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# Magnetic resonance imaging findings of the proximal metacarpus in Quarter Horses used for cutting: Retrospective analysis of 32 horses 2009–2012

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## Summary

**Background:** Injury to the proximal suspensory ligament is a common cause of lameness in cutting horses. Radiographic and ultrasonographic imaging of lesions responsible for lameness can provide ambiguous results. MRI provides the most comprehensive diagnostic imaging evaluation of lesions specifically affecting cutting horses.
**Objectives:** To describe the distribution and severity of bone and soft tissue lesions present in the proximal metacarpus of Quarter Horse cutting horses and to assess the impact of these lesions on return to competition.
**Study design:** Retrospective case series.
**Methods:** Retrospective analysis of 32 cutting horses referred for MRI of the proximal metacarpus between 2009 and 2012 with a 2-year follow-up period. MRI studies were evaluated by a board-certified veterinary radiologist; the severity of lesions was graded from 0 (absent) to 3 (severe).
**Results:** A total of 20 right and 24 left forelimbs (12 bilateral studies) of 32 horses were evaluated. The most common findings were: third metacarpal (McIII) sclerosis at the proximal suspensory ligament (PSL) origin (42/44), McIII resorption at the PSL origin (32/44), PSL dorsal margin fibre irregularity (30/44) and McIII bone contusion (22/39). Of the 30 horses, 22 horses successfully returned to competition, irrespective of severity of injury. Strong correlation exists between the degree of resorption in the palmar cortex of proximal McIII, degree of McIII sclerosis and severity of dorsal margin fibre irregularity.
**Main limitations:** Statistical significance was limited by small study population. Further analysis of prognosis was limited by availability of comprehensive medical records.
**Conclusions:** Cutting horses with proximal metacarpal pain have significant pathological change within the proximal suspensory ligament and its enthesis on the palmar cortex of McIII. Severity of lesions and degree of lameness at the time of diagnosis does not influence return to performance. Accurate diagnosis of proximal metacarpal lesions based on MRI offers clinicians the capacity to select treatment protocols targeted to each disease process.

**Keywords:** horse; suspensory ligament; magnetic resonance imaging; cutting

## Introduction

Proximal metacarpal pain is a common source of lameness in performance horses [1–5]. The Quarter Horse is the primary breed used in the western discipline of cutting [1,2], and these horses commence training as 2-year-olds and compete in Limited Age Events from 3 to 6 years of age [1–3]. Cutting horses are of consistent phenotype, are selectively bred for athleticism and trainability, and undergo rigorous training prior to reaching skeletal maturity [1–3].

Lameness associated with proximal metacarpal pain can range from mild to severe [6–8]. Techniques for localising lameness to this region include anaesthesia of the lateral palmar nerve at accessory carpal bone, anaesthesia of the medial and lateral branches of the palmar metacarpal nerves, and direct infiltration of the proximal suspensory ligament (PSL) region [6–8]. None of these techniques have proven specificity for diagnosing proximal suspensory disease (PSD) [8]; at best, they are effective in identifying an area of suspicion to the proximal metacarpus and carpus [6–8].

Although frequently used for evaluation of the proximal metacarpus, ultrasonographic and radiographic studies have inherent limitations [9–11]. These limitations include a lack of specificity and sensitivity, and the fact that lesions identified using these modalities may not demonstrate strong correlation with clinical lameness [8]. Ultrasound techniques that allow evaluation of the PSL and its attachment to the third metacarpal bone (McIII) have been described by several authors [9–11]. Visualisation of the PSL is complicated by acoustic shadowing and by the presence of fat and muscle fibres within the ligament, which result in a heterogeneous appearance [9–11]. The diagnostic value of ultrasound is largely operator dependent and remains limited to soft tissues and the surface of bone [8–11]. Radiographic evaluation of the proximal metacarpus can provide information regarding the structural integrity of McIII at the PSL attachment, osseous irregularity of the second and fourth metacarpal bones (McII and McIV), and concurrent abnormalities in the carpus [8]. Nuclear scintigraphy (NS) of the proximal metacarpus and metatarsus has been described in normal and lame horses diagnosed with proximal suspensory desmitis [12,13]. Although NS has demonstrated sensitivity for identifying bone injury, interpretation in conjunction with more detailed imaging studies is necessary, and unfortunately shows limited correlation with ultrasound in the forelimb [13]. Computed tomography (CT) is capable of identifying pathological bone change; however, CT cannot identify bone oedema-like changes and provides limited soft tissue detail, even with contrast enhancement. [14]. For these reasons, magnetic resonance imaging (MRI) is considered the gold-standard imaging modality capable of providing best characterisation of changes in both hard and soft tissues [15–18].

Pathological changes within the proximal metacarpal area detected by MRI have shown good correlation with histological morphology of the PSL [16–18]. Lesions commonly diagnosed using MRI include thickening of the SL, discrete tearing, fibre disruption, osseous contusion of the palmar cortex of McIII at the PSL origin, and exostoses between McII and McIV [10,11,15,18–23]. Although normal anatomical parameters in sound horses with regard to size, shape, and the distribution of muscle and adipose tissue within the PSL have been documented [10,18], variation in these parameters is observed both within and between horse breeds, making direct comparison difficult [10,11,15,18–20].

The purpose of this investigation is to describe clinical lesions present in a group of horses with limited physiological variation, and document lesions associated with clinical lameness specific to the discipline of cutting. Secondly, this study aims to establish prognostic indicators for return to performance by evaluating a 24-month follow-up period on each case. We hypothesise that horses with more severe bone and soft tissue lesions will have a poor prognosis for return to performance, and will require longer periods of convalescence.

## Materials and methods

Medical records from a referral imaging centre were reviewed from 2009 to 2012. Cases were included in retrospective analysis if they were referred for an MRI of the proximal metacarpus following lameness examination that localised a component of lameness to the proximal metacarpus, and were registered Quarter Horses currently in training for, or competing in, cutting events. Lameness evaluation (AAEP Scale 0–5), diagnostic anaesthesia and basic diagnostic imaging (US $\pm$ radiographs) were performed by the referring veterinarian. The predominant lame limb was confirmed by one author (J.H.) prior to MRI.

MRI grading analysis was performed on a minimum of transverse proton density (PD) and sagittal fat-saturated proton density (PDFS) sequences, with frequent use of short TI inversion recovery (STIR) and T1 gradient echo (T1GRE) or T1 volumetric interpolated breath hold exam (T1 VIBE) sequences when available. Horses examined in 2009 and 2010 had studies obtained on a 1 Tesla high-field MRI, after which the facility upgraded to a 3 Tesla high-field MRI for 2011 and 2012. The slice thickness of 4 mm was obtained for transverse sequences and 3 mm slice thickness was obtained for sagittal sequences. VIBE images were acquired at 0.7 mm volumetric slice thickness. The region imaged was based on individual cases; bilateral studies were obtained on horses with clinical indication of bilateral proximal metacarpal pain or when anaesthetic time allowed for comparative sequences of the contralateral limb to be obtained. A single board-certified veterinary radiologist (M.B.), graded severity of pathological change from 0 (absent) to 3 (severe) for the following criteria based on previously described pathologic lesions: PSL enlargement, dorsal margin fibre damage, disruption of fat/muscle/ligament tissue architecture, periligamentous thickening, PD and STIR signal intensity of lesions, osseous proliferation at the enthesis on McIII, endosteal/trabecular fluid, sclerosis, and resorption within McIII, exostoses between McIII and McII/IV, and the presence or absence of osteoarthritis in the carpometacarpal and middle carpal joints (Table 1) [18–23]. In addition to subjective grading, PSL cross-sectional area (CSA) was measured on transverse PD sequences at four equidistant locations between the carpometacarpal joint and the nutrient foramen of McIII (Fig 1). MRI analyses were performed using OsiriX DICOM viewing software Version 7.0.[a] ‘Normal’ PSL size was established based on the absence of subjective enlargement across all studies including the lame and nonlame limb.

**TABLE 1: The subjective grading criteria used for each of the bone and soft tissue categories assessed by a single board-certified veterinary radiologist**

| Grade | 0 | 1 (Mild) | 2 (Moderate) | 3 (Severe) |
|---|---|---|---|---|
| SL size | Normal | <10% increase | 10–30% increase | >30% increase |
| Fat/muscle/ligament tissue architecture | Normal | <10% disruption | 10–30% disruption | >30% disruption |
| Dorsal margin irregularity | Normal | Mild irregularity-one lobe | Moderate irregularity-one lobe or mild irregularity-both lobes | Significant irregularity affecting the entire dorsal margin of the SL |
| PSL PD signal | Normal | Mild increased signal-focal regions | Moderate signal-focal regions or mild diffuse signal | Diffuse signal increase affecting >50% of the PSL |
| PSL STIR signal | Normal | Mild increased signal-focal regions | Moderate signal-focal regions or mild diffuse signal | Diffuse signal increase affecting >50% of the PSL |
| McIII STIR signal | None | Mild signal-focal regions | Moderate signal-focal regions or mild diffuse signal | Diffuse signal increase-large region of the palmar aspect of McIII |
| McIII sclerosis | None | Mild sclerosis – focal regions affecting less than 10% of the bone | Moderate sclerosis – focal regions or mild diffuse sclerosis affecting 10–30% of the bone | Diffuse sclerosis – large region of the palmar aspect of McIII affecting >30% of the bone |
| McIII resorption | None | Mild resorption – focal regions affecting less than 10% of the palmar cortex of McIII | Moderate resorption – focal regions or mild diffuse resorption affecting 10–30% of the palmar cortex of McIII | Diffuse resorption of the palmar aspect of the McIII affecting >30% of the bone |
| McIII proliferation at PSL origin | Normal | Mild bone proliferation affecting <10% of the palmar cortex | Mild bone proliferation affecting 10–30% of the palmar cortex | Mild bone proliferation affecting >30% of the palmar cortex |
| Osseous reaction with McII and McIV | None | Mild osseous proliferation of axial aspect of splint bones or mild change in signal of the interosseous ligaments | Moderate osseous reaction between McIII/MtIII and splint bones or moderate change in signal of the interosseous ligaments | Severe osseous reaction with suspect adhesion formation to the SL and severe change in signal of the interosseous ligaments |
| Carpometacarpal joint osteoarthritis | None | Mild osteophyte formation, enthosopathy, sclerosis or subchondral bone damage | Moderate osteophyte formation, enthosopathy, sclerosis or resorption | Severe osteophyte formation, enthosopathy, sclerosis or resorption |
| Middle carpal joint osteoarthritis | None | Mild osteophyte formation, enthosopathy, sclerosis or resorption | Moderate osteophyte formation, enthosopathy, sclerosis or resorption | Severe osteophyte formation, enthosopathy, sclerosis or resorption |

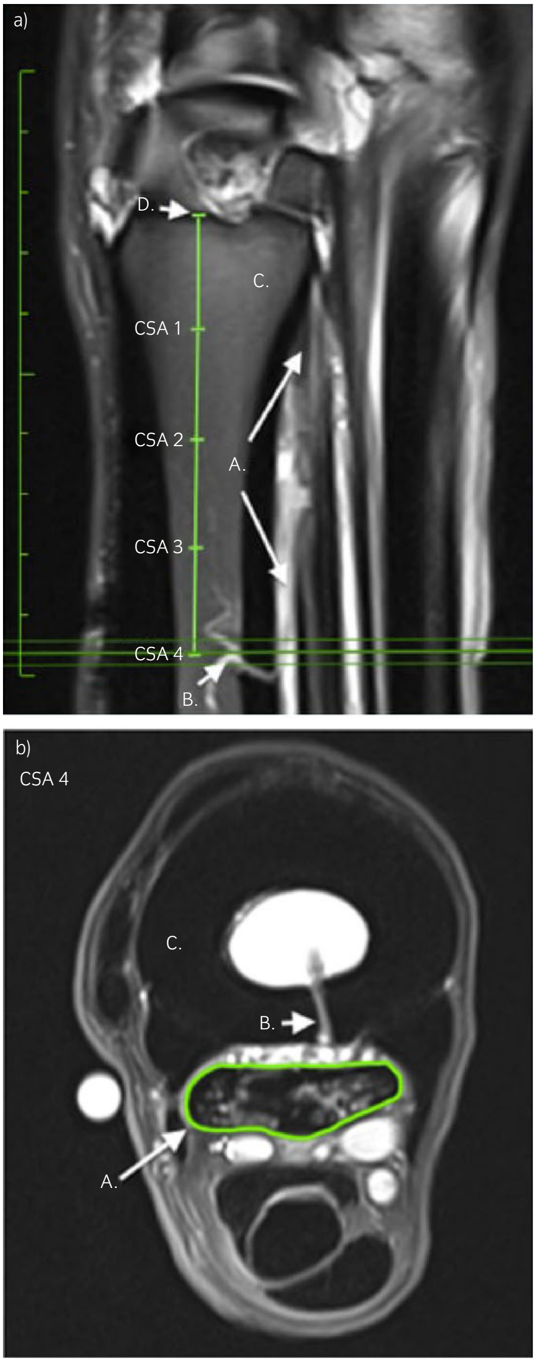


Fig 1: The measurement technique used to establish cross-sectional area of the PSL. a) Sagittal PD FS view of the proximal metacarpus and the relevant anatomical structures: A. Normal Suspensory Ligament B. Nutrient Foramen C. Third Metacarpal Bone D. Carpometacarpal joint. b) Corresponding transverse PD view of the metacarpus (C) at cross-sectional area level 4 (CSA 4) established by the location of the nutrient foramen (B), and measurement of the cross-sectional area of the suspensory ligament (A).

Official show records were obtained from the National Cutting Horse Association for each horse to evaluate Lifetime Earnings ($LTE). Records detailed the dollar value earned and date of competition for each Limited Age Event. In the absence of a show record, horse-owners were contacted to establish whether the horse ever competed in cutting events. A horse was considered to have a 'successful return to competition' on the basis that additional $LTE was recorded for the horse after the time of diagnosis. The date at which this occurred was used to calculate the number of days from diagnosis to 'successful return to competition'.

Descriptive statistical analysis of type and distribution of lesions were performed using Microsoft Excel; mean values were calculated and reported with 95% confidence interval. Pairwise Pearson correlation coefficients between each of the graded categorical variables were performed to detect significant correlation between categories of pathological change based on MRI findings ($P \leq 0.05$).

Severity of lameness, overall severity of soft tissue lesions, overall severity of bone lesions, $LTE post diagnosis and time until return to performance were used for regression analysis, with both age and $LTE at the time of diagnosis as covariants in the model. An overall grade for bone and soft tissue pathologic change was assigned to each horse based on the most severe lesion in each tissue type in the predominantly lame limb (Table 1). These grades were incorporated into a logistic regression model to assess significance of lameness, overall severity of bone lesions and overall severity of soft tissue lesions on return to performance. In a similar fashion, a linear regression model was used to assess significance of lameness, overall severity of bone lesions and overall severity of soft tissue lesions on time to return to performance. Regression models and Pearson correlations were performed using Statistical Analyses Software (SAS).

## Results

We evaluated 32 horses consisting of 20 right forelimbs and 24 left forelimbs (12 bilateral studies). The most frequent lameness score on presentation was a Grade 2/5, range 1–3. Mean age for all horses included in follow-up analyses was $3.9 \pm 0.3$ years, range 3–7 years. Mean duration of lameness until MRI diagnosis was $7 \pm 2$ weeks, range 1–22 weeks. The left forelimb was considered the primary lame limb in 17 horses, and the right forelimb was considered the primary lame limb in 15 horses. Based on diagnostic analgesia performed by each referring veterinarian, four horses had an MRI performed for bilateral forelimb lameness; the remaining eight bilateral studies were performed for comparison purposes and to assess for possible concurrent subclinical PSD of the nonlame limb.

Follow-up data were available for 30/32 horses included in the study. A total of 22/30 horses successfully returned to competition; 14 horses returned to competition within 6 months and 8 additional horses returned to competition within 12 months. No additional horses returned to competition between 12 and 24 months' post-injury. Mean time to return to competition was $157 \pm 38.2$ days, range 22–345 days. Of the eight horses that did not return to competition, five horses had previously competed successfully and were retired following injury and three horses never successfully competed in the intended discipline of cutting.

The changes identified in the PSL and McIII are summarised in Table 2. Enlargement of the PSL was noted on 30/44 studies, with the degree of enlargement graded as 'Moderate' or 'Severe' in 16. Of the 12 horses that had both forelimbs examined, nine were graded as having an enlarged PSL in the limb contralateral to the primary lameness. Four horses presented with bilateral forelimb lameness following diagnostic analgesia, three of which had bone and soft tissues lesions in the contralateral (less lame) limb. PSL fibre irregularity along the dorsal margin was the most consistently diagnosed lesion of the PSL on PD sequences, present in 30 of 44 studies. The distribution of these lesions was often confined to the medial bundle (16/30), or involved the entire dorsal margin (12/30); the latter observed predominantly in more advanced lesions. Moderate correlation was found between the degree of PSL enlargement and the severity or dorsal margin lesions present ($r^2 = 0.76$, $P<0.001$).

Mean CSA of 'Normal' PSL subjectively graded to have zero enlargement was $1.90 \pm 0.15$ cm$^2$, $1.71 \pm 0.10$ cm$^2$, $1.65 \pm 0.11$ cm$^2$ and $1.61 \pm 0.09$ cm$^2$ at levels one through four of the proximal metacarpus respectively. Figure 2 illustrates mean CSA of the PSL of Quarter Horses with Normal, Mild, Moderate and Severe enlargement at four equidistant locations between the carpometacarpal joint and nutrient foramen of the third metacarpal bone as demonstrated in Figure 1. From these data, there appears to be the greatest difference in CSA size as the ligament extends

**TABLE 2: The distribution of pathologic findings identified with MRI per limb**

| Grade | 0 (Normal) | 1 (Mild) | 2 (Moderate) | 3 (Severe) |
|---|---|---|---|---|
| SL size | 13/44 (30%) | 14/44 (32%) | 8/44 (18%) | 8/44 (18%) |
| Fat/muscle/ligament tissue architecture | 33/44 (75%) | 4/44 (9%) | 5/44 (11%) | 2/44 (5%) |
| Dorsal margin irregularity | 14/44 (32%) | 17/44 (39%) | 7/44 (16%) | 6/44 (14%) |
| PSL PD signal | 19/44 (43%) | 13/44 (30%) | 9/44 (20%) | 3/44 (7%) |
| PSL STIR signal[a] | 21/39 (54%) | 13/39 (33%) | 5/39 (13%) | 0/39 (0%) |
| McIII STIR signal[a] | 17/39 (44%) | 9/39 (23%) | 8/39 (21%) | 5/39 (13%) |
| McIII sclerosis | 2/44 (4%) | 20/44 (44%) | 11/44 (25%) | 12/44 (27%) |
| McIII resorption | 12/44 (27%) | 11/44 (25%) | 12/44 (27%) | 10/44 (23%) |
| McIII proliferation at PSL origin | 10/44 (23%) | 17/44 (39%) | 13/44 (30%) | 4/44 (9%) |
| Osseous reaction with McII and McIV | 24/44 (55%) | 16/44 (36%) | 5/44 (11%) | 0/44 (0%) |
| Carpometacarpal joint osteoarthritis[a] | 24/33 (73%) | 6/33 (18%) | 3/33 (9%) | 0/33 (0%) |
| Middle carpal joint osteoarthritis[a] | 25/28 (89%) | 2/28 (7%) | 1/28 (4%) | 0/28 (0%) |

[a]In these categories, total limb count is lowered because of study limitations that excluded evaluation of these parameters.

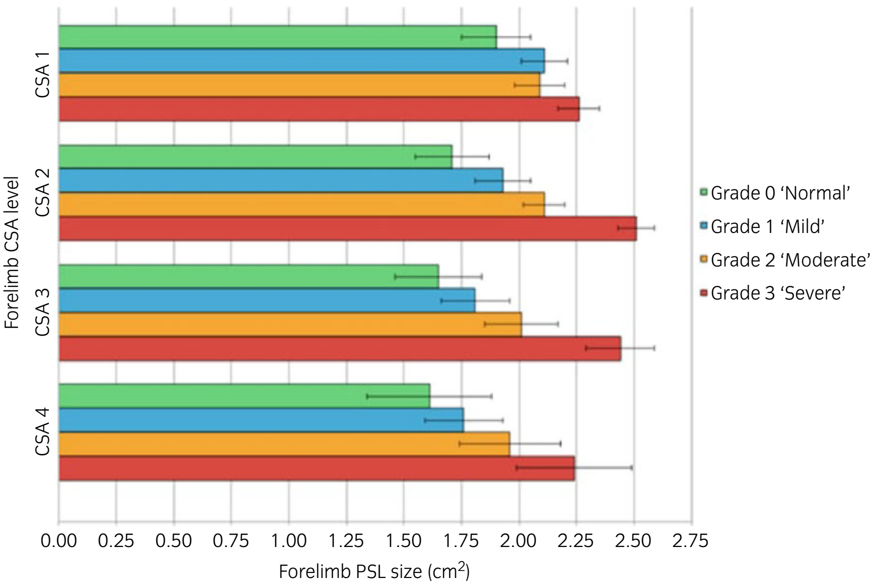


Fig 2: Mean cross-sectional area and standard error of the suspensory ligament at each level of the metacarpus from proximal (CSA 1) to distal (CSA 4), grouped by subjective grading of enlargement.

distally; thus, differences in subjective grading of PSL enlargement is most appreciable in these regions.

Some degree of osseous irregularity was diagnosed in nearly all horses. Sclerosis of McIII was noted in 42 of 44 studies (20 'Mild', 11 'Moderate' and 12 'Severe'). Osseous resorption of the palmar cortex of McIII was noted in 32/44 studies, of which 22 were graded 'Moderate' or 'Severe'. Finally, increased STIR signal within McIII consistent with endosteal fluid or 'bone contusion' was evident in 22/39 studies, with 13 graded as 'Moderate' or 'Severe'. In five studies, imaging limitations precluded evaluating abnormal bone fluid.

Of the eight unilaterally lame horses that had bilateral studies, six of eight had abnormal findings in the nonlame limb. Bone changes predominated, with mild endosteal sclerosis of McIII in five and moderate sclerosis in one; of these six, two horses had concurrent mild osseous resorption. Two horses had mild endosteal fluid signal. Mild PSL enlargement was noted in three horses and moderate enlargement and mild dorsal margin damage on two others.

Multiple osseous irregularities were noted in the proximal metacarpus that held modest correlations between both PSL size and the extent of dorsal margin fibre irregularity, relative to the degree of both sclerosis and osseous resorption present in the palmar cortex of proximal McIII (Fig 3). In addition to marked pathological change in both the PSL and McIII, Pearson correlation statistics between variables were considered significant with an $r^2$>0.5 and P≤0.05. A significant correlation was found to exist between both the degree of sclerosis and the degree of resorption present in the palmar cortex of proximal McIII ($r^2$ = 0.87, P<0.001). Moderate correlation was found to exist between the degree of osseous resorption and the severity of dorsal margin fibre irregularity present ($r^2$ = 0.72, P<0.001). Modest correlation was also found between the degree of osseous resorption and PSL enlargement, as well as osseous resorption and the amount of endosteal fluid present ($r^2$ = 0.62, P<0.001 and $r^2$ = 0.58, P = 0.001 respectively). Degree of sclerosis was also found to demonstrate modest correlation with PSL enlargement ($r^2$ = 0.61, P<0.001), severity of dorsal margin fibre irregularity ($r^2$ = 0.65, P<0.001) and amount of endosteal fluid present ($r^2$ = 0.66, P<0.001).

Proliferative osseous reaction between the PSL and the axial border of the McII or McIV was present in 20 studies (17 horses), of which 18 involved the McII. Finally, osseous irregularity characterised by bone resorption and/or sclerosis between the second and third carpal bones was also noted in 12 studies (11 horses).

No significant relationship was found to exist between return to performance (Yes/No) and age (P = 0.1), degree of lameness (P = 0.4), severity bone lesions (P = 0.5) and severity of soft tissue lesions (P = 0.9) when evaluated using a logistic regression model. Similarly, no significant relationship was found to exist between time to return to performance (days) and age (P = 0.2), degree of lameness (P>0.9), severity of bone lesions (P = 0.9) and severity of soft tissue lesions (P = 0.8) when evaluated using a linear regression model. Finally, no significant correlation

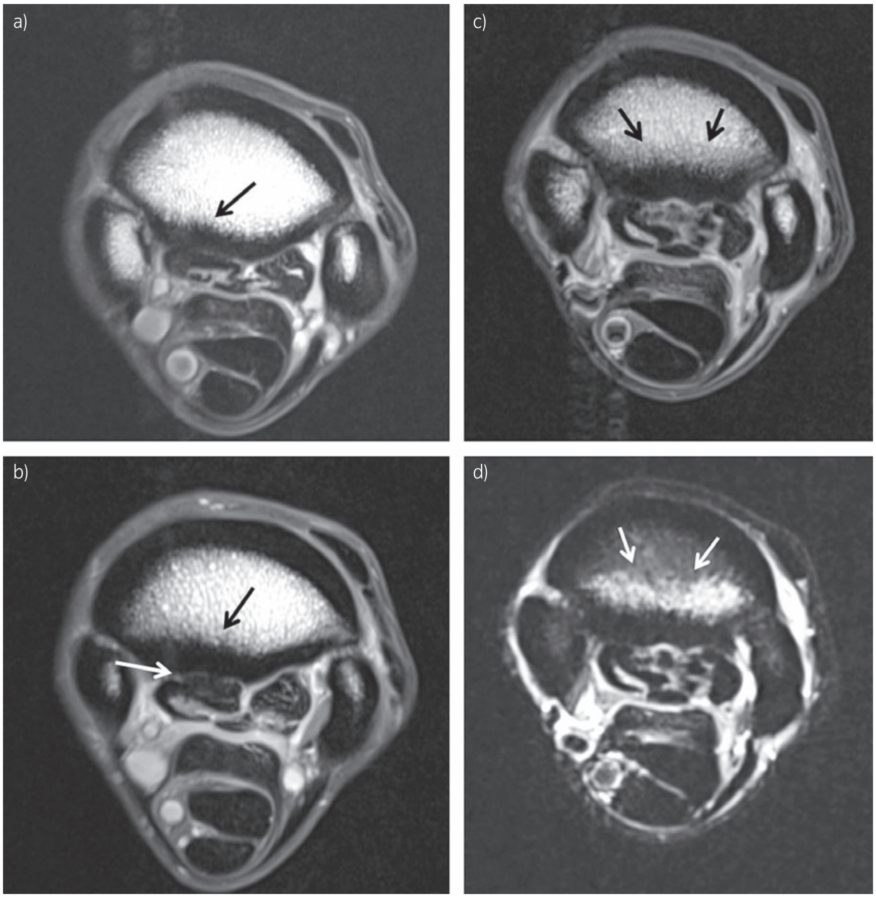


Fig 3: Transverse MR images of the proximal metacarpus at CSA Level 1 showing variation in degree of pathologic finding. a) Transverse PD image of a normal size suspensory ligament with mild endosteal sclerosis of McIII (black arrow). b) Transverse PD of a moderately enlarged suspensory ligament with palmar displacement of the fat and muscle bundles. Moderate endosteal sclerosis and osseous resorption. c) Transverse PD and d) transverse STIR images of the same limb. Severe suspensory ligament enlargement with dorsal margin damage, disruption of the fat and muscle tissue, severe endosteal sclerosis, osseous resorption and marked STIR fluid signal of McIII.

was found between the severity of lameness and the severity of bone lesions present ($r^2 = 0.005$, $P = 0.7$), nor the severity of lameness and the severity of soft tissue lesions present ($r^2 = 0.04$, $P = 0.3$).

## Discussion

In contrast to our hypothesis, degree of lameness at time of diagnosis and severity of lesions (bone and/or soft tissue) were not found to be significantly associated with successful return to performance or time to successful return. It must be recognised that this population of horses frequently sustain multiple orthopaedic injuries impacting athletic performance [1,2], and thus affect $LTE post-injury and longevity of competitive career. For this reason, follow-up analyses was restricted to return to performance only, rather than quantitative assessment of $LTE, due to difficulties controlling for prize money availability, level of competition and additional orthopaedic injury sustained in the follow-up period. No significant correlation was found between the type or severity of lesion/s present and the severity of lameness at the time of diagnosis. Lack of correlation between severity of lameness and severity of lesions, and lack of influence of these factors on the duration of convalescence or successful return to competition were all unexpected. In the light of these findings, it is possible to contend that a horse may compete successfully in cutting in spite of injury to the proximal suspensory ligament.

Pathological change described in both the PSL and the surrounding bone may both contribute to clinical lameness. It is important to note that McIII sclerosis and resorption frequently occurred in conjunction with PSL enlargement in this group of horses, and should therefore be considered when selecting appropriate treatment modalities. Results of this study demonstrate that proximal metacarpal pain will likely have some degree of both bone and soft tissue involvement; care should be taken to assess the dorsal margin of the PSL, particularly the medial lobe and potential exostoses with McII as these are frequent sites of clinical lesions in cutting horses.

The examination of this group of horses indicated that nearly all horses have some degree of sclerosis in the palmar cortex of McIII, and this was strongly correlated with the presence and severity of osseous resorption. The frequency at which both these physiological processes occur within the same region of bone may ultimately weaken the enthesis of the PSL, and play a critical role in the development of PSD. Repetitive stress response vs. repetitive stress injury of subchondral bone has been well-documented in Thoroughbred racehorses [24,25]. The process of bone adaptation vs. pathological change may also play a critical role in the development of PSD in cutting horses. As bone sclerosis was also seen in 75% of nonlame limbs, there is likely a subclinical component of bone remodelling and a continuum between adaptive remodelling and degenerative change. Further investigation into the role of bone modelling and remodelling in response to stress to the proximal metacarpal region may be necessary to better understand the development of PSL enthesopathy.

Subjective assessment of PSL enlargement using MRI was less accurate at CSA Level 1, evidenced by the overlap between objective measurement of 'Mild' and 'Moderate' categories (Fig 2). Difficulty in establishing the boundaries of the PSL enthesis at CSA Level 1 may be responsible for the apparent disparity in subjective grading of ligament size. Previous publications also show greater variance in the more proximal CSA measurements when comparing MRI, ultrasound and histology of the PSL in normal Quarter Horses of similar age range [11]. Although sound horses without history of proximal metacarpal pain were not used to establish 'normal' CSA parameters for this study, our objective measurements of 'Normal' PSL size are consistent with previous findings in normal Quarter Horses of similar phenotype at 2, 4 and 6 cm distal to the carpometacarpal joint measured using MRI [11]. A second publication reported substantially larger mean CSAs of the PSL in normal Warmblood horses measured using MRI [10]. At a level comparable to CSA Level 2 in the current study, normal Warmblood horses were found to have a mean PSL CSA of 2.86 $cm^2$ (min = 2.37 $cm^2$, max = 3.59 $cm^2$), whereas Quarter Horses in the current study subjectively graded to have a normal PSL had a mean PSL CSA of 1.71 $cm^2$ (min = 1.40 $cm^2$, max = 2.0 $cm^2$) [13]. Our findings in conjunction with the published literature further demonstrate the difference in PSL size between Quarter Horse and Warmblood breeds [10,11]. Previous literature describing forelimb PSL CSA measurements in normal Quarter Horses demonstrated moderate to strong correlations between CSA measured using MRI, Angle Contrast Ultrasound Technique and histology at levels 4–8 cm distal to the carpometacarpal joint [11]. When interpreted in conjunction with the strong correlations found between PSL enlargement and McIII sclerosis and resorption in the current study, it is possible to contend that lameness clinicians can have some indication of the presence of McIII resorption and sclerosis, based on PSL CSA measurements obtained with appropriate ultrasound technique.

One critical weakness of this study is the small population limiting statistical significance. Limitations including availability of comprehensive patient history, subjective lameness evaluation by multiple veterinarians, varying diagnostic analgesia techniques and treatment protocols prevented more in-depth analysis of prognosis or effect of treatment type. Although the referring veterinarians generally performed ultrasound and radiographs prior to referral for MRI, unfortunately these studies were not available for review. The majority of referring veterinarians of the horses in this study are highly experienced with treating cutting horses and recognise that pathologic bone change at the PSL enthesis is often found in horses with lameness localised to the PSL. In part due to this, horses among this study population are frequently referred for MRI when initial treatment protocols do not resolve performance-limiting lameness (in comparison to clinical lameness). This selection bias may exclude less severe cases of PSD from the study population, and is one possible explanation for the unexpected results. However, in some cases, the decision to perform an MRI is based on acquiring more information to determine best course of action for the horse. Considering the rapid timeline for performance at a young age, accurate diagnosis is often needed to make an appropriate decision. Unfortunately, the information necessary to characterise the decision for MRI are not available.

Despite these limitations, the results of this study demonstrate that among cutting horses, moderate to severe bone and soft tissue lesions of the proximal metacarpus should not be considered career-ending injuries. In most cases, approximately 6 months convalescence is necessary with various treatment and rehabilitation protocols. Horses frequently received extra-corporeal shockwave therapy, systemic and regional administration of tiludronate, and periligamentous injection of platelet-rich plasma or triamcinolone acetonide. In this retrospective case series, lack of standardisation and the combination of several aforementioned treatments prevents further statistical analysis. Eight horses had lameness examinations performed in close proximity to their successful return to competition; four horses were considered sound and four horses had persisting grade 1/5 lameness in the affected limb. It should be recognised that cutting horses are permitted to compete on low doses of nonsteroidal anti-inflammatory drugs under the governing regulations of the American Quarter Horse Association and the United States Equestrian Federation.

It cannot be concluded from these results whether PSL enlargement and dorsal margin fibre irregularity occurs as the primary disease process with secondary osseous resorption, or vice versa. Further MRI studies of horses with less-advanced clinical disease are necessary to better elucidate the order in which these processes take place. Moreover, there is inherent value in repeating MRI examinations of clinical horses at a time point where clinical lameness has improved or resolved to better assess healing of pathologic bone and soft tissue lesions. Thorough diagnostic imaging utilising multiple modalities is essential for better understanding of the disease process, which in turn may lead to improved treatment strategies and management of PSD.

From this evaluation, it may be concluded that pathological change in both the PSL and proximal McIII are responsible for the clinical manifestation of PSD. Enlargement of the PSL can be subjectively assessed and confirmed with CSA measurement; an increase in this parameter supports the presence of concurrent osseous resorption and sclerosis in palmar McIII. The severity of these lesions does not appear to influence long-term athletic performance in the discipline of cutting. Future characterisation of the disease process responsible for clinical lameness is essential to implement appropriate treatment of PSD improve future treatment and rehabilitation of PSD.

## Authors' declaration of interests

No competing interests have been declared.

## Ethical animal research

This study was approved by the Colorado State University Gail Holmes Equine Orthopaedic Research Center. Explicit owner informed consent for inclusion of animals in this retrospective study was not stated.

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## Authorship

M. Barrett was responsible for interpretation of diagnostic imaging, study design and manuscript preparation. P. Manchon was responsible for data collection, study design and manuscript preparation. C. Kawcak was responsible for study design and manuscript preparation. J. Hersman was responsible for original data collection.

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