.* [8] reported that the prevalence of this radiographic abnormality was 0.5% in the forelimb and 5.9% in hindlimb [8], Jackson *et al.* [7] reported that it was 0.4% in forelimb and 6.1% in hindlimb and Cohen *et al.* [4] reported that it was 0.3% in the forelimb and 2.9% in the hindlimb.



**Fig. 1.** Enlargement of the proximal sesamoid bones (white arrow) was observed in the dorsal 30° proximal-palmar distal oblique view of the metacarpophalangeal joint. Enlargement of the proximal sesamoid bones was defined as proximal, distal, or abaxial enlargement of the proximal sesamoid bones. This radiograph is of the right forelimb; the medial sesamoid shows distal enlargement compared with the lateral sesamoid.

The prevalence of the present study was similar to that found in previous studies of yearlings (Kane *et al.* [8], Jackson *et al.* [7], Cohen *et al.* [4]). The result of Kane *et al.* [9] and those of the present study show that this radiographic abnormality was not significantly associated with whether a horse started a race. One study of racing Standardbreds and racing Thoroughbreds reported that arthroscopic treatment resulted in an improvement in performance in a high percentage of cases [14]. However, Carmalt *et al.* [3] found that there was no difference in racing speed between horses with a proximal palmar/plantar P1 osteochondral fragment as compared with those raced before surgery and control horses, and they suggested the need to reevaluate the previously reported benefits of surgical intervention for a proximal palmar/plantar P1 osteochondral fragment.

In the present study, 3 and zero horses were diagnosed with subchondral cystic lesions at the distal MC3/MT3 or the proximal P1 in fore (0.4%, 3/691) and hind (0%, 0/660) limbs, respectively. These prevalences were not higher than those found in previous studies of yearlings, with the prevalence being 0.7% in the fore limb and 0.2% in the hind limb in the study of Kane *et al.* [8] and 0.3% in the forelimb and 0.6% in the hindlimb in the study of Cohen *et al.* [4]. It was difficult for us to draw a conclusion regarding the relationships between these radiographic abnormalities in the radiographic repository and whether a horse started a race, as the features of these radiographic abnormalities were different.

In the present study, 11 and 4 horses were diagnosed with the presence of a fragment on the distal aspect of the MC3/MT3 in fore (1.6%, 11/691) and hind (0.6%, 4/660) limbs, respectively. These prevalences were not much higher than those found in previous studies of Thoroughbred yearlings, with Kane *et al.* [8] reporting prevalences of 0.8% in the forelimb and 1.5% in the hindlimb and Jackson *et al.* [7] reporting prevalences 0.4% in the forelimb.

In the present study, 2 and 4 horses were diagnosed with the presence of irregular lucencies at the dorsal aspect of the distal MC3/MT3 in the fore (0.3%, 2/691) and hind (0.6%, 4/660) limb, respectively. These prevalences were not higher than in those found in previous studies of Thoroughbred yearlings, with Kane *et al.* [8] reporting prevalences of 2.0% in the forelimb and 1.7% in the hindlimb, but they were lower than those in the study of Jackson *et al.*, which reported prevalences of 38.1% in the forelimb and 7.5% in the hindlimb [7]. Jackson *et al.* [7] found that horses with the presence of a defect greater than 10 mm in length in the sagittal ridge of the metatarsus were less likely to start a race than horses without this radiographic abnormality. This result was similar to that of a previous study showing that Standardbred racehorses with sagittal ridge lesions show poorer performance than those without

lesions [6]. However, in the results of the present study, this radiographic abnormality was not related with starting a race, and this was similar to the result of the study of Kane *et al.* [9]. McIlwraith *et al.* found that the prognosis for conservative treatment of lucency at the dorsal aspect of the MC3/MT3 is good; 80% (12/15) of horses were clinically resolved, and 8 of those horses showed remodeling of the lesions with improvement on radiographic examination [10].

In the present study, 25 horses were diagnosed with osteophytes at the dorsal aspect of the MC3 (3.6%, 25/691) in the forelimbs. This radiographic abnormality usually relates to chronic proliferative synovitis within horses with soft-tissue swelling [2]. The results of the present study did not find a relationship between this radiographic abnormality and whether a horse started a race.

In the present study, 17 and 16 horses were diagnosed with enthesophytes on the palmar/plantar surface of the P1 in the fore (2.5%, 17/691) and hind (2.4%, 16/660) limbs, respectively. This radiographic abnormality was observed at the attachments of the oblique sesamoidean ligaments in the present study, and it probably resulted from trauma that occurred at least 3–6 weeks prior to radiography [2].

The results of the present study suggest that enlargement of the proximal sesamoid bones in the fore and hind limbs does not affect whether a horse starts a race at 2–3 years of age; however, the racing performance of 2-year-old Thoroughbred racehorses is affected. In the present study, 19 and 9 horses were diagnosed with enlargement of the proximal sesamoid bones in the fore (2.7%, 19/691) and hind (1.4%, 9/660) limbs, respectively. These prevalences were similar to previous data (3.0 and 2.1% in fore and hind limbs, respectively) for an abnormal sesamoid shape, which was defined as proximal, distal, or abaxial enlargement of the proximal sesamoid bones [8]. All of these studies and our results for horses at 2–3 years of age show that enlargement of the proximal sesamoid bones in the fore and hind limbs does not affect whether a horse starts a race. However, no previous studies have suggested that enlargement of the proximal sesamoid bones could significantly contribute to the future performance of 2-year-old horses. Enlargement or abnormal shape of proximal sesamoid bones could result from enthesophyte formation and mineralization (calcification) at the transition of the sesamoid bone and ligament subsequent to sesamoidean desmitis or micro-rupture [1]. Ligamentous injuries and subsequent desmitis might be repeated and/or accumulated in 2-year-old horses owing to the persistently increasing mechanical loads placed on the fast elongating limbs; however, these injuries may decrease and cease as the horses approach maturity. In the present study, enlargement of the proximal sesamoid bones was not related to the increase in failure to start a race at 2–3 years of

age. In addition, this result is in agreement with a previous study in which an abnormal shape of the proximal sesamoid bones did not relate to failure to start a race within horses between the ages of 2 and 3 years [9]. These results suggest that radiographic enlargement of the proximal sesamoid bone found at in-training sales could derail the race debut of horses at 2 years of age; however, it might not necessarily result in a poor prognosis causing retirement from racing at 2–3 years of age.

In the present study, 3 and 8 horses were diagnosed with fractures of the proximal sesamoid bones in the fore (0.4%, 3/691) and hind (1.2%, 8/660) limbs, respectively. The prevalences of this radiographic abnormality in the present study were not higher than those observed in previous studies of yearlings, with Kane *et al.* [8] reporting prevalences of 1.1% in the forelimb and 2.9% in hind limb and Jackson *et al.* [7] reporting prevalences of 1.5% in the forelimb and 1.7% in hindlimbs. In addition, similar results were obtained in a study of 2-year-old horses by Meagher *et al.* [11], with the prevalences being 0.7% in the forelimb and 2.0% in hindlimb. The results of the previous studies of yearlings, which found that fractures of the proximal sesamoid bones in the fore and hind limbs were not associated with whether a horse started a race [9], were similar to the result of the present study. In contrast, Jackson *et al.* reported that the proximal sesamoid bone fractures in the forelimbs were associated with reduced performance in one category that started a race or not at 2 and 3 years of age and that proximal sesamoid bones fractures in the hind limbs were not associated with whether horses started a race [7]. The study of Meagher *et al.* of 2-year-old Thoroughbreds at in-training sales reported that the probability of starting a race was significantly lower for horses with proximal sesamoid fractures (particularly when a front limb was affected) than for horses without this radiographic abnormality [11]. The results of their study are consistent with a study that reported that Thoroughbred horses aged  $\geq 2$  years with forelimb fractures had a reduced probability of returning to racing (67%) compared to those with hind limb fractures (83%) when treated surgically [12].

In the present study, 37 and 22 horses were diagnosed with modeling of the proximal sesamoid bones in the fore (5.4%, 37/691) and the hind (3.3%, 22/660) limbs, respectively. The prevalences of this ailment in the present study were not higher than those observed in the previous study of yearlings by Jackson *et al.*, which reported prevalences of 3.7% in the forelimb and 3.9% in hindlimb [7]. The results of the present study were not similar to those of the study of Jackson *et al.* of yearlings, which also reported that modeling of the borders of the proximal sesamoid bones of the fore limbs was associated with a reduced probability of starting a race at the age of 2 or 3 years [7].

There are several potential limitations of the present study. First is the lack of clinical signs in the joints associated with enlargement of the proximal sesamoid bones in the fore and hind fetlocks. Second is selection bias regarding the horses included in this study; it is likely that horses with clinical symptoms resulting from more severe radiographic abnormalities would not have been listed at the sales. Third, we did not know whether the horses with radiographic abnormalities would be treated in the future. Further study of radiographic abnormalities at Thoroughbred sales should resolve the aforementioned limitations of the present study; therefore, future studies should obtain detailed clinical information of horses with radiographic abnormalities before and after sales to resolve the first and third limitation mentioned above. In addition, collection of information for horses with severe radiographic abnormalities should solve the second limitation mentioned above for the present study.

We believe that radiographic information for limbs at in-training sales is of lower importance than radiographic information for limbs at yearling sales. The horses attending training sales are subjected to intense training, which incorporates galloping for at least 2 furlongs in a workout. The horses that had radiographic abnormalities and were listed at in-training sales showed that they could gallop within a workout despite the radiographic abnormalities.

We conclude that radiographic examination of 2-year-old Thoroughbreds at in-training sales can provide information that can be used to evaluate the horses at sales; however, the majority of horses with radiographic abnormalities are able to start racing.

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