THESIS

THE RELATIONSHIP BETWEEN RADIOGRAPHIC CHANGES AND PERFORMANCE OUTCOME IN QUARTER HORSE CUTTING HORSES

Submitted by

Myra Frances Barrett

Department of Clinical Sciences

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2010

Master's Committee:

Department Head: D. Paul Lunn

Advisor: C. Wayne McIlwraith

Richard Park
Christopher Kawcak
Natasha Werpy

ABSTRACT OF THESIS

THE RELATIONSHIP BETWEEN RADIOGRAPHIC CHANGES AND PERFORMANCE OUTCOME IN QUARTER HORSE CUTTING HORSES

Reason for Performing the Study

Radiographic repositories are become increasingly popular in multiple disciplines as a screening tool prior to sale. However, the importance of the radiographic findings must be objectively assessed relative to potential significance. While studies have been done to correlate survey radiographic findings with performance outcomes in Thoroughbreds, no such published study exists in Quarter Horses. This paper serves as part two of a study examining the relationship between radiographic changes in survey radiographs relative to objective performance outcomes in Quarter Horse cutting horses.

The goal of this study is to better clarify the potential significance of radiographic changes on repository radiographs relative to performance. This in turn will allow veterinarians and their clients to make more objective, informed decisions prior to purchase about the potential implications of various radiographic changes.

Methods

Radiographic changes of 436 Quarter Horses, which were quantified in a previous paper (Contino *et al* 2009), were compared to objective performance outcome parameters. The parameters were: 1) likelihood of competing, 2)likelihood of earning money as a three year old, four year old and as a three and four year old combined, 3) average amount of money earned as a three year old, four year old and as a three and four year old combined. Mailed questionnaires and phone calls to owners of horses that did not earn money were used to try to determine why the horse had no recorded earnings.

Results

When the tarsometatarsal (TMT) and distal intertarsal (DIT) joints were examined together, the presence of mild (grade 2) osteophytes, which affected 19% of the horses, was associated with reduced chance of competing, earning money and mean money earned. Very mild and mild osteophytes of the third and central tarsal bone assessed individually at the level of the TMT and DIT also had some significant effects in multiple performance outcome categories. The presence of thickening of the dorsal cortex of the hind second phalanx as well as osteophytes as this location was associated with an increased likelihood of earning money. Several other potentially significant findings are reported but affect a relatively small number of the horses included in the study. Radiographic changes of the medial femoral condyle of the stifle were not significantly associated with performance outcome.

Conclusions

Many radiographic changes were not found to be significantly associated with performance outcome. However, some mild changes were associated with decreased performance. In addition, some radiographic changes were correlated with improved performance outcome. The findings of this study can be used to help veterinarians make more objective assessments of survey radiographic findings prior to sale. This research helps lay the groundwork for further investigations of the significance of survey radiographic findings in individual breeds and disciplines.

ACKNOWLEDGEMENTS

Thank you, Dr. McIlwraith, for the opportunities that you have provided for me; you have opened many doors, and I am very grateful for all that you have taught me. To Dr. Park, you have been a wonderful mentor to me, showing me true kindness and professionalism. Dr. Kawcak, you too have provided many opportunities for my professional development, and I am very grateful for your confidence and friendship. Dr. Werpy, I am glad that we are where we are today: you are both a mentor and friend.

I am also very grateful for the tireless work and great patience of Dr. Sangeeta Rao, whose statistical expertise was integral to this study, as well to Dr. Francisco Olea-Popelka for his involvement in the statistical analysis. Thank you as well to Taryn Yates, who helped me with data entry, for her diligence, efficiency and excellent work ethic.

Dr. Erin Contino, who was my trailblazer – thank you for your advice, help and true friendship. And of course, thank you also to Dave and Siena, for keeping it all in perspective.

TABLE OF CONTENTS

ABSTRACT OF THESIS…………………………………………………………..ii

ACKNOWLEDGEMENTS………………………………………………….........iv

CHAPTER 1: LITERATURE REVIEW

Radiographic Sales Repositories and Existing Research………………………….1
Specific Radiographic Findings – Stifle………………………………………..3
Femorotibial Joint……………………………………………………………4
Femoropatellar Joint…………………………………………………………6
Specific Radiographic Findings – Tarsus………………………………………8
Tarsocrural Joint……………………….……………………………………..8
Distal Tarsal Joints……………………………………………………….10
Specific Radiographic Findings – Metatarso/metacarpophalangeal Joint……….12
Proximal Sagittal Ridge of the Third Metacarpal/tarsal Bone………...…12
Fragmentation of Proximodorsal First Phalanx………………………….14
Fragmentation of Palmar/Plantar First Phalanx………………………….16
Palmar Supracondylar Lysis……………………………………………..18
Specific Radiographic Findings – Carpus……………………………….….19
Summary……………………………………………………………………19

CHAPTER 2: MATERIALS AND METHODS

Included Horses………………………………………………………….21
Follow-up Parameters…………………………………………………….22
Lesions of the Stifle……………………………………………………...23
Lesions of the Tarsus………………………………………...…………..24
Lesions of the Fetlock…………………………………………………….25
Lesions of the Carpus…………………………………………………….25
Data Analysis…………………………………………………………...….25

CHAPTER 3: RESULTS

Radiographic Changes Significantly Associated with Likelihood of
Competing in Cutting Competitions……………………………………………..30
Radiographic Changes Significantly Associated with Likelihood of
Earning Money in Cutting Competitions……………………………….….31
Radiographic Changes Significantly Associated with Amount of Money
Earned in Cutting Competitions………………………………………....…33
Radiographic Changes Not Associated with a Performance Outcome………..…36
Radiographic Changes with Insufficient Numbers with which to
Draw Conclusions…………………………………………………………….38
Reasons for Not Competing……………………………………………………...38
Tables……………………………………………………………...………..40

CHAPTER 4: DISCUSSION……………………………………………………...……..49

REFERENCES………………………………………………………………………..54

CHAPTER 1

Radiographic Sales Repositories and Existing Research

Radiographic repositories have long been included as standard practice in the racing Thoroughbred yearling sales (Kane *et al.* 2003a, Hance and Morehead 2000). Additionally, while standardized radiographic repositories are less common outside the racing Thoroughbred industry, radiographs are commonly available for viewing prior to sales in other equine disciplines. The goal of these pre-sale radiographs is to provide information about current orthopaedic status as well as attempt to be predictive of the development of future orthopaedic disease (Bladon and Main 2003). Radiograph repositories differ from pre-purchase radiographs in that repositories generally contain a required set of views and are performed on young horses thought to be free of disease (Kane *et al.* 2003a, Martin *et al* 2003), whereas pre-purchase radiographs are included as part of a more complete clinical workup and targeted at specific areas of concern which may affect performance in the individual horse (Van Hoogmoed *et al* 2003, Mitchell 2009).

There has been research dedicated to determining the prevalence (Howard *et al.* 1992, Oliver *et al* 2008) and, more importantly, clinical significance (Cohen *et al* 2006, Jackson *et al* 2009, Kane *et al.* 2003a, 2003b, Spike-Pierce and Bramlage, 2003) of pre-sale radiographic findings in Thoroughbred yearlings. Standardbred trotters have also been the focus of multiple studies attempting to correlate pre-racing radiographic findings with racing performance (Alvarado 1989, Couroucé-Malblanc *et al* 2006, Grǿndahl and Engeland 1995, Jorgensen *et al* 1997, Robert *et al* 2006). However, the clinical significance of findings in young racing Thoroughbreds and Standardbreds is not necessarily comparable as different breeds and disciplines tend to suffer from distinctive types of orthopaedic pathology (Pool 1996). For example, racing Thoroughbreds are prone to pathologic change in the carpi and fetlocks; therefore, these regions are the most frequently included in sales radiographs (Howard *et al.* 1992, Kane *et al.* 2003a). On the other hand, Western performance horses are more commonly afflicted in the feet, tarsi and stifles (Carter 2009, Dabareiner *et al* 2005a, 2005b, Jackman 2001). In order for veterinarians to more accurately predict future performance and development of disease, the clinical significance of radiographic findings of young horses of other breeds and disciplines must be explored.

Although, as stated above, the majority of previous research involving radiographic repositories or the use of pre-sale radiographs and clinical outcome has been focused on racehorses, there has been a growing demand for studies aimed at other disciplines. In particular, the Western performance industry has grown significantly in recent years. Subjective papers (Black 1999, Carter 2009) have been presented regarding pre-purchase examinations of Western performance horses; and Dabareiner *et al* (2005a, 2005b) have published research examining radiographic abnormalities and lameness in barrel horses and roping horses. Although most Western performance horses are typically Quarter Horses, their individual disciplines can affect the types of stresses they undergo and the clinical significance of various radiographic findings (Carter 2009, Jackman 2001). Therefore, the demand exists to study more specific disciplines within the category of Quarter Horses and Western performance horses.

With this focus on specific disciplines in mind, the first large scale study of prevalence of radiographic lesions in Quarter Horse cutting horses was undertaken by Contino *et al* (2009). The authors reported on the prevalence of changes found on repository radiographs of 458 yearling and two-year old cutting horses. The findings of that study form the framework for the follow-up study that will be presented here, comparing the radiographic findings to performance outcomes.

Specific Radiographic Findings

Stifle

Including complete and incomplete studies, the stifles (99.1%) were the most commonly included joints in the repository series examined by Contino (2009), reflecting one of the greatest areas of interest of pathologic change in horses of this discipline. In order to be included in the analysis, a stifle study was required to contain a caudal 10^o proximal-cranial (CC) to be complete, and many also contained a caudo 30^o lateral-craniomedial oblique (CdL-CrMO). This is in contrast to the study by Kane *et al* (2003a), in which merely 57% of the studies contained stifle radiographs and included only a LM view. A CC, CdL-CrMO or flexed LM is necessary to thoroughly evaluate the MFC, as the condyles are superimposed on the standing LM; therefore, the lack of inclusion of the CC or oblique view as well as the low overall submission of stifle radiographs in the repositories examined by Kane *et al* (2003a) reflected the decreased focus of the racing Thoroughbred industry on pathologic change of the femorotibial joint relative to other joints. Although since the time of that study specific guidelines for the Keeneland Thoroughbred repository have been put in place that require both a LM and CdL-CrMO to be included, the femorotibial joint still generally receives less emphasis in the racing industry than it does in the Western performance horse industry.

Femorotibial Joint

Changes to the MFC were the most frequent finding in the analysis by Contino *et al* (2009), with 41.4% of horses having some degree of change in at least one limb. The grading system used by the researchers was as follows: A grade 0 represented a normal MFC, which is continuously convex in contour; grade 1 described a flattened contour but no radiographic evidence of changes in the subchondral bone; grade 2 indicated subchondral bone sclerosis and/or defects in the subchondral bone that did not extend all the way through the subchondral bone plate; grade 3 applied to defects that extended through the subchondral bone such as wide, shallow subchondral lucencies; grade 4 described a well defined round or oval radiolucent area in the middle of the MFC that extended to and communicated with the femorotibial joint. Of the affected horses, 51.6% had bilateral lesions. Overall, 21.6% horses had flattening of the MFC, 8.1% had a grade 2 lesion that did not extend through subchondral bone, 6.6% had a grade 3 defect extending through subchondral bone and 5.1% had a grade 4 well-defined SBC.

The radiographic repository study of 2401 Australian racehorses by Jackson *et al* (2009) reported osseous cyst-like lesions in the MFC of 5.6% of horses. However the classification system used in that study was different, with only two categories assigned to changes of the MFC: one for lesions >6mm in depth, and one for ≤6mm. Only 21 out of 2401 horses (0.9%) had lesions which were >6mm. Horses with lesions of the MFC >6mm were less likely to start a race as 2 and 3 year-olds compared to horses with no lesion.

Cohen *et al* (2006) reported SBCs of the MFC on 18 horses in their study of the repository findings of 348 Texas Thoroughbred yearlings. That work showed no significant association between performance outcomes and presence of a cystic lesion of the MFC. However, there was no reported quantification of the size of the SBC or a grading scheme mentioned for MFC defects.

Previous work focused on SBCs of the MFC does report a potential for decreased performance associated with the presence of these lesions, especially when treated conservatively. In a study of 51 horses with unilateral or bilateral SBCs of the MFC, 42 (82%) of the horses partially or completely improved following surgical curettage of the cysts (White *et al* 1988). Of the horses that improved with surgery, many had previously been rested with little to no success, leading the authors to recommend surgery in cases where three months of rest did not yield improvement. Work done by Howard *et al* (1995) found a 74% success rate in horses treated with arthroscopic curettage of SBC. A study of surgical curettage of 85 cases of SBCs found that age affected the chance of success of surgical debridement, with a success rate of 64% in horses $\leq$ 3 years old and only 34% in horses older than 3 years of age (Smith *et al* 2005). The size of the articular cartilage defect associated with an SBC can also affect outcome, with lesions greater than 15 mm having been shown to decrease the likelihood of starting a race in Thoroughbred racehorses (Sandler *et al* 2002).

Wallis *et al* (2008) described 52 cases of SBCs that had been treated with arthroscopic injection in the fibrous tissue lining. The grading scheme used in that study was modified from the work of Howard *et al* (1995) and differs from that used by Contino *et al* (2009). The grading was as follows: Type 1 were <10 mm in depth and dome shaped; Type 2A lesions were >10 mm in depth and described as lollipop or mushroom shaped with a narrow cloaca and cystic lucency; Type 2B lesions were >10 mm in depth with a large domed lucency extending to wide articular surface defect; Type 3 lesions were flattening or small defects in the subchondral bone; Type 4 lesions had a lucency in the MFC with or without an articular defect, but with no apparent cloaca in the subchondral bone. The results reported by Wallis *et al* (2008) were that 67% of horses successfully worked at their intended use, and 77% were sound, but not necessarily performing in their intended athletic use. Significant factors that improved the likelihood of success included surgeon, multiple injection sites, shorter time to follow-up and return to exercise, lack of pre-operative osteophytes and unilateral lesions. Unlike the findings of Smith *et al* (2005), age did not affect outcome. Although it was not statistically significant, cutting horses did have a less successful outcome (55%) than the average.

Femoropatellar Joint

Changes in the femoropatellar joint (FPJ) were relatively uncommon in the study of Contino (2009). Out of the 433 horses in which the FPJ could be assessed, only 14 horses had radiographic changes. Lesions of the lateral trochlear ridge (LTR) were the most common finding, affecting 10 (2.3%) horses. Of these 10, flattening of the LTR affected 3 horses (0.7%) and the other 7 (1.6%) had a fragment and associated defect in this location. Only 1 horse had a lesion of the medial trochlear ridge (MTR). This is consistent with previous reports of the LTR being much more frequently afflicted with osteochondritis dessicans (OCD) than the MTR (Blevins and Widmer 1990, Foland *et al.* 1992, Martinelli and Rantanen 2002).

In a study of femoropatellar OCD in 161 horses that underwent arthroscopic surgery, Thoroughbreds were more commonly affected (51%) than were Quarter Horses (24%) (Foland *et al.* 1992). The reported radiographic prevalence of femoropatellar OCD in Thoroughbreds has varied from 11% (13 of 120) to 4.3% (2 of 47) (McIntosh and McIlwraith 1993, Howard *et al.* 1992). Kane *et al.* (2003a) reported that of 660 Thoroughbred yearlings, 38 (5.7%) had changes in the LTR including flattening, defects or fragments. LTR changes were found in 3.8% (91 of 2401) of Thoroughbreds by Jackson *et al* (2009). A similar prevalence of LTR lesions (4.3%, 15 of 348) in Thoroughbreds was reported by Cohen *et al* (2006).

When comparing radiographic repository findings to performance outcomes, Jackson *et al* (2009) found that horses with a mild femoropatellar OCD lesion (20 mm or less in length) took longer to make their first start by an average of 66 days and were less likely to place two or more times (OR 0.48). Conversely, Cohen *et al* (2006) found no significant association between number of starts, earnings or sales price and abnormal radiographic findings of the femoral trochlear ridges.

Good surgical outcomes have been reported for horses that have clinical signs of femoropatellar OCD. Foland *et al* (1992) reported that of 134 horses with follow-up information available, 86 (64%) returned to their intended use and an additional 9 (7%) were in training. The chance of a successful outcome was influenced by the size of the lesion. Horses with lesions < 2 cm were significantly more likely to be successful than those with larger lesions. In a study of 24 horses, including 9 Thoroughbreds and 8 Quarter Horses, the clinical signs of all horses improved immediately following arthroscopy, and of the 21 horses with follow-up, 13 (61.9%) were performing, or in training for, their intended use (McIlwraith and Martin 1985).

Tarsus

In the Quarter Horse radiographic repository examined by Contino (2009), tarsi were the most commonly included region after stifles, with radiographs available for 95.6% of the horses. Like the high rate of inclusion of stifles in the repository, the large percentage of horses with tarsal radiographs reflects that this is a particular area of concern in the Western performance horse (Carter 2009, Dabareiner *et al* 2005a, 2005b, Jackman 2001). Further indication of the emphasis on tarsal pathologic change in the Quarter Horse is that a full set of four views of the tarsus was required in the repository examined by Contino (2009). In contrast, the Keeneland Thoroughbred yearling repository only requires three views of the tarsus, and excludes the DLPMO from its criteria.

Tarsocrural Joint

The most common finding in the tarsocrural joint recorded by Contino (2009) was flattening of the MTR of the talus, which affected 54 (12.3%) horses. However, this is a normal variant and not pathologic change, and thus is not considered clinically significant (Becht and Park 2000, Butler *et al.* 2008).

Change to the distal intermediate ridge of the tibia (DIRT) was the pathologic change most commonly detected by Contino (2009) in the tarsocrural joint, affecting 38 of 438 (8.7%) of horses. This rate is lower than has been reported in Thoroughbreds. Kane *et al.* (2003a) found that out of 1101 Thoroughbred yearlings, 48 (4.4%) had a concavity or fragment of the DIRT. An even lower prevalence of DIRT lesions was found by Howard *et al.* (1992), with 13 out of 710 (1.8%) yearling Thoroughbreds affected. In contrast, Warmbloods tend to be more frequently affected than Thoroughbreds or Quarter Horses. In a study of Dutch Warmbloods, Dik *et al.* (1999) found the prevalence of DIRT OCD to be 18% of 43 horses. Similarly, Hoppe (1984) found DIRT OCD in 15% of 27 clinically normal Swedish Warmbloods. The prevalence of DIRT OCD in Standardbred trotters was reported by Carlsten *et al* (1993) to be 10.4%, which is similar to what Contino (2009) in Quarter Horses.

The reported clinical effect of OCD of the DIRT is variable. Neither Cohen *et al* (2006) nor Jackson *et al* (2009) found an association of DIRT lesions found on repository radiographs and performance outcomes in Thoroughbred racehorses. Likewise, Kane *et al* (2003b) also found no significant differences in chances of starting a race, placings, money earned or earnings per start between Thoroughbred yearlings with tarsocrural OCD and those without. It is not uncommon for horses with DIRT lesions to have tarsocrural joint effusion and yet not necessarily be lame. In a study of 114 Standardbreds with OCD in the DIRT, 82 (72%) were reported to have tarsocrural joint effusion but only 49 (43%) were lame in the affected limb (Laws *et al* 1993); lameness was more common in horses of training or racing age. When reporting on tarsocrural OCD associated with clinical signs, McIlwraith *et al* (1991) found that articular cartilage degeneration or erosion found at arthroscopy was associated with a decreased prognosis, whereas lesion size and resolution of effusion did not influence prognosis. Effusion associated with lesions affecting the DIRT resolved more frequently than lesions in the lateral trochlear ridge (LTR) or medial malleolus (MM). Quarter Horse racehorses had a lower percentage of successful outcomes (60%) than Quarter Horses used for other disciplines (87.5%).

Distal Tarsal Joints

The presence of osteophytes was the most common finding in the distal tarsus in the study by Contino (2009), affecting 201 out of 438 (45.8%) horses and were bilateral in 67 (33%). Osteophytes were graded on a scale of 1-4, from very small to large; 79 (18%) horses had grade 1, 82 (18.7%) had grade 2, 31 (7.1%) had grade 3 and 9 (2.1%) had grade 4 osteophytes. Proximodorsal MTIII was the most common location for tarsal osteophytes (100, 22.8%). Similarly, Jackson *et al* (2009) reported osteophytes most frequently affecting the tarsometatarsal joint (TMT) in yearling Thoroughbreds at a rate of 35.4% (849 of 2401). This is a higher prevalence than what has been previously reported in Thoroughbred yearlings. Kane *et al* (2003a) reported osteophytes or enthesophytes in the distal tarsal joints of 193 of 1101 (17.5%) horses, and Howard *et al* (1992) found osteophytes in only 16 of 710 (2.3%) TMT joints in Thoroughbred yearlings.

Contino (2009) reported lysis of the distal tarsal bones as the next most frequent finding in the tarsus, with 76 (17.3%) horses affected. By severity, 28 (6.4%) horses had grade 1, 35 (8%) had grade 2, 13 (3%) had grade 3 lysis, and no horses had grade 4 lysis.

The proximal aspect of third tarsal bone was the most commonly affected site (46, 10.5%). Sclerosis was recorded in 29 (6.6%) horses; the majority of affected horses had grade 1 (25, 86.2%) sclerosis; grade 2 and 3 sclerosis affected 3 (10.3%) and 1 (3.4%) horses, respectively. In Thoroughbred yearlings, Kane *et al.* (2003a) reported that 80 out of 1101 (7.3%) had subchondral lucency in the DIT or TMT joint. The Thoroughbred repository study by Jackson *et al* (2009) reported solely on osteophytes as changes in the distal tarsal joints, and Cohen *et al* (2006) did not discuss distal tarsal changes. A study of 214 multiple breed horses conducted by Van Hoogmoed *et al.* (2003) demonstrated very subtle bony remodeling, classified as grade 1, in the proximal intertarsal joint (PIT), distal intertarsal joint (DIT), and TMT joints in 10.4%, 45.8% and 50.4% respectively. Mild to moderate periarticular osteophyte production and mild subchondral lysis (grade 2) was recorded in 3.8% and 15.6% of DIT and TMT joints respectively. Grade 3 changes, such as marked periarticular osteophyte production, subchondral sclerosis, cystic lucencies and joint space narrowing or fusion was found in 3.8% of DIT and 4.5% of TMT joints.

Lameness due to distal tarsal pain is commonly reported in Western performance horses (Jackman 2001, Dabareiner 2005a, 2005b). However, there is some discrepancy reported between radiographic abnormalities of the distal tarsal joints and clinical findings. In a retrospective study of prepurchase exams, Van Hoogmoed *et al.* (2003) found that there was not a significant correlation between the radiographic abnormalities of the tarsus and soundness, although horses with mild changes were more likely to be sound than those horses with severe changes. Byam-Cook and Singer (2009) reported on 91 horses with a history of lameness. The severity of radiographic change in the distal tarsal joints was not correlated with duration or degree of lameness. There was, however, a significant relationship between response to treatment and severity of radiographic changes in the TMT, but not the DIT, with less radiographically severe lesions responding better. Kane *et al.* (2003b) found that yearling Thoroughbreds with osteophytes or enthesophytes in the DIT or TMT joints started significantly (p=0.03) fewer races than yearlings without these radiographic changes. Seventy-six percent of 193 horses with DIT or TMT osteophytes started a race compared to 83% of horses without this finding. Conversely, Jackson *et al* (2009) found no effect of the presence of distal tarsal osteophytes on performance outcomes of yearling Thoroughbreds, including time from sale to first race, chance of starting, number of starts, placings, or earnings.

Metatarso/metacarpophalangeal joint (Fetlock)

Proximal Sagittal Ridge of the Third Metacarpal/tarsal Bone

Contino (2009) found that the proximal sagittal ridge (SR) was the most commonly affected site in both the hind and fore fetlocks. Out of 355 horses for which hind fetlock radiographs were available, 54 (15.2%) horses had flattening of the proximal SR or distal dorsal aspect of the third metatarsal bone (MRIII), 14 (3.9%) had a lucency or dissecting lesion and 1 (0.3%) had a loose fragment. For the fore fetlocks, 361 horses had radiographs available for interpretation. Of these, 54 (15%) horses had changes of the distal dorsal aspect of the third metacarpal bone (MCIII) and proximal SR. Flattening of the sagittal ridge was recorded in 37 (10.3%), 14 (3.9%) horses had a lucency and 3 (0.8%) had a fragment.

The rate of lucency and fragmentation of the proximal SR was slightly higher in the Quarter Horses than was seen by Kane *et al.* (2003a) in Thoroughbred yearlings. Kane *et al* (2003a) found that of 1102 horses with hind fetlock radiographs, 18 (1.7%) had a lucency and 16 (1.5%) had fragments or loose bodies associated with distal dorsal MTIII or proximal SR. Out of 1127 yearling Thoroughbreds with fore fetlock radiographs, 22 (2%) had a lucency and 9 (0.8%) had a fragment or loose body in this region. A study of 2401 Thoroughbreds reported a much higher rate of SR lesions, with 890 (37.1%) of horses affected in the fore fetlock and 159 (7.5%) of horses affected in the hind fetlock (Jackson *et al* 2009). However, SR lesions were not divided into proximal SR/dorsal distal MCIII/MTIII and distal SR as was done by Kane *et al* (2003a), making a direct comparison difficult. Jackson *et al* (2009) did report fragments of MCIII in 6 (0.4%) horses. Cohen *et al* (2006) found an irregular margin, flattening or lucency of the proximal sagittal ridge of the fore and hind fetlocks in 16% (17/106) of Thoroughbred yearlings and fragments in 3 (2.8%). Howard *et al* (1992) reported that 76 of 1018 (7.5%) fore fetlocks and 8 of 700 (1.6%) hind fetlocks had OCD lesions of dorsal distal MCIII/proximal sagittal ridge.

A grading scheme for proximal SR OCD was developed by McIlwraith and Vorhees (1990): Type I: flattening or defect; Type II: flattening or defect with associated fragmentation; Type III: flattening or defect with or without fragmentation and one or more loose bodies. The authors reported that the prognosis for type I lesions is good (80%) with conservative management. For type II and III lesions, the prognosis is poorer, with only 52% of 42 horses experiencing a successful outcome. In addition, type II and III lesions can affect a horse’s chance of being sold. In a survey of 38 veterinarians, 19 (50%) would not recommend purchase of a horse with grade II lesions and 28 (74%) would not for horses with grade III lesions (McIlwraith and Vorhees 1990). When comparing Texas Thoroughbred yearlings with radiographic proximal SR abnormalities to outcome, Cohen *et al* (2006) found that while there was no significant association between presence of lesions and performance, there was a significant association between proximal SR abnormalities and sales price. Horses with lesions of the proximal SR sold for significantly less (median price $5,500) than horses without that particular lesion (median price $9,100) and horses with no abnormal radiographic findings (median price $9,700). Jackson *et al* (2009) found that defects greater than 10mm in length in the SR of MTIII were associated with decreased likelihood of starting a race, fewer starts, decreased chance of earning money and less total prize money than unaffected horses. When abnormalities of the proximal SR on repository radiographs were compared to performance outcomes of 1162 Thoroughbred yearlings, no correlation between number of starts or earnings and the presence or absence of a lesion in this location was found (Kane *et al* 2003b).

Fragmentation of Proximodorsal First Phalanx

Fragments of the dorsal aspect of the first phalanx (P1) were relatively rare in the fore and hind fetlocks of Quarter Horse cutting horses, with 5 of 361 (1.4%) and 4 of 361 (1.1%) affected respectively (Contino 2009). This is similar to what has been reported in the fore fetlocks of Thoroughbred yearlings. Howard *et al* (1992) reported dorsal P1 fragments the fore fetlocks of 12 of 1018 (1.2%) Thoroughbred yearlings, and Kane *et al* (2003a) found 18 of 1127 (1.6%) Thoroughbred yearlings affected. An even lower prevalence was found by Jackson *et al* (2009), with fragmentation of fore dorsal P1 seen in 18 of 2401 (0.7%) Thoroughbred yearlings, and similarly, Cohen *et al* (2006) reported only 3 of 348 (0.9%) Texas yearling Thoroughbreds affected. Higher rates have been reported in the fore fetlocks of Standardbred trotters, with 36 of 753 (4.8%) yearlings affected (Grondahl 1992).

Prevalence of P1 fragments in hind fetlocks is generally higher in Thoroughbreds than what Contino (2009) reported in Quarter Horses. Both Howard *et al* (1992) and Kane *et al* (2003a) reported similar prevalence in hind fetlocks of Thoroughbred yearlings, with 24 of 700 (3.4%) and 36 of 1102 (3.3%) affected respectively. A slightly lower prevalence of 53 of 2401 (2.2%) was reported in Australian Thoroughbred yearlings (Jackson *et al* 2009). Likewise, 2.0% (7 of 348) Texas Thoroughbred yearlings had radiographic evidence of dorsal P1 fragments in the hind fetlock (Cohen *et al* 2006).

In racehorses, surgical removal of dorsal P1 fragments is recommended and generally results in a good outcome (Bramlage 2009). Yovich and McIlwraith (1986) found that following arthroscopic removal of dorsal P1 fragments, 80% (37 of 46 horses for which follow-up information was available) returned to racing at the same or higher level. Similarly, Kawcak and McIlwraith (1994) found that fetlock arthroscopy for treatment of dorsal P1 fragments was successful in 73% of 286 horses, and Colon *et al* (2000) reported a success rate of 82% in 461 Thoroughbreds. Dorsal fragmentation of P1 in the hind fetlock in Thoroughbred yearlings was associated with decreased likelihood of starting a race as a two or three year old (Kane *et al* 2003b). The fact that surgical removal of P1 fragments in the fore fetlocks of young racehorse is commonly performed could have affected these findings, as many horses may have undergone arthroscopy in the time before follow-up data were collected.

Fragmentation of Palmar/Plantar First Phalanx

Palmar and plantar P1 fragments have been categorized in the literature as Type I and Type II (Foerner *et al* 1987). Type I, or axial, fragments are more commonly reported. Type II fragments are much less frequently discussed in the literature. For the purposes of this study, unless stated otherwise, the palmar/plantar P1 fragments that are discussed are Type I fragments.

Contino (2009) found only one Quarter Horse of 361 (0.3%) had a palmar P1 fragment in the fore fetlock. Like the findings of Contino (2009) in Quarter Horses, palmar P1 fragments are also reported at a low rate in Thoroughbreds. Out of 2401 Australian Thoroughbred yearlings, 9 (0.4%) had palmar P1 fragments (Jackson *et al* 2009). Other repository studies showed similar low prevalence of palmar P1 fragments in the fore fetlocks of Thoroughbred yearlings: Kane *et al* (2003a) reported 5 of 1127 (0.5%) affected; Howard *et al* (1992) found 1 of 1018 (0.1%); and Cohen *et al* (2006) reported 1 of 348 (0.3%) affected.

Plantar P1 fragments were found in the hind fetlocks of 8 of 355 (2.3%) cutting horses (Contino 2009). Plantar P1 fragments have also been reported as more common than palmar P1 fragments in Thoroughbreds. Kane *et al* (2003a) found that 65 of 1102 (5.9%) of yearling Thoroughbreds were affected. A similar prevalence was found in Australian Thoroughbred yearlings, with 6.1% (150 of 2401) (Jackson *et al* 2009). Slightly lower rates in Thoroughbred yearling were found by Howard *et al* (1992) with

14 of 700 (2%) affected, and by Cohen *et al* (2006) with 10 of 348 (2.9%) affected. Plantar P1 fragments are more common in Standardbred trotters, with a reported prevalence of 89 of 753 (11.8%) in a radiographic survey of Standardbred yearlings (Grondahl 1992).

Type I palmar/plantar P1 fragments frequently don't cause explicit lameness, but may result in decreased performance or preference for the other lead. Lameness can develop when the horse is in strenuous training or if the fragments become large enough to interfere with the mechanics of the joint (Foerner *et al* 1987, Barclay *et al* 1987, McIlwraith 1993, Bramlage 2009). The severity of response to flexion and degree of joint distention and inflammation varies (Foerner *et al* 1987, McIlwraith 1993, Whitton and Kannegieter 1994, Bramlage 2009)

If Type I fragments are found incidentally on radiographs, there is generally no indication for treatment (McIlwraith 1993). In horses whose performance is affected by the presence of a fragment, arthroscopic removal of Type I fragments is generally an effective treatment (Bramlage 2009). In a study of arthroscopic removal of palmar/plantar P1 fragments, 63% (55 of 87) of racehorses returned to work at the same level. Outcome was affected by the degree of concurrent pathologic change in the joint, with 10 of 32 (31%) of unsuccessful horses suffering articular cartilage damage and/or synovial proliferation. The nine non-racehorses in the study had an excellent outcome, with 100% return to pre-surgical levels of work (Fortier *et al* 1995). Good outcome for arthroscopic removal of palmar/plantar P1 fragements was reported by Whitton and Kannegieter (1994), with 16 of 21 (76%) of horses returning to racing, 12 of which performed at a higher level then pre-operatively.

Palmar Supracondylar Lysis

Of 361 horses for which there were fore fetlock radiographs, Contino (2009) found that 47 (13.3%) had radiographic evidence of palmar supracondylar lysis (PSCL). Of those affected, 36 (76.6%) were classified as mild, 9 (19.1%) as moderate, and 2 (4.3%) as severe. Kane *et al* (2003a) found a lower prevalence in Thoroughbred yearlings, with 30 of 1127 (2.7%) reported to have mild PSCL, and 24 (2.1%) to have moderate to severe PSCL. An even lower prevalence was reported in Australian Thoroughbred yearlings, with only 2 of 2401 (0.1%) affected. In a retrospective study of 340 fetlock radiographs of 262 horses, Haynes *et al* (1982) found that mild, moderate and severe PSCL in 142 (41.7%), 92 (27.1%) and 39 (11.5%) of horses respectively. This is a much higher prevalence than is reported in the aforementioned radiographic repository studies, which is likely due to the fact that many of the horses were radiographed due to suspected fetlock joint disease.

Haynes *et al* (1982) found that of their clinical population, Thoroughbreds were at greater risk of PSCL than Quarter Horses. This was attributed to the fact that racing Thoroughbreds have comparatively more rigorous training schedules, engage in longer distance competitions and undergo high velocity lead changes compared to the Quarter Horse population examined by the investigators. Thoroughbred yearlings with moderate to severe PSCL have been shown to be significantly less likely than mildly or unaffected horses to start a race as 2- and 3- year-olds (Kane *et al* 2003a).

Carpus

Carpal radiographs were available for 342 Quarter Horses in the repository study by Contino (2009). Twelve (3.5%) horses had osteophytes, 5 (41.7%) of which were bilaterally affected. Of the 18 total carpal osteophytes, 11 (61.1%) were located on the dorsodistal aspect of the radial carpal bone, 5 (27.8%) were on the dorsoproximal aspect of the intermediate carpal bone, and 1 (5.6%) was located on each the dorsodistal intermediate carpal bone and dorsoproximal radial carpal bone. Of 515 Thoroughbred yearlings, Howard *et al* (1992) reported osteophytes affected the intermediate carpal bone in 3 (0.3%), the radial carpal bone in 2 (0.2%) and the third carpal bone in 2 (0.2%) of horses. Kane *et al* (2003a) found carpal osteophytes in 19 of 1130 (1.9%) of Thoroughbred yearlings. Out of 2401 Australian yearling racehorses, 79 (3.3%) were reported to have carpal osteophytes (Jackson *et al* 2009). Neither Kane *et al* (2003b) nor Jackson *et al* (2009) found an association between the presence of carpal osteophytes and reduced performance.

Summary

Radiographic repositories have become an accepted practice in the racing industry, and are now being utilized by other disciplines. While the repositories are advantageous to the potential buyer, their usefulness is limited by the amount of substantiated research demonstrating the clinical significance of various radiographic findings. To date, there are a limited number of studies comparing survey yearling radiographs to performance outcome in racehorses, and none exist for Quarter Horses. Due to the large amount of variability in types of radiographic lesions and musculoskeletal injuries sustained by horses of different breeds and different disciplines, the findings in racing Thoroughbreds cannot be directly applied to horses of other breeds and uses. Therefore, breed and discipline specific research is warranted to improve the predictive accuracy of radiographic repositories. The aim of this study is to correlate the radiographic changes in Quarter Horse cutting horses reported by Contino *et al* (2009) to objective performance outcome.

CHAPTER 2

Materials and Methods

Included Horses

Contino *et al* (2009) described the radiographic findings in repository radiographs of 458 yearling and two-year old Quarter Horse cutting horses. Radiographs were obtained from two sources: the Western Bloodstock radiograph repository that was used at National Cutting Horse Association (NCHA) sales in 2005 and 2006, and from Iron Rose Ranch, a privately owned cutting horse farm in Carbondale, Colorado. Included in the study were stifles (454 horses), tarsi (438 horses), hind fetlocks (355 horses), fore fetlocks (361 horses) and carpi (342 horses).

Of the 458 horses in the study by Contino *et al* (2009), 436 are included in the follow-up data analysis. Of the included horses, 75 were born in 2003, 141 were born in 2004 and 220 were from the 2005 foal crop. Twenty horses that were born in 2006 had radiographs described by Contino *et al* (2009) but were not used in this study as all included horses were required to have follow-up data through the end of their four-year old year. Follow-up information was unavailable for the two other horses that were included in the work of Contino *et al* (2009) but not in this study.

Required Radiographic Projections

In order for radiographs to be entered into the Western Bloodstock repository, a minimum number of views per joint was mandated. For the fetlocks, a lateral and dorsopalmar (DP) view were required, with the horse standing on blocks, to allow visualization of the distal phalanges as well. A single flexed lateral view of the carpus was required. The tarsal views included a DP, lateral, dorsolateral-palmaromedial oblique (DLPMO), and dorsomedial-palmarolateral oblique (DMPLO), and the required stifle projections were a cranio-caudal (CC) and a caudal 30˚lateral-craniomedial oblique. In their radiographic analysis, Contino *et al* (2009) excluded fetlocks without a LM view, stifles without a CC view, and tarsi without a DMPLO and at least three views. If an abnormality was questionable due to poor radiographic positioning or technique, it was assigned a lower grade, and, likewise, if an anatomic area could not be sufficiently evaluated, a grade was not assigned.

Follow-up Parameters

Follow-up data were obtained via performance records obtained from the NCHA as well as mailed questionnaires and phone calls to owners. Outcome parameters were as follows: 1) did the horse earn money in a cutting competition, yes or no? If so, how much? 2) Did the horse compete in a cutting competition, yes or no? 3) If the horse did not compete, why not? Earnings were calculated from records provided by the NCHA, and the amount of money earned in the three year old and four year old years was recorded. Earnings data for NCHA sanctioned events through the end of the four year-old year were available for all horses included in the study. For all horses that did not earn money, attempts were made to contact the owner via phone and/or mailed questionnaires to find out why not. Some horses had competed but did not earn money. Reasons for not competing included lameness, non-lameness related medical reasons (such as colic surgery), lack of talent, trained for other use, or still in training.

With a few exceptions, radiographic changes that affected less than 5% of horses in the study by Contino *et al* were not included in the current follow-up analysis due to the prospect of a lack of meaningful data. In some cases, however, changes with a prevalence less than 5% were included, due to the particular clinical interest in the radiographic abnormality. In such cases, only frequency analysis was performed as there was not a sufficient number of horses affected to allow for reasonable analysis of statistical significance. For the rest of the included radiographic lesions, complete statistical analysis performed. When evaluating the association between radiographic lesions and outcome parameters, lesions were generally examined individually, with the exception of several combined lesions in the distal tarsus. No statistical analysis was performed of combined lesions in multiple different joints; however, the effect of bilateral versus unilateral lesions was examined. The following are included lesions as described by Contino *et al.*:

Lesions of the Stifle

Within the stifle, the presence of changes of the medial femoral condyle (MFC) and lateral trochlear ridge (LTR) were included in the analysis. The grading system used by Contino *et al* to describe changes of the MFC was as follows: A grade 0 represented a normal MFC, which is continuously convex in contour; grade 1 described a flattened contour but no radiographic evidence of changes in the subchondral bone; grade 2 indicated subchondral bone sclerosis and/or defects in the subchondral bone that did not extend all the way through the subchondral bone plate; grade 3 applied to defects that extended through the subchondral bone such as wide, shallow subchondral lucencies; grade 4 described a well defined round or oval radiolucent area in the middle of the MFC that extended to and communicated with the femorotibial joint (Figure 1). Because grade 1 changes of the MFC are considered by some to be a normal variant, the changes of the MFC were also analyzed with grade 1 changes classified with grade 0 as normal. The LTR was grades on a scale of 1-3. Grade 1 represented flattening, grade 2 a concavity without a fragment, and grade 3 a fragment with an associated bone defect.

Lesions of the Tarsus

Included lesions of tarsocrural joint were changes of the distal intermediate ridge of the tibia (DIRT). Lesions of the DIRT were graded on a scale of 1 to 3, with grade 1 representing flattening, grade 2 a defect, and grade 3 a separate osseous fragment.

Within the distal tarsus, the presence of osteophytes, lysis or sclerosis of the distal tarsal bones, both by location and highest grade was examined. Additionally, the combined effect of osteophytes and lysis and osteophytes and sclerosis of the distal tarsal bones was analyzed. Osteophytes were ranked from 0-4, corresponding to none, very small, small, medium and large (Figure 2). Lysis and sclerosis were also graded on a scale of 0-4, ranging from none to severe. Malformation of the third and central tarsal bones, which was graded on a scale of 0-2, was also included.

Lesions of the Fetlock

In the hind fetlock, presence of dorsal and plantar first phalanx (P1) fragments and changes to the sagittal ridge of MTIII were examined. In the fore fetlock, the presence of dorsal P1 fragments, changes in the sagittal ridge of MCIII, palmar supracondylar lysis of MCIII and osteophytes of the proximal sesamoid bones were included in the analysis. Fragments were categorized as present or absent. Changes to the sagittal ridge of MC/MTIII were assigned a grade 1 for smooth flattening, grade 2 for a radiolucent defect, and grade 3 for a defect and associated fragmentation. Palmar supracondylar lysis was categorized as mild, moderate or severe.

Osteophytes of both fore and hind second phalanges (P2) were examined, as was thickening of the dorsal cortex of the hind P2 (Figure 3). The degree of thickening was graded as mild, moderate or severe. If the dorsal border was irregular, a minimum of a grade 2 was applied.

Lesions of the Carpus

The only lesion of the carpus included in the analysis was the presence of osteophytes, graded present or absent.

Data Analysis

Data was analyzed using Statistical Analysis Systems (SAS 9.2) software. Logistic regression analysis (PROC GENMOD) was performed when the outcome variable was binary to generate odds-ratios and 95% confidence intervals. Included in this analysis was the probability of competing based on the grade of lesion, probability of competing based on bilateral versus unilateral lesions, and probability of earning money as a three year old, four year old, and three and four year old years combined.

A linear regression analysis was used to evaluate the continuous variable outcome of amount of money earned as a three year old, four year old and three and four year old years combined. The data were normalized using a log10 transformation. Type 3 p-values were generated to examine the overall group effect. Individual p-values and 95% confidence intervals were generated to examine the significance of an individual grade of lesion relative to no lesion. For both logistic and linear regression analysis, a cut-off p-value of 0.05 was used to determine statistical significance.

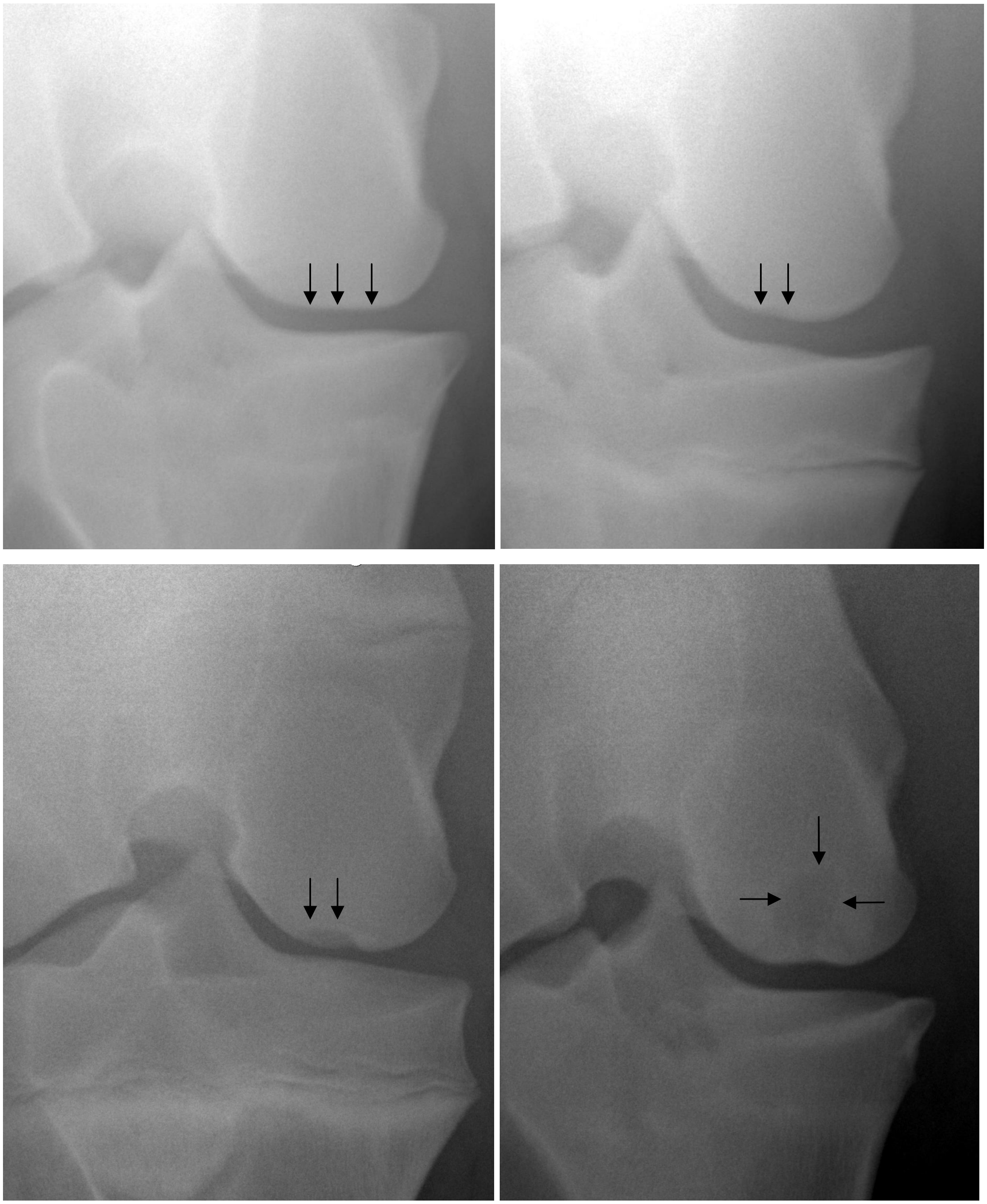

Figure 1. Caudocranial radiographic views of the femorotibial joint. Upper left: The contour of the medial femoral condyle (MFC) is flat (Grade 1). Upper right: There is a small defect in the articular surface, but it does not extend through the subchondral bone plate (Grade 2). Lower left: A shallow, crescent-shaped lucency extends through the subchondral bone in the MFC (Grade 3). Lower right: A well defined subchondral bone cyst that communicates with the articular surface is seen in the MFC (Grade 4). (Courtesy of Erin Contino).

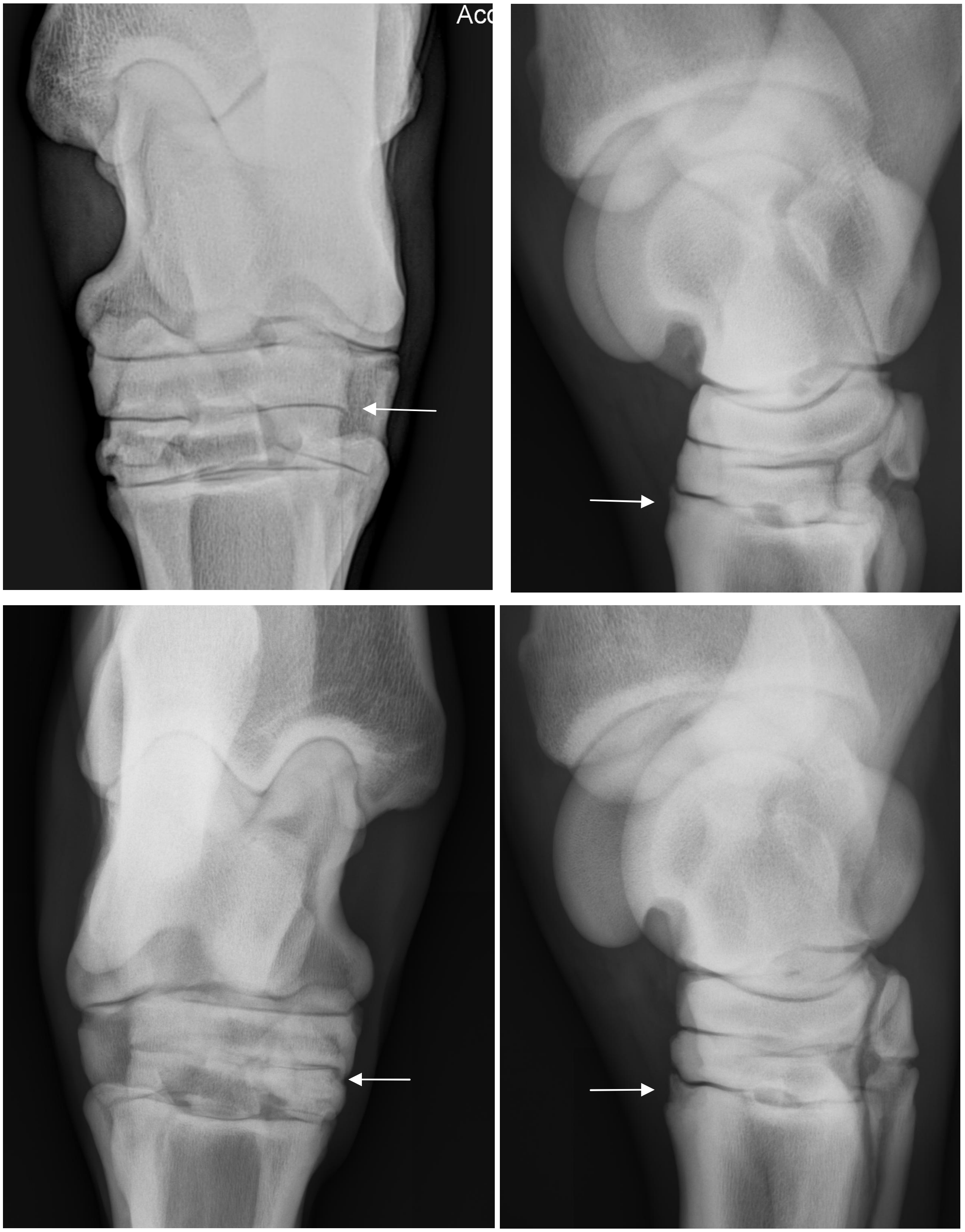

Figure 2. Tarsal osteophytes. Upper left: A very small (grade 1) osteophyte can be seen extending from the lateral aspect of central tarsal bone (TC) into the distal intertarsal (DIT) joint. Upper right: The proximal dorsal aspect of the 3rd metatarsal bone (MTIII) has a small (grade 2) osteophyte associated with the tarsometatarsal (TMT) joint. Lower left: The distal medial aspect of TC has a medium sized (grade 3) osteophyte extending into the DIT joint. Lower right: There is a large, (grade 4) osteophyte on the proximal dorsal aspect of MTIII associated with the TMT joint. (Courtesy of Erin Contino).

Figure 3: The proximal aspect of the dorsal cortex of the middle phalanx (P2) is thickened but smooth representing grade 1 dorsal P2 thickening. (Courtesy of Erin Contino).

CHAPTER 3

Results

Various radiographic changes of the tarsus were associated with changes in performance outcome parameters (Tables 1 – 6). No radiographic changes in the stifle were significantly associated with any outcome parameter (Tables 7 & 8). Radiographic changes of the hind (Tables 9 & 10) and fore (Tables 11 & 12) fetlocks had some association with performance outcome, but were limited by a relatively small number of horses affected. There was an insufficient number of horses with radiographic changes of the carpus for meaningful statistical analysis (Tables 7 & 8).

Radiographic Changes Significantly Associated with Likelihood of Competing in Cutting Competitions

While earnings data were available for all horses in the follow-up analysis, competition data could not be obtained for all horses, thus the total numbers in this category are lower than that of the earnings category.

Factors significantly associated with a decreased chance of competing were grade 3 osteophytes of the central tarsal bone of the distal intertarsal (DIT) joint (6 of 347 horses affected, 5 of 6 didn't compete, OR 0.07, CI 0.01 – 0.57, $p = 0.01$) and grade 2 osteophytes of the third tarsal bone of the DIT (8 of 347 horses affected, 5 of 8 didn't compete, OR 0.19, CI 0.05 – 0.83, $p = 0.03$). When the highest grade osteophyte for the distal tarsus was a grade 2, which affected 71 out of 347 horses, 25 of which didn't compete, there was also a decreased likelihood of competing (OR 0.50, CI 0.27 – 0.91, p = 0.02) (Table 1). Likewise, when the combination of osteophytes and sclerosis of the distal tarsal bones was examined, grade 2 lesions were significantly associated with lower likelihood of competing (71 of 347 horses affected, 25 of 71 didn't compete, OR 0.49, CI 0.27 – 0.89, p = 0.02) (Table 3). Sclerosis alone was not associated with decreased chance of competing

Radiographic Changes Significantly Associated with Likelihood of Earning Money in Cutting Competitions

Likelihood of Earning Money as a Three Year Old

Grade 3 changes of DIRT were recorded in nine of 418 horses for which this information was available. Of these, five horses earned money as a three year old. The likelihood of a horse with a grade 3 DIRT lesion earning money is greater than that of a horse with no lesion (OR 3.97, CI 1.04 – 115.11, p = 0.04) (Table 1). Grade 2 bony proliferation on the dorsal cortex of the hind second phalanx, which was recorded in six of 344 horses, was also associated with an increased likelihood of earning money as a three year old (2 of 4 horses didn't earn money, OR 7.36, CI 1.32 – 41.13, p = 0.02) (Table 9). No radiographic lesions were associated with a decreased likelihood of earning money as a three year old.

Likelihood of Earning Money as a Four Year Old

In the tarsometatarsal joint (TMT), grade 2 osteophytes of the third tarsal bone, affecting 22 of 418 horses, 16 of which did not compete, were associated with a decreased chance of earning money as a four year old (OR 0.37, CI 0.14 – 0.96, p = 0.04). Additionally, when the overall highest grade osteophyte affecting the distal tarsus was a grade 2, affecting 81 of 418 horses, 50 of which did not compete, there was lower chance of earning money compared to horses with no recorded osteophytes (OR 0.50, CI 0.30 – 0.84, p = 0.01) (Table 1). When the combined highest grade of osteophytes and sclerosis of the distal tarsal bones were examined together, four year old horses with grade 1 (83 of 418 horses, 48 of 83 didn't earn money) and grade 2 changes (81 of 418 horses affected, 51 didn't earn money), had a lower likelihood of earning money (OR 0.59, CI 0.35-0.98, p=0.04 and OR 0.48, CI 0.28-0.80, p = 0.01, respectively) (Table 3). Highest grade of sclerosis alone, however, did not affect a four year old horse's chance of earning money.

Two different radiographic changes of hind P2 were associated with an increased likelihood of earning money as a four year old: Grade 1 thickening of the dorsal cortex of hind P2 (38 of 344 horses affected, 12 of 38 didn't earn money, OR 2.69, CI 1.31 – 5.54, p = 0.01); and the presence of osteophytes on hind P2 (44 of 344 horses, 15 of 44 didn't earn money, OR 2.40, CI 1.23 – 4.65, p = 0.01) (Table 9).

Likelihood of Earning Money as both a Three and Four Year Old

Similar to what was seen in four year olds alone, radiographic changes that were associated with a decreased chance of earning money in the three and four year old years combined were grade 2 osteophytes affecting the third tarsal bone of the TMT (22 of 418 horses, 15 of 22 didn't earn money, OR 0.38, CI 0.15-0.95, p = 0.04), and an overall highest grade osteophyte of the distal tarsus of grade 2 (81 of 418 horses affected, 47 of 81 didn't earn money, OR 0.51, CI 0.31- 0.86, p = 0.01) (Table 1). Likewise, when the combined highest grade of osteophytes and sclerosis of the distal tarsal bones were examined together, grade 2 changes were associated with a decreased likelihood of earning money (47 of 81 didn't earn money, OR 0.49, CI 0.29-0.83, p < 0.01) (Table 3).

Increased likelihood of earning money as a three and four year old was associated with the same factors as that of chance of earning money as a four year old. Grade 1 thickening of the dorsal cortex of hind P2 (38 of 344 horses, 12 of 38 didn't win money, OR 2.26, CI 1.10 – 4.64, p = 0.03) was significant, as well as the presence of hind P2 osteophytes (44 of 344 horses, 15 of 44 didn't earn money, OR 2.40, CI 1.23 – 4.65, p = 0.01) (Table 9).

Radiographic Changes Significantly Associated with Amount of Money Earned in Cutting Competitions

Amount of Money Earned as a Three Year Old

When the highest grade of osteophyte affecting all the distal tarsal bones was a grade 2, horses were also less likely to earn as much money as three year olds (17 of 104 horses, CI -0.84 – -0.10, p = 0.01). Horses with grade 2 osteophytes of the third tarsal bone affecting the DIT were significantly less likely to earn as much money as horses without osteophytes (1 of 104 horses, CI -3.18 – -0.49, p = 0.01) (Table 4). Grade 2 sclerosis of the central tarsal bone was also found to be significant (1 of 104 horses, CI -3.16 – -0.48, p = 0.01) (Table 6). However, both these categories only contained one horse, resulting in little statistical value to this finding. Grade 3 lysis affecting the central tarsal bone and third tarsal bone at the DIT (3 of 104 horses, CI -1.68 – -0.11, p = 0.03 for both), and an overall highest grade of grade 3 lysis affecting the distal tarsal bones (3 of 104, CI -1.69 – -0.11, p = 0.03) were all significantly associated with decreased earnings (Table 5). When osteophytes and sclerosis of the distal tarsus were examined together, grade 2 changes were significant (17 of 104 horses, CI -0.81 – -0.07, p = 0.02) (Table 6).

Greater mean earnings as a three year old were seen in horses with grade 2 thickening of hind P2 relative to horses with no changes (4 of 77 horses, CI -1.65 – -0.44, $p < 0.001$) (Table 10).

Amount of Money Earned as a Four Year Old

The presence of grade 1 osteophytes on the central tarsal bone of the DIT was associated with lower average earnings in four year old horses (13 of 203 horses, CI -0.84 – -0.01, p = 0.04). Grade 2 osteophytes on the proximodorsal MTIII at the level of the TMT were seen with decreased mean earnings (19 of 203 horses, CI -0.81 – -0.10, p = 0.01) (Table 4). Lysis of the central tarsal bone at the level of the DIT was more likely to be associated with reduced earnings if the horse was affected unilaterally (14 horses) versus bilaterally (10 horses) (CI 0.04 – 2.18, $p = 0.04$). Grade 1 lysis of the third tarsal bone at the DIT was also seen with lower amounts of money earned (5 of 203, CI -1.37 – -0.06, $p = 0.03$). Similarly, when the highest grade of lysis in the distal tarsus was grade 1, lower earnings were seen in four year olds (10 of 203 horses, CI -1.09 – -0.15, $p < 0.01$) , and when osteophytes and lysis were examined in combination, both grade 1 (37 of 203 horses) and grade 2 lesions (36 horses) were associated with lower earnings (CI -0.62 – -0.08, $p = 0.01$ and CI -0.57 – -0.02, $p = 0.04$, respectively) (Table 5). Another significant radiographic finding was grade 2 palmar supracondylar lysis (PSCL) (5 of 163 horses, CI -1.35 – -0.04, $p = 0.04$) (Table 11).

Amount of Money Earned as a Three and Four Year Old

As was seen in four year olds, grade 2 osteophytes on the proximodorsal MTIII, at the level of the TMT also associated with decreased mean earnings (20 of 224 horses, CI -0.81 – -0.10, $p = 0.01$) in the three and four year old years combined. Similar to three year olds, when the highest grade of osteophyte in the distal tarsus was grade 2, mean earnings were lower (34 of 224 horses, CI -0.58 – -0.00, $p = 0.05$) (Table 4). When osteophytes and sclerosis of the distal tarsus were examined together, grade 2 changes were significant (34 of 224, CI -0.59 – -0.01, $p = 0.05$) (Table 6). Lysis of the distal tarsal bones unilaterally affected 22 horses, and bilaterally affected 15 horses. When lysis within the distal tarsus was bilateral, horses were more likely to earn money in their three and four year old years than horses with unilateral lysis (CI 0.01 – 1.77, $p = 0.05$) (Table

5). Changes to the proximal sagittal ridge of MTIII, when categorized as grade 2, were significant (5 of 176 horses, CI -1.39 – -0.03, p = 0.04) (Table 10).

Radiographic Changes Not Associated with a Performance Outcome

No radiographic changes of the MFC of the stifle were significantly associated with performance outcomes. This was the case both when grade 1 changes were considered a lesion, and when grade 1 changes were classified as normal and added to the grade 0 category. (There was very little difference between the any of the MFC results either way that grade 1 was categorized; therefore to avoid redundancy, the results reported are for when grade 1 was included as a lesion, unless otherwise noted.)

When examining changes of the MFC relative to the likelihood of competing, grade 1 (OR 0.89, CI 0.49 – 1.62, p = 0.70), grade 2 (OR 1.07, CI 0.43 – 2.63, p = 0.88) and grade 3 (OR 0.59, CI 0.23 – 1.46, p = 0.25) were all insignificant. There was a trend for horses with grade 4 lesions of the MFC to be less likely to compete, both in the analyses when grade 1 was included as lesion (21 of 358 horses, OR 0.42, CI 0.17 – 1.05, p = 0.06) and when grade 1 changes were considered normal (OR 0.43, CI 0.17 – 1.06, p = 0.07). Relative to the likelihood of earning money as a three year old, four year old and three and four year old, grade 1 (OR 1.37, CI 0.81 – 2.33, p = 0.24; OR 1.03, CI 0.64 – 1.66, p = 0.90; and OR 1.10, CI 0.63 – 1.63, p = 0.96, respectively), grade 2 (OR 0.59, CI 0.23 – 1.47, p = 0.26; OR 0.60, 0.30 – 1.22, p = 0.16; and OR 0.66, CI 0.33 – 1.31, p = 0.23, respectively), grade 3 (OR 0.52, CI 0.17 – 1.56, p = 0.25; OR 0.67, CI 0.30 – 1.48, p = 0.32; and OR 0.53, CI 0.24 – 1.17, p = 0.11 respectively) and grade 4 (OR 1.46, CI 0.57 – 3.75, p = 0.43; OR 1.24, CI 0.52 – 2.97, p = 0.63; and OR 0.98, CI 0.41 – 2.34, p =

0.96 respectively), were all insignificant (Table 7). Similarly, when the average amount of money earned as a three year old, four year old and three and four year old was examined, no significant relationship was seen with grade 1 (CI -0.36 – 0.26, p = 0.75; CI -0.38 – 0.12, p = 0.32; and CI -0.33 – -0.16, p = 0.51, respectively), grade 2 (CI -.80 – 0.36, p = 0.46; CI -0.66 – 0.15, p = 0.22, and CI -0.72 – 0.05, p = 0.08, respectively), grade 3 (CI -0.57 – 0.83, p = 0.71; CI -0.55 – 0.37, p = 0.70 and CI -0.48 – 0.46, p = 0.96, respectively) or grade 4 lesions (CI -0.24 – 0.84, p = 0.28; CI -0.43 – 0.45, p = 0.95 and CI -0.17 – 0.73, p = 0.22 respectively) (Table 8).

In the distal tarsus, neither lysis nor sclerosis alone had a significant relationship between the likelihood of competing or the likelihood of earning money (Tables 2 and 3), although, as mentioned above, both did have some significant relationships to the average amount of money earned (Tables 5 and 6). Lysis of the third tarsal bone at the level of the TMT and tarsal bone malformation were not significant for any outcome parameter. However, both these categories had relatively low numbers, making the results somewhat less conclusive. In the fore fetlock, changes to the sagittal ridge (SR) of MCIII were not shown to be associated with performance outcome (Tables 11 and 12).

The effect of bilateral versus unilateral lesions was assessed for all included radiographic changes. There was a trend (p = 0.06) for horses with bilateral osteophytes (10 horses) of the third tarsal bone at the TMT to earn less money as three year olds and as three and four year olds, when compared to horses that had unilateral lesions (47 horses). There was also a trend (p = 0.08) for horses with bilateral osteophytes of MTIII (17 horses) at the TMT to be more likely to compete than horses with unilateral lesions (65 horses). Other than the previously mentioned unilateral lysis of the central tarsal bone at the DIT associated with lower average earnings as a four year old, and presence of unilateral lysis in the distal tarsus associated with lower average earning of the three and four year old years combined (when compared to horses with bilateral lesions), no difference in performance outcome was seen with unilateral versus bilateral radiographic changes.

Radiographic Changes with Insufficient Numbers with which to Draw Conclusions

Changes to the lateral trochlear ridge of the femur (8 horses, tables 7 and 8), presence of osteophytes in the proximal intertarsal (PIT) joint (one horse), and carpal osteophytes (12 horses, tables 7 and 8) all affected a very low number of horses. Likewise, plantar (9 horses) and dorsal (4 horses) hind P1 fragments (tables 9 and 10), dorsal fore P1 fragments (2 horses), osteophytes of the proximal sesamoid bones of the fore fetlock (7 horses), and osteophytes of fore P2 (9 horses) (tables 11 and 12), all had insufficient data to render a meaningful statistical analysis.

Reasons for Not Competing

Of the 436 horses included in the study, 235 horses earned money. For the 201 horses that did not earn money, follow up data via questionnaire or phone call was obtained on 127 horses (63%). Out of these 127 horses for which follow up information was available, 93 did not compete. Of those 93, lameness was the reported cause for not competing in 22 of the horses (24%). Lameness referable to the stifle was reported in six horses, both hocks and stifles in two horses, hocks alone in two horses, forelimb suspensory desmitis in one horse, hock pain and forelimb suspensory desmitis in one horse, hind limb suspensory desmitis in two horses, one horse had lameness associated with the carpus, one horse fractured a sesamoid bone in the left fore fetlock, shoulder injuries were reported in two horses and one horse had reported back and hip pain. Foot pain was responsible for lameness in one horse, one horse was in an accident and the cause of lameness was not determined in one horse. Other reported reasons that horses did not compete included: lack of talent (12 horses), medical causes unrelated to lameness (11 horses), used for other disciplines (22 horses), still in training (9 horses), and miscellaneous other reasons such as financial limitations or disagreements with trainers.

Table 1: Changes of the tarsocrural joint and osteophytes of the distal tarsus relative to likelihood of competing and earning money. Total number of horses in the "compete" category is 347, for the "earn money" category is out of 418 horses.

Variable	Compete						Earn Money 3 Y/O					
	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value
	%	%					%	%				
Tarsus -- Tarsocrural Joint												
DIRT Grade 0	77	222	reference				273	86	reference			
	26	74					76	24				
DIRT Grade 1	7	24	1.19	0.49	2.87	0.70	28	10	1.13	0.53	2.43	0.75
	23	77					74	26				
DIRT Grade 2	4	6	0.52	0.14	1.89	0.32	9	3	1.06	0.28	4	0.93
	40	60					75	25				
DIRT Grade3	2	5	0.87	0.16	4.56	0.87	4	5	3.97	1.04	15.11	**0.04**
	29	71					44	56				
Tarsus - Distal												
DIT TC OP 0	72	219	reference				266	88	reference			
	25	75					75	25				
DIT TC OP 1	5	17	1.12	0.40	3.14	0.83	20	8	1.21	0.51	2.84	0.66
	23	77					71	29				
DIT TC OP 2	8	17	0.70	0.29	1.69	0.43	18	7	1.18	0.48	2.91	0.73
	32	68					72	28				
DIT TC OP 3	5	1	0.07	0.01	0.57	**0.01**	7	0	0.00	0.00	N/A	1.00
	83	17					100	0				
DIT TC OP 4	0	3	N/A	0.00	N/A	1.00	3	1	1.01	0.10	9.81	0.99
	0	100					75	25				
DIT T3 OP 0	77	238	reference				281	99	reference			
	24	76					74	26				
DIT T3 OP 1	8	16	0.65	0.27	1.57	0.34	24	4	0.47	0.16	1.4	0.18
	33	67					86	14				
DIT T3 OP 2	5	3	0.19	0.05	0.83	**0.03**	9	1	0.32	0.04	2.52	0.28
	63	38					90	10				
TMT T3 OP 0	72	225	reference				270	91	reference			
	24	76					75	25				
TMT T3 OP 1	10	20	0.64	0.29	1.43	0.28	23	10	1.29	0.59	2.81	0.52
	33	67					70	30				
TMT T3 OP 2	7	11	0.5	0.19	1.35	0.17	19	3	0.47	0.14	1.62	0.23
	39	61					86	14				
TMT T3 OP 3	1	1	0.32	0.02	5.18	0.42	2	0	N/A	N/A	N/A	1.00
	50	50					100	0				
TMT MT OP 0	65	200	reference				239	81	reference			
	25	75					75	25				
TMT MT OP 1	9	17	0.61	0.26	1.44	0.26	23	6	0.77	0.3	1.96	0.58
	35	65					79	21				
TMT MT OP 2	13	24	0.6	0.29	1.25	0.17	36	9	0.74	0.34	1.6	0.44
	35	65					80	20				
TMT MT OP 3	2	13	2.11	0.46	9.61	0.33	11	8	2.15	0.83	5.52	0.11
	13	87					58	42				
TMT MT OP 4	1	3	0.98	0.1	9.54	0.98	5	0	N/A	0	N/A	1.00
	25	75					100	0				
DT OP high 0	40	147	reference				171	56	reference			
	21	79					75	25				
DT OP high 1	16	43	0.73	0.37	1.43	0.36	51	22	1.32	0.73	2.36	0.36
	27	73					70	30				
DT OP high 2	25	46	0.5	0.27	0.91	**0.02**	64	17	0.81	0.44	1.5	0.50
	35	65					79	21				
DT OP high 3	8	15	0.51	0.2	1.29	0.15	20	8	1.22	0.51	2.93	0.65
	35	65					71	29				
DT OP high 4	1	6	1.63	0.19	13.96	0.65	8	1	0.38	0.05	3.12	0.37
	14	86					89	11				

Variable	Earn Money 4 Y/O						Earn Money 3 & 4 Y/O					
	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value
	%	%					%	%				
Tarsus -- Tarsocrural Joint												
DIRT Grade 0	184	174	reference				166	193	reference			
	51	49					46	54				
DIRT Grade 1	19	19	1.06	0.54	2.06	0.87	17	21	1.06	0.54	2.08	0.86
	50	50					45	55				
DIRT Grade 2	7	5	0.76	0.24	2.42	0.64	7	5	0.61	0.19	1.97	0.41
	58	42					58	42				
DIRT Grade3	5	4	0.85	0.22	3.2	0.81	4	5	1.08	0.28	4.07	0.92
	56	44					44	56				
Tarsus - Distal												
DIT TC OP 0	180	173	reference				161	193	reference			
	51	49					45	55				
DIT TC OP 1	15	13	0.90	0.42	1.95	0.79	14	14	0.83	0.39	1.80	0.64
	54	46					50	50				
DIT TC OP 2	13	12	0.96	0.43	2.16	0.92	12	13	0.90	0.40	2.04	0.81
	52	48					48	52				
DIT TC OP 3	6	1	0.17	0.02	1.46	0.11	6	1	0.14	0.02	1.17	0.07
	86	14					86	14				
DIT TC OP 4	1	3	3.12	0.32	30.30	0.33	1	3	2.50	0.26	24.29	0.43
	25	75					25	75				
DIT T3 OP 0	190	189	reference				172	208	reference			
	50	50					45	55				
DIT T3 OP 1	18	10	0.56	0.25	1.24	0.15	15	13	0.72	0.33	1.55	0.40
	64	36					54	46				
DIT T3 OP 2	7	3	0.43	0.11	1.69	0.23	7	3	0.35	0.09	1.39	0.14
	70	30					70	30				
TMT T3 OP 0	178	182	reference				162	199	reference			
	49	51					45	55				
TMT T3 OP 1	20	13	0.64	0.31	1.32	0.22	16	17	0.86	0.42	1.77	0.69
	61	39					48	52				
TMT T3 OP 2	16	6	0.37	0.14	0.96	**0.04**	15	7	0.38	0.15	0.95	**0.04**
	73	27					68	32				
TMT T3 OP 3	1	1	0.98	0.06	15.76	0.99	1	1	0.81	0.05	13.12	0.88
	50	50					50	50				
TMT MT OP 0	160	160	reference				143	177	reference			
	50	50					45	55				
TMT MT OP 1	17	12	0.71	0.33	1.53	0.38	17	12	0.57	0.26	1.23	0.15
	59	41					59	41				
TMT MT OP 2	26	18	0.69	0.37	1.31	0.26	25	20	0.65	0.34	1.21	0.17
	59	41					56	44				
TMT MT OP 3	9	10	1.11	0.44	2.81	0.82	6	13	1.75	0.65	4.72	0.27
	47	53					32	68				
TMT MT OP 4	3	2	0.67	0.11	4.04	0.66	3	2	0.54	0.09	3.27	0.50
	60	40					60	40				
DT OP high 0	103	124	reference				94	133	reference			
	45	55					41	59				
DT OP high 1	42	31	0.61	0.36	1.04	0.07	36	37	0.73	0.43	1.23	0.24
	58	42					49	51				
DT OP high 2	50	30	0.5	0.3	0.84	**0.01**	47	34	0.51	0.31	0.86	**0.01**
	63	38					58	42				
DT OP high 3	16	12	0.62	0.28	1.38	0.24	13	15	0.82	0.37	1.79	0.61
	57	43					46	54				
DT OP high 4	4	5	1.04	0.27	3.97	0.96	4	5	0.88	0.23	3.38	0.86
	44	56					44	56				

Legend: DIRT: *distal intermediate ridge of the tibia*; TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; MT: *third metatarsal bone;* DT OP high: *highest grade of osteophytes in the distal tarsal joints*

Note: While all osteophytes were graded on a scale of 0-4, if no horses had changes in a certain category, that category is not included in the table (eg grade 4 osteophytes of T3).

Table 2: Lysis in the distal tarsus relative to likelihood of competing and earning money. Total number of horses in the "compete" category is 347, for the "earn money" category is out of 418 horses.

Variable	Compete						Earn Money 3 Y/O						Earn Money 4 Y/O						Earn Money 3 & 4 Y/O					
	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value
	%	%					%	%					%	%					%	%				
Tarsus - Distal																								
DIT TC Lysis 0	75	228	reference				274	92	reference				187	178	reference				168	198	reference			
	25	75					75	25					51	49					46	54				
DIT TC Lysis 1	7	9	0.42	0.15	1.17	0.10	15	4	0.79	0.26	2.45	0.69	13	6	0.48	0.18	1.3	0.15	12	7	0.49	0.19	1.29	0.15
	44	56					79	21					68	32					63	37				
DIT TC Lysis 2	5	13	0.86	0.3	2.48	0.77	15	5	0.99	0.35	2.81	0.99	7	13	1.95	0.76	5	0.16	7	13	1.58	0.61	4.04	0.34
	28	72					75	25					35	65					35	65				
DIT TC Lysis 3	3	7	0.77	0.19	3.04	0.71	10	3	0.89	0.24	3.32	0.87	8	5	0.66	0.21	2.05	0.47	7	6	0.73	0.24	2.21	0.57
	30	70					77	23					62	38					54	46				
DIT T3 Lysis 0	78	230	reference				280	92	reference				193	178	reference				173	199	reference			
	25	75					75	25					52	48					47	53				
DIT T3 Lysis 1	4	6	0.51	0.14	1.85	0.30	11	2	0.55	0.12	2.54	0.45	8	5	0.68	0.22	2.11	0.50	8	5	0.54	0.17	1.69	0.29
	40	60					85	15					62	38					62	38				
DIT T3 Lysis 2	5	14	0.95	0.33	2.72	0.92	14	7	1.52	0.6	3.89	0.38	7	14	2.17	0.86	5.5	0.10	7	14	1.74	0.69	4.41	0.24
	26	74					67	33					33	67					33	67				
DIT T3 Lysis 3	3	7	0.79	0.2	3.13	0.74	9	3	1.01	0.27	3.83	0.98	7	5	0.77	0.24	2.48	0.67	6	6	0.87	0.28	2.75	0.81
	30	70					75	25					58	42					50	50				
TMT T3 Lysis 0	85	247	reference				298	101	reference				205	193	reference				184	215	reference			
	26	74					75	25					52	48					46	54				
TMT T3 Lysis 1	2	3	0.52	0.08	3.14	0.47	6	1	0.49	0.06	4.13	0.51	5	2	0.42	0.08	2.22	0.31	5	2	0.34	0.07	1.79	0.20
	40	60					86	14					71	29					71	29				
TMt T3 Lysis 2	3	7	0.8	0.2	3.17	0.75	10	2	0.59	0.13	2.74	0.50	5	7	1.49	0.46	4.76	0.50	5	7	1.2	0.37	3.84	0.76
	30	70					83	17					42	58					42	58				
TMT MT Lysis 0	87	246	reference				302	100	reference				207	194	reference				187	215	reference			
	26	74					75	25					52	48					47	53				
TMT MT Lysis 1	1	5	1.77	0.2	15.35	0.61	6	1	0.5	0.06	4.23	0.53	3	4	1.42	0.31	6.44	0.65	3	4	1.16	0.26	5.25	0.85
	17	83					86	14					43	57					43	57				
TMt MT Lysis 2	2	6	1.06	0.21	5.36	0.94	6	3	1.51	0.37	6.15	0.57	5	4	0.85	0.23	3.23	0.82	4	5	1.09	0.29	4.11	0.90
	25	75					67	33					56	44					44	56				
DT Lysis High 0	71	214	reference				254	88	reference				174	168	reference				155	187	reference			
	25	75					74	26					51	49					45	55				
DT Lysis High 1	7	15	0.71	0.28	1.81	0.48	23	5	0.63	0.23	1.7	0.36	18	10	0.58	0.26	1.28	0.18	17	11	0.54	0.24	1.18	0.12
	32	68					82	18					64	36					61	39				
DT Lysis High 2	9	21	0.77	0.34	1.77	0.54	27	8	0.63	0.23	1.7	0.36	16	19	1.23	0.61	2.47	0.56	15	20	1.11	0.55	2.23	0.78
	30	70					77	23					46	54					43	57				
DT Lysis High 3	3	7	0.77	0.19	3.07	0.72	10	3	0.87	0.23	3.22	0.83	8	5	0.65	0.21	2.02	0.45	7	6	0.71	0.23	2.16	0.55
	30	70					77	23					62	38					54	46				
DT OP lysis 0	36	130	reference				153	49	reference				94	108	reference				86	116	reference			
	22	78					76	24					47	53					43	57				
DT OP lysis 1	19	50	0.73	0.38	1.39	0.34	60	25	1.3	0.74	2.29	0.36	48	37	0.67	0.4	1.12	0.13	41	44	0.8	0.48	1.32	0.38
	28	72					71	29					56	44					48	52				
DT OP lysis 2	25	50	0.55	0.3	1.01	0.06	66	19	0.9	0.49	1.64	0.73	49	36	0.64	0.38	1.07	0.09	46	39	0.63	0.38	1.05	0.07
	33	67					78	22					58	42					54	46				
DT OP lysis 3	9	21	0.65	0.27	1.53	0.32	27	10	1.16	0.52	2.56	0.72	21	16	0.66	0.33	1.34	0.25	17	20	0.87	0.43	1.76	0.70
	30	70					73	27					57	43					46	54				
DT OP lysis 4	1	6	1.66	0.19	14.25	0.64	8	1	0.39	0.05	3.2	0.38	4	5	1.09	0.28	4.17	0.90	4	5	0.93	0.24	3.55	0.91
	14	86					89	11					44	56					44	56				

Legend: TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; MT: *third metatarsal* bone; DT lysis high: *highest grade of lysis in the distal tarsal joints*; DT OP lysis: *highest combined grade of lysis and osteophytes in the distal tarsal joints*

Note: While all lysis was graded on a scale of 0-3, if no horses had changes in a certain category, that category is not included in the table.

Table 3: Sclerosis and cuboidal bone malformation in the distal tarsus relative to likelihood of competing and earning money. Total number of horses in the "compete" category is 347, for the "earn money" category is out of 418 horses.

Variable	Compete						Earn Money 3 Y/O						Earn Money 4 Y/O						Earn Money 3 & 4 Y/O					
	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value
	%	%					%	%					%	%					%	%				
Tarsus - Distal																								
TC sclerosis 0	85	244	reference				294	100	reference				203	190	reference				183	211	reference			
	26	74					75	25					52	48					46	54				
TC sclerosis 1	4	12	1.05	0.33	3.33	0.94	18	3	0.49	0.14	1.7	0.26	10	11	1.18	0.49	2.83	0.72	9	12	1.16	0.48	2.81	0.75
	25	75					86	14					48	52					43	57				
TC sclerosis 2	1	1	0.35	0.02	5.63	0.46	2	1	1.47	0.13	16.39	0.75	2	1	0.53	0.05	5.94	0.61	2	1	0.43	0.04	4.82	0.50
	50	50					67	33					67	33					67	33				
T3 sclerosis 0	84	248	reference				298	101	reference				204	194	reference				184	215	reference			
	25	75					75	25					51	49					46	54				
T3 sclerosis 1	5	7	0.47	0.15	1.53	0.21	13	2	0.45	0.1	2.05	0.30	9	6	0.7	0.24	2.01	0.51	8	7	0.75	0.27	2.1	0.58
	42	58					87	13					60	40					53	47				
T3 sclerosis 2	1	1	0.34	0.02	5.48	0.45	2	1	1.48	0.13	16.44	0.75	2	1	0.53	0.05	5.85	0.60	2	1	0.43	0.04	4.76	0.49
	50	50					67	33					67	33					67	33				
T3 sclerosis 3	0	1	NA	0	N/A	1.00	1	0	0	0	N/A	1.00	0	1	N/A	0	N/A	1.00	0	1	N/A	0	N/A	1.00
	0	100					100	0					0	100					0	100				
Sclerosis high 0	83	243	reference				290	100	reference				201	189	reference				180	210	reference			
	25	75					74	26					52	48					46	54				
Sclerosis high 1	6	12	0.68	0.25	1.88	0.46	21	3	0.41	0.12	1.42	0.16	13	11	0.9	0.39	2.06	0.80	12	12	0.86	0.38	1.96	0.71
	33	67					88	13					54	46					50	50				
Sclerosis high 2	1	1	0.34	0.02	5.52	0.45	2	1	1.45	0.13	16.16	0.76	2	1	0.53	0.05	5.91	0.61	2	1	0.43	0.04	4.77	0.49
	50	50					67	33					67	33					67	33				
Sclerosis high 3	0	1	NA	0	N/A	1.00	1	0	0	0	N/A	1.00	0	1	N/A	0	N/A	1.00	0	1	N/A	0	N/A	1.00
	0	100					100	0					0	100					0	100				
Sclerosis OP 0	38	143	reference				162	55	reference				97	120	reference				88	129	reference			
	21	79					75	25					45	55					41	59				
Sclerosis OP 1	18	47	0.69	0.36	1.33	0.27	60	23	1.13	0.64	2	0.68	48	35	0.59	0.35	0.98	0.04	42	41	0.67	0.4	1.11	0.12
	28	72					72	28					58	42					51	49				
Sclerosis OP 2	25	46	0.49	0.27	0.89	0.02	64	17	0.78	0.42	1.45	0.44	51	30	0.48	0.28	0.8	**0.01**	47	34	0.49	0.29	0.83	**0.01**
	35	65					79	21					63	37					58	42				
Sclerosis OP 3	8	15	0.5	0.2	1.26	0.14	20	8	1.18	0.49	2.83	0.71	16	12	0.61	0.27	1.34	0.22	13	15	0.79	0.36	1.74	0.55
	35	65					71	29					57	43					46	54				
Sclerosis OP 4	1	6	1.59	0.19	13.65	0.67	8	1	0.37	0.05	3.01	0.35	4	5	1.01	0.26	3.87	0.99	4	5	0.85	0.22	3.26	0.82
	14	86					89	11					44	56					44	56				
DT bone malformation 0	85	255	reference				302	105	reference				210	197	reference				187	221	reference			
	25	75					74	26					52	48					46	54				
DT bone malformation 1	8	11	0.46	0.18	1.18	0.11	22	3	0.39	0.12	1.34	0.13	15	10	0.71	0.31	1.62	0.42	15	10	0.56	0.25	1.29	0.17
	42	58					88	12					60	40					60	40				
DT bone malformation 2	0	3	N/A	0	N/A	1.00	1	2	5.75	0.52	64.09	0.15	0	3	N/A	0	N/A	1.00	0	3	N/A	0	N/A	1.00
	0	100					33	67					0	100					0	100				

Legend: TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; Sclerosis High: *highest grade of sclerosis in the distal tarsal joints*; Sclerosis OP: *highest combined grade of sclerosis and osteophytes in the distal tarsal joints,* DT bone malformation: *distal tarsal cuboidal bone malformation*

Note: While all sclerosis was graded on a scale of 0-3, if no horses had changes in a certain category, that category is not included in the table.

Table 4: Changes of the tarsocrural joint and osteophytes of the distal tarsus relative to average amount of money earned.

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Tarsus - Tarsocrural Joint																		
			3.64	3.49	3.79				3.62	3.51	3.73				3.71	3.6	3.82	
DIRT Grade 0	86	12061.4	reference				175	15679.8	reference				193	19510.7	reference			
DIRT Grade 1	10	10822.9	-0.02	-0.49	0.44	0.92	19	12121.8	-0.17	-0.53	0.18	0.33	21	16121.1	-0.16	-0.51	0.18	0.36
DIRT Grade 2	3	7218.66	0.15	-0.67	0.96	0.72	5	12150.8	0.07	-0.59	0.74	0.82	5	16482	0.08	-0.61	0.76	0.82
DIRT Grade 3	5	24075	0.05	-0.58	0.69	0.87	4	12517	0.39	-0.35	1.13	0.30	5	34088.7	0.63	-0.06	1.31	0.07
Tarsus - Distal																		
			3.64	3.5	3.79				3.65	3.54	3.76				3.72	3.61	3.83	
DIT TC OP 0	88	12558.4	reference				174	15594.8	reference				193	19704.9	reference			
DIT TC OP 1	8	5319.9	-0.05	-0.56	0.46	0.85	13	4245.26	-0.43	-0.84	-0.01	**0.04**	14	6981.97	-0.13	-0.55	0.29	0.55
DIT TC OP 2	7	18648.5	0.06	-0.49	0.6	0.84	12	25527.9	-0.04	-0.47	0.39	0.85	13	33605.7	-0.03	-0.47	0.4	0.88
DIT TC OP 3	0	0	N/A				1	1058.37	-0.62	-2.07	0.83	0.40	1	1058.37	-0.7	-2.22	0.83	0.37
DIT TC OP 4	1	9300	0.32	-1.07	1.72	0.65	3	2982.84	-0.3	-1.14	0.54	0.49	3	6082.84	0.02	-0.87	0.9	0.97
			3.67	3.54	3.81				3.63	3.52	3.73				3.73	3.63	3.84	
DIT T3 OP 0	99	12796	reference				190	15091.5	reference				208	19803.3	reference			
DIT T3 OP 1	4	5166	-0.15	-0.83	0.54	0.68	10	17668.6	-0.41	-0.88	0.06	0.09	13	15180.7	-0.37	-0.81	0.06	0.09
DIT T3 OP 2	1	68.43	-1.84	-3.18	-0.49	**0.01**	3	13485.8	0.05	-0.79	0.9	0.9	3	13508.6	-0.05	-0.93	0.83	0.91
			3.64	3.5	3.79				3.62	3.51	3.73				3.71	3.6	3.82	
TMT T3 OP 0	91	12712.7	reference				183	15403.9	reference				199	19901.3	reference			
TMT T3 OP 1	10	8366.07	0.12	-0.34	0.58	0.60	13	18277	0.03	-0.39	0.45	0.90	17	18897.8	0.12	-0.26	0.51	0.53
TMT T3 OP 2	3	15672.7	-0.19	-1	0.62	0.64	6	3906.77	-0.39	-1	0.21	0.21	7	10065.6	-0.28	-0.86	0.3	0.35
TMT T3 OP 3	0	0	N/A				1	4878.39	0.07	-1.39	1.53	0.93	1	4878.39	-0.02	-1.55	1.5	0.98
			3.66	3.51	3.81				3.64	3.53	3.76				3.75	3.64	3.86	
TMT MT OP 0	81	12042.5	reference				160	15608	reference				177	19619.9	reference			
TMT MT OP 1	6	30688.8	0.3	-0.28	0.88	0.31	12	25875.7	0.08	-0.35	0.51	0.73	12	41220.1	0.11	-0.34	0.56	0.64
TMT MT OP 2	9	7292.55	-0.36	-0.84	0.12	0.14	19	6567.86	-0.46	-0.81	-0.1	**0.01**	20	9192.72	-0.46	-0.81	-0.1	**0.01**
TMT MT OP 3	8	7790.72	0	-0.51	0.5	0.99	10	13180.6	0.05	-0.42	0.52	0.84	13	14933.2	-0.1	-0.53	0.34	0.67
TMT MT OP 4	0	0	N/A				2	5804.95	0.11	-0.92	1.13	0.84	2	5804.95	0	-1.07	1.06	0.99
			3.71	3.54	3.89				3.69	3.55	3.82				3.77	3.64	3.9	
DT OP high 0	56	13337.6	reference				124	16398.8	reference				133	20904.9	reference			
DT OP high 1	22	13101.4	0.06	-0.28	0.39	0.74	31	13462.8	-0.2	-0.49	0.09	0.18	37	19069.6	-0.01	-0.29	0.28	0.97
DT OP high 2	17	10633.8	-0.47	-0.84	-0.1	**0.01**	31	15344.5	-0.26	-0.55	0.04	0.09	34	18856.1	-0.29	-0.58	0	**0.05**
DT OP high 3	8	7790.72	-0.06	-0.56	0.45	0.83	12	11478.5	-0.05	-0.49	0.39	0.82	15	13337.9	-0.15	-0.56	0.26	0.47
DT OP high 4	1	9300	0.25	-1.1	1.61	0.71	5	4111.68	-0.18	-0.84	0.48	0.60	5	5971.68	-0.02	-0.71	0.66	0.95

Legend: DIRT: *distal intermediate ridge of the tibia*; TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; MT: *third metatarsal bone;* DT OP high: *highest grade of osteophytes in the distal tarsal joints*

Note: While all osteophytes were graded on a scale of 0-4, if no horses had changes in a certain category, that category is not included in the table (eg grade 4 osteophytes of T3).

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

Table 5: Lysis in the distal tarsus relative to average amount of money earned

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Tarsus - Distal																		
			3.65	3.51	3.79				3.61	3.5	3.72				3.71	3.61	3.82	
DIT TC lysis 0	92	11979.7	reference				179	15228.8	reference				198	19256.9	reference			
DIT TC lysis 1	4	10465.9	0.04	-0.64	0.72	0.90	6	1955.25	-0.5	-1.1	0.11	0.11	7	7656.45	-0.2	-0.78	0.39	0.51
DIT TC lysis 2	5	26280.3	0.52	-0.1	1.13	0.10	13	19562.3	0.15	-0.26	0.57	0.47	13	29670	0.14	-0.29	0.58	0.52
DIT TC lysis 3	3	4045.68	-0.89	-1.68	-0.11	**0.03**	5	18531	0.11	-0.55	0.77	0.74	6	17465.3	-0.21	-0.84	0.42	0.52
			3.64	3.51	3.78				3.62	3.51	3.72				3.71	3.61	3.82	
DIT T3 lysis 0	92	12160.6	reference				179	15190.6	reference				199	19209.6	reference			
DIT T3 lysis 1	2	6772.65	0.16	-0.79	1.12	0.74	5	1613.97	-0.71	-1.37	-0.06	**0.03**	5	4323.03	-0.51	-1.2	0.17	0.14
DIT T3 lysis 2	7	20439.8	0.38	-0.15	0.9	0.16	14	18912.7	0.12	-0.28	0.52	0.55	14	29132.5	0.25	-0.17	0.67	0.24
DIT T3 lysis 3	3	4045.68	-0.89	-1.68	-0.11	**0.03**	5	18531	0.1	-0.55	0.76	0.75	6	17465.3	-0.21	-0.83	0.42	0.52
			3.63	3.5	3.77				3.61	3.51	3.72				3.71	3.61	3.82	
TMT T3 lysis 0	101	12374.7	reference				194	15558.8	reference				215	19779.9	reference			
TMT T3 lysis 1	1	10238.3	0.38	-1.01	1.76	0.59	2	6983.68	0.21	-0.83	1.25	0.69	2	12102.8	0.27	-0.81	1.36	0.62
TMT T3 lysis 2	2	13729	0.49	-0.5	1.47	0.33	7	7517.18	-0.12	-0.68	0.44	0.68	7	11439.8	-0.14	-0.73	0.44	0.63
			3.64	3.5	3.78				3.61	3.51	3.72				3.72	3.61	3.82	
TMT MT lysis 0	100	12491.5	reference				195	15498	reference				215	19794.2	reference			
TMT MT lysis 1	1	10238.3	0.37	-1.02	1.76	0.60	4	3961.44	-0.23	-0.97	0.51	0.54	4	6521.02	-0.25	-1.02	0.52	0.52
TMT MT lysis 2	3	9384.66	0.05	-0.76	0.86	0.90	4	11744.2	0.17	-0.57	0.91	0.65	5	15026.2	-0.01	-0.7	0.68	0.97
			3.66	3.51	3.8				3.64	3.53	3.76				3.74	3.63	3.85	
DT lysis high 0	88	12331.2	reference				168	15988.2	reference				187	20166.7	reference			
DT lysis high 1	5	9295.52	0.03	-0.59	0.65	0.93	10	1731.39	-0.62	-1.09	-0.15	**0.01**	11	5799.23	-0.42	-0.89	0.05	0.08
DT lysis high 2	8	17971.8	0.22	-0.28	0.72	0.38	19	14391.7	-0.07	-0.41	0.28	0.71	20	20860.8	-0.04	-0.4	0.31	0.81
DT lysis high 3	3	4045.68	-0.9	-1.69	-0.11	0.026	5	18531	0.08	-0.58	0.73	0.82	6	17465.3	-0.23	-0.86	0.39	0.46
			3.71	3.52	3.91				3.74	3.6	3.88				3.81	3.67	3.95	
DT OP lysis 0	49	13979.3	reference				108	18161.1	reference				116	22813.6	reference			
DT OP lysis 1	25	12936	0.05	-0.28	0.38	0.77	37	11491.6	-0.35	-0.62	-0.08	**0.01**	44	17013.4	-0.16	-0.42	0.11	0.25
DT OP lysis 2	19	10906.9	-0.24	-0.61	0.13	0.20	36	13500.9	-0.29	-0.57	-0.02	0.04	39	17776	-0.26	-0.54	0.02	0.06
DT OP lysis 3	10	6261.98	-0.37	-0.84	0.1	0.13	16	11015.9	-0.15	-0.53	0.23	0.44	20	11943.7	-0.29	-0.66	0.07	0.12
DT OP lysis 4	1	9300	0.26	-1.11	1.63	0.71	5	4111.68	-0.24	-0.89	0.42	0.48	5	5971.68	-0.07	-0.76	0.62	0.84

Legend: TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; MT: *third metatarsal* bone; DT lysis high: *highest grade of lysis in the distal tarsal joints*; DT OP lysis: *highest combined grade of lysis and osteophytes in the distal tarsal joints*

Note: While all lysis was graded on a scale of 0-3, if no horses had changes in a certain category, that category is not included in the table.

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

Table 6: Sclerosis and cuboidal bone malformation in the distal tarsus relative to average amount of money earned

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Tarsus - Distal																		
			3.66	3.52	3.79				3.62	3.51	3.72				3.72	3.62	3.83	
TC sclerosis 0	100	11186.6	reference				191	15406	reference				211	19174.4	reference			
TC sclerosis 1	3	56270.7	0.3	-0.49	1.08	0.46	11	9986.21	-0.21	-0.67	0.24	0.35	12	23221.7	-0.31	-0.76	0.13	0.17
TC sclerosis 2	1	68.43	-1.82	-3.16	-0.48	**0.01**	1	32448.5	0.9	-0.56	2.35	0.23	1	32517	0.79	-0.73	2.31	0.31
T3 sclerosis 0	101	12626.1	N/A				195	15251.8	N/A				215	19693.4	N/A			
T3 sclerosis 1	2	6115.5					6	11790.5					7	11853.4				
T3 sclerosis 2	1	68.43					1	32448.5					1	32517				
T3 sclerosis 3	0	0					1	7395.34					1	7395.34				
			3.66	3.52	3.79				3.62	3.51	3.72				3.72	3.62	3.83	
Sclerosis high 0	100	11186.6	reference				189	15454.5	reference				210	19236	reference			
Sclerosis high 1	3	56270.7	0.3	-0.49	1.08	0.46	11	9879.86	-0.22	-0.67	0.23	0.34	12	23124.2	-0.32	-0.77	0.13	0.16
Sclerosis high 2	1	68.43	-1.82	-3.16	-0.48	**0.01**	1	32448.5	0.9	-0.56	2.35	0.23	1	32517	0.79	-0.73	2.31	0.31
Sclerosis high 3	**0**	0	N/A				1	7395.34	0.25	-1.21	1.71	0.73	1	7395.34	0.15	-1.37	1.66	0.85
			3.69	3.51	3.87				3.69	3.56	3.82				3.77	3.64	3.9	
Sclerosis OP 0	55	10733.2	reference				120	16657.1	reference				129	20071.2	reference			
Sclerosis OP 1	23	19339.6	0.15	-0.19	0.48	0.39	35	12912.6	-0.2	-0.48	0.07	0.15	41	21872	-0.01	-0.28	0.26	0.92
Sclerosis OP 2	17	10633.8	-0.44	-0.81	-0.07	**0.02**	30	15344.5	-0.26	-0.56	0.03	0.08	34	18856.1	-0.3	-0.59	-0.01	**0.05**
Sclerosis OP 3	8	7790.72	-0.03	-0.53	0.48	0.91	12	11478.5	-0.06	-0.5	0.38	0.80	15	13337.9	-0.15	-0.56	0.26	0.47
Sclerosis OP 4	1	9300	0.28	-1.07	1.63	0.68	5	4111.68	-0.18	-0.85	0.48	0.59	5	5971.68	-0.03	-0.71	0.66	0.94
			3.63	3.5	3.76				3.61	3.51	3.71				3.7	3.6	3.81	
DT malform 0	106	12223.7	reference				198	15674.5	reference				221	19779.9	reference			
DT malform 1	3	4843.1	-0.03	-0.83	0.78	0.95	10	7025.25	0.08	-0.39	0.55	0.75	10	8478.18	0.04	-0.45	0.53	0.87
DT malform 2	2	9465.67	0.34	-0.63	1.32	0.49	3	7986.13	0.06	-0.79	0.91	0.90	3	14296.6	0.42	-0.45	1.3	0.34

Legend: TC: *central tarsal bone*; T3: *third tarsal bone*; OP: *osteophytes*; Sclerosis High: *highest grade of sclerosis in the distal tarsal joints*; Sclerosis OP: *highest combined grade of sclerosis and osteophytes in the distal tarsal joints*, DT bone malformation: *distal tarsal cuboidal bone malformation*

Note: While all sclerosis was graded on a scale of 0-3, if no horses had changes in a certain category, that category is not included in the table.

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

Table 7: Radiographic changes to the stifle and carpus relative to likelihood of competing and earning money.

Variable	Compete							Earn Money 3 Y/O						
	No	Yes	Total	OR	95% CI		p-value	No	Yes	Total	OR	95% CI		p-value
	%	%						%	%					
Stifle														
MFC Grade 0	49	157	206	reference				191	61	252	reference			
	24	76						76	24					
MFC Grade 1	20	57	77	0.89	0.49	1.62	0.70	64	28	92	1.37	0.81	2.33	0.24
	26	74						70	30					
MFC Grade 2	7	24	31	1.07	0.43	2.63	0.88	32	6	38	0.59	0.23	1.47	0.26
	23	77						84	16					
MFC Grade3	8	15	23	0.59	0.23	1.46	0.25	24	4	28	0.52	0.17	1.56	0.25
	35	65						86	14					
MFC Grade 4	9	12	21	0.42	0.17	1.05	0.06	15	7	22	1.46	0.57	3.75	0.43
	43	57						68	32					
Total	93	265	358					326	106	432				
LTR Grade 0	88	248	336	N/A				305	98	403	N/A			
	26	74						76	24					
LTR Grade 2	0	3	3					2	1	3				
	0	100						67	33					
LTR Grade 3	1	4	5					4	1	5				
	20	80						80	20					
Total	89	255	344					311	100	411				
Carpus														
Osteophyte No	69	198	267	N/A				241	74	316	N/A			
	26	74						76	23					
Osteophyte Yes	1	6	7					10	2	12				
	14	86						83	17					
Total	70	204	274					251	76	328				

Variable	Earn Money 4 Y/O							Earn Money 3 & 4 Y/O						
	No	Yes	Total	OR	95% CI		p-value	No	Yes	Total	OR	95% CI		p-value
	%	%						%	%					
Stifle														
MFC Grade 0	128	124	252	reference				113	139	252	reference			
	51	49						45	55					
MFC Grade 1	46	46	92	1.03	0.64	1.66	0.9	41	51	92	1.01	0.63	1.63	0.96
	50	50						45	55					
MFC Grade 2	24	14	38	0.6	0.3	1.22	0.16	21	17	38	0.66	0.33	1.31	0.23
	63	37						55	45					
MFC Grade3	17	11	28	0.67	0.3	1.48	0.32	17	11	28	0.53	0.24	1.17	0.11
	61	39						61	39					
MFC Grade 4	10	12	22	1.24	0.52	2.97	0.63	10	12	22	0.98	0.41	2.34	0.96
	45	55						45	55					
Total	225	207	432					202	230	432				
LTR Grade 0	206	197	403	N/A				187	216	403	N/A			
	51	49						46	54					
LTR Grade 2	0	3	3					0	3	3				
	0	100						0	100					
LTR Grade 3	3	2	5					3	2	5				
	60	40						60	40					
Total	209	202	411					190	221	411				
Carpus														
Osteophyte No	159	156	316	N/A				145	171	316	N/A			
	50	49						46	54					
Osteophyte Yes	8	4	12					8	4	12				
	67	33						67	33					
Total	167	160	328					153	175	328				

Table 8: Radiographic changes to the stifle and carpus relative to the average amount of money earned.

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Stifle																		
			3.66	3.48	3.8				3.65	3.52	3.8				3.74	3.61	3.9	
MFC Grade 0	61	12181.6	reference				124	17064.2	reference				139	20568.6	reference			
MFC Grade 1	28	11501.5	-0.05	-0.36	0.3	0.75	46	13138.3	-0.13	-0.38	0.1	0.32	51	18164.7	-0.08	-0.33	0.2	0.51
MFC Grade 2	6	3868.66	-0.22	-0.8	0.4	0.46	14	4272.74	-0.26	-0.66	0.2	0.22	17	4884.14	-0.34	-0.72	0.1	0.08
MFC Grade 3	4	9835.88	0.13	-0.57	0.8	0.71	11	9088.95	-0.09	-0.55	0.4	0.70	11	12665.6	-0.01	-0.48	0.5	0.96
MFC Grade 4	7	25140.8	0.3	-0.24	0.8	0.28	12	20224.4	0.01	-0.43	0.5	0.95	12	34889.8	0.28	-0.17	0.7	0.22
LTR Grade 0	98	12973.9	N/A				197	15109.1	N/A				216	19666.3	N/A			
LTR Grade 2	1	8414					3	36205.2					3	39009.9				
LTR Grade 3	1	2000					2	693.425					2	1693.43				
Carpus																		
Osteophyte N	75	10462.5	N/A				157	14986.6	N/A				171	18199.6	N/A			
Osteophyte Y	2	9571.5					4	7972.68					4	12758.4				

Legend: MFC: *medial femoral condyle*; LTR: *lateral trochlear ridge*

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

Table 9: **Radiographic changes to the hind fetlock relative to likelihood of competing and earning money. Total number of horses in the "compete" category is 282, for the "earn money" category is out of 344 horses.**

Variable	Compete						Earn Money 3 Y/O						Earn Money 4 Y/O						Earn Money 3 & 4 Y/O					
	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value	No	Yes	OR	95% CI		p-value
	%	%					%	%					%	%					%	%				
Fetlock - Hind																								
Prox SR 0	60	164	reference				215	61	reference				149	128	reference				138	139	reference			
	27	73					78	22					54	46					50	50				
Prox SR 1	12	37	1.13	0.55	2.31	0.74	40	14	1.23	0.63	2.42	0.54	25	29	1.35	0.75	2.42	0.31	22	32	1.44	0.8	2.61	0.22
	24	76					74	26					46	54					41	59				
Prox SR 2	3	5	0.61	0.14	2.63	0.51	10	1	0.35	0.04	2.81	0.32	6	5	0.97	0.29	3.25	0.96	6	5	0.83	0.25	2.77	0.76
	38	63					91	9					55	45					55	45				
Prox SR 3	0	0	N/A				1	0	N/A	0	N/A	1.00	1	0	N/A	0	N/A	1.00	1	0	N/A	0	N/A	1.00
	.	.					100	0					100	0					100	0				
Dorsal Frag 0	74	205	N/A				263	76	N/A				179	161	N/A				165	175	N/A			
	27	73					77	22					53	47					49	51				
Dorsal Frag 1	1	2					4	0					2	2					2	2				
	33	67					100	0					50	50					50	50				
Plantar Frag 0	73	202	N/A				261	73	N/A				176	159	N/A				162	173	N/A			
	27	73					78	22					53	47					48	52				
Plantar Frag 1	2	5					6	3					5	4					5	4				
	29	71					67	33					56	44					56	44				
P2 - Hind																								
P2 dorsal cortex 0	68	174	reference				232	63	reference				164	132	reference				151	145	reference			
	28	72					78	21					55	45					51	49				
P2 dorsal cortex 1	5	26	2.03	0.75	5.51	0.16	29	9	1.14	0.51	2.54	0.74	12	26	2.69	1.31	5.54	**0.01**	12	26	2.26	1.1	4.64	**0.03**
	16	84					76	24					32	68					32	68				
P2 dorsal cortex 2	0	6	N/A	0	N/A	1.00	2	4	7.36	1.32	41.13	**0.02**	1	5	6.21	0.72	53.82	0.10	0	6	N/A	0	N/A	1.00
	0	100					33	67					17	83					0	100				
P2 dorsal cortex 3	2	1	0.2	0.02	2.19	0.19	4	0	N/A	0	N/A	1.00	4	0	N/A	0	N/A	1.00	4	0	N/A	0	N/A	1.00
	67	33					100	0					100	0					100	0				
P2 Osteophyte 0	64	178	reference				234	65	reference				166	134	reference				152	148	reference			
	26	74					78	22					55	45					51	49				
P2 Osteophyte 1	11	29	0.95	0.45	2.01	0.89	33	11	1.2	0.58	2.5	0.63	15	29	2.4	1.23	4.65	**0.01**	15	29	1.99	1.02	3.85	**0.04**
	28	73					75	25					34	66					34	66				

Table 10: **Radiographic changes to the hind fetlock relative to average amount of money earned.**

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Fetlock - Hind																		
			3.72	3.56	3.88				3.6	3.47	3.72				3.72	3.59	3.84	
Prox SR 0	62	11530	reference				128	15381.1	reference				139	19223.9	reference			
Prox SR 1	14	6554.97	-0.29	-0.66	0.07	0.12	29	12766.4	0.07	-0.22	0.37	0.63	32	14437.4	0	-0.3	0.29	0.98
Prox SR 2	1	10000	0.28	-0.96	1.53	0.66	5	8907.15	-0.63	-1.28	0.03	0.06	5	10907.2	-0.71	-1.39	-0.03	**0.04**
Dor Frag 0	77	10593.5	N/A				161	14806.5	N/A				175	18222.6	N/A			
Dor Frag 1	0	0					2	503.645					2	503.645				
Pltr Frag 0	74	10738	N/A				159	14821.4	N/A				173	18153	N/A			
Pltr Frag 1	3	7075.48					4	7063.01					4	12369.6				
P2 - Hind																		
			3.73	3.58	3.88				3.58	3.45	3.71				3.68	3.56	3.81	
P2 Dorsal Cortex 0	64	11548.6	reference				132	15451.6	reference				145	19083.9	reference			
P2 Dorsal Cortex 1	9	7559.52	-0.05	-0.47	0.37	0.81	26	9936.62	0.07	-0.24	0.38	0.67	26	12553.4	0.09	-0.23	0.41	0.60
P2 Dorsal Cortex 2	4	2375.82	-1.05	-1.65	-0.44	**0.001**	5	17378.6	-0.06	-0.72	0.6	0.86	6	16066	-0.05	-0.68	0.57	0.87
			3.69	3.54	3.85				3.58	3.46	3.71				3.69	3.56	3.81	
P2 OP 0	66	10828.2	reference				134	14677.5	reference				148	18044.8	reference			
P2 OP 1	11	9206.33	-0.15	-0.56	0.26	0.47	29	14415.9	0.03	-0.27	0.33	0.85	29	17907.9	0.03	-0.28	0.34	0.85

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

Table 11: **Radiographic changes to the fore fetlock relative to likelihood of competing and earning money. Total number of horses in the "compete" category is 282, for the "earn money" category is out of 344 horses.**

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Fetlock - Fore																		
			3.65	3.49	3.8				3.57	3.45	3.7				3.67	3.55	3.79	
Prox SR 0	69	10994.6	reference				136	14714.5	reference				150	18325.3	reference			
Prox SR 1	8	6858.13	0.06	-0.42	0.54	0.81	21	12580.7	0.12	-0.22	0.46	0.48	22	14502.7	0.11	-0.23	0.46	0.52
Prox SR 2	0	0	N/A				5	23883.4	0.22	-0.44	0.87	0.52	5	23883.4	0.12	-0.57	0.8	0.74
Prox SR 3	1	2832.48	-0.2	-1.49	1.09	0.77	1	807.76	-0.66	-2.11	0.79	0.37	1	3640.24	-0.11	-1.62	1.41	0.89
Dor Frag 0	78	10458.8	N/A				160	14891.9	N/A				175	18217.3	N/A			
Dor Frag 1	0	0					3	962.143					3	962.143				
			3.69	3.53	3.84				3.62	3.5	3.74				3.7	3.58	3.82	
PSCL 0	66	11425.5	reference				146	15675.6	reference				158	19185.4	reference			
PSCL 1	9	5658.55	-0.08	-0.53	0.37	0.73	11	7890.24	-0.09	-0.53	0.36	0.71	14	9837.11	-0.04	-0.46	0.38	0.86
PSCL 2	3	3915.14	-0.63	-1.37	0.12	0.10	5	1207.06	-0.69	-1.35	-0.04	**0.04**	5	3556.14	-0.39	-1.07	0.3	0.27
PSCL 3	0	0	N/A				1	4117.94	-0.002	-1.44	1.44	1.00	1	4117.94	-0.09	-1.6	1.43	0.91
Prox Sesamoid OP 0	75	10702.4	N/A				157	15000.5	N/A				172	18296.8	N/A			
Prox Sesamoid OP 1	3	4450.7					6	5086.38					6	7311.73				
P2 - Fore																		
P2 OP 0	76	10721.4	N/A				161	14755.4	N/A				175	18169.8	N/A			
P2 OP 1	2	612.8					2	4986.03					3	3732.55				

Table 12: **Radiographic changes to the fore fetlock relative to average amount of money earned.**

Variable	Amount Money 3 Y/O						Amount Money 4 Y/O						Amount Money 3 & 4 Y/O					
	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value	N	Mean	Estimate	95% CI		p-value
Fetlock - Fore																		
			3.65	3.49	3.8				3.57	3.45	3.7				3.67	3.55	3.79	
Prox SR 0	69	10994.6	reference				136	14714.5	reference				150	18325.3	reference			
Prox SR 1	8	6858.13	0.06	-0.42	0.54	0.81	21	12580.7	0.12	-0.22	0.46	0.48	22	14502.7	0.11	-0.23	0.46	0.52
Prox SR 2	0	0	N/A				5	23883.4	0.22	-0.44	0.87	0.52	5	23883.4	0.12	-0.57	0.8	0.74
Prox SR 3	1	2832.48	-0.2	-1.49	1.09	0.77	1	807.76	-0.66	-2.11	0.79	0.37	1	3640.24	-0.11	-1.62	1.41	0.89
Dor Frag 0	78	10458.8	N/A				160	14891.9	N/A				175	18217.3	N/A			
Dor Frag 1	0	0					3	962.143					3	962.143				
			3.69	3.53	3.84				3.62	3.5	3.74				3.7	3.58	3.82	
PSCL 0	66	11425.5	reference				146	15675.6	reference				158	19185.4	reference			
PSCL 1	9	5658.55	-0.08	-0.53	0.37	0.73	11	7890.24	-0.09	-0.53	0.36	0.71	14	9837.11	-0.04	-0.46	0.38	0.86
PSCL 2	3	3915.14	-0.63	-1.37	0.12	0.1	5	1207.06	-0.69	-1.35	-0.04	0.04	5	3556.14	-0.39	-1.07	0.3	0.27
PSCL 3	0	0	N/A				1	4117.94	-0.002	-1.44	1.44	1.0	1	4117.94	-0.09	-1.6	1.43	0.91
Prox Sesamoid OP 0	75	10702.4	N/A				157	15000.5	N/A				172	18296.8	N/A			
Prox Sesamoid OP 1	3	4450.7					6	5086.38					6	7311.73				
P2 - Fore																		
P2 OP 0	76	10721.4	N/A				161	14755.4	N/A				175	18169.8	N/A			
P2 OP 1	2	612.8					2	4986.03					3	3732.55				

* Statistical analysis of earnings performed and reported on a log10 scale in order to normalize data.

CHAPTER 4

Discussion

Changes to the distal tarsus, osteophytosis in particular, was the most frequent radiographic change associated performance outcome. When examining the DIT and TMT combined, grade 2 (small) osteophytes of the distal tarsus, were associated with a decreased likelihood of competing, decreased chance of earning money as a four year old and as a three and four year old combined, and a lower average earnings as a three year old and as a three and four year old combined. When osteophytes and sclerosis were examined together, grade 2 changes were also significant, associated with the likelihood of competing, earning money as a four year old and the amount of money earned as a three and four year old. Another interesting finding was that grade 2 osteophytes of the proximal MTIII were associated with decreased amount of money earned as four year old and as three and four year olds combined.

In a study of yearling Thoroughbreds, Kane *et al* (2003b) found that osteophytes/enthesophytes of the DIT and TMT were significantly associated with a decreased likelihood of starting a race. Of 193 horses with osteophytes/enthesophytes of the distal tarsus, 147 (76%), started a race, while 753 of 908 horses (83%) without these changes started a race ($p = 0.03$). Other radiographic survey studies have not found osteophytosis of the distal tarsal joints to be significantly associated with performance outcome (Robert *et al* 2006, Jackson *et al* 2009). In a study of 91 horses with tarsal lameness, Byam-Cook and Singer (2009) found no association between radiographic changes of distal tarsal joints and degree or duration of lameness.

While small osteophytes of the distal tarsus are often regarded as having dubious clinical significance, including by the authors of this study, the findings of this research call that into question. More research with greater numbers of horses is warranted for further evaluation of the association of osteophytosis of the distal tarsus and performance. Advanced imaging such as MRI could also be of value, allowing visualization of more subtle changes to the bone and cartilage that may co-exist with small osteophytes. The fact that medium and large osteophytes were not found to be significantly associated with performance could be due in part to the low numbers of horses in these categories or may represent a different stage or manifestation of tarsal disease, again emphasizing the need for further research.

An increased likelihood of earning money was seen with osteophytosis and bony proliferation of hind P2. Contino *et al* described thickening of the dorsal cortex of hind P2 that had not been reported in the past, and speculated that it could be the result of the stresses placed on the hind limbs when horses are pivoting on the hind feet, performing cutting type movements. These movements can be observed even in very young cutting horses that are not yet in training. It is possible that horses that are more likely to be performing this type of movement, even without training, are naturally more talented, resulting in a greater likelihood of earning money. The relationship of the presence of hind P2 osteophytes and improved performance outcome could be explained along the same lines – horses that most frequently perform cutting type motions may be more likely to develop osteophytes secondary to stress placed on the pastern joint, and these same horses may be working harder or be independently performing more cutting type motions than horses without these changes.

Fragmentation of the distal intermediate ridge of the tibia was associated with a greater likelihood of earning money as a three year old. A relatively small number of horses were affected, which limits the statistical strength of this observation. Other studies looking at the effect of tarsocrural OCD in racehorses have had mixed outcomes. No effect on performance in Thoroughbreds or French Trotters was found by Kane *et al* 2003b or Robert *et al* 2006, respectively. Decreased earnings and fewer starts were found in Norwegian Trotters by Grondhal and Engeland (1995). Conversely, Torre and Motta (2000) found that Italian Standardbred yearlings with radiographic changes, including tarsocrural OCD, had greater earnings and more wins than non-affected horses.

Grade 2 (moderate) palmar supracondylar lysis was associated with a decreased mean earning potential as a four year old. However, this finding affected only a small number of horses, limiting the conclusions that can be drawn from this finding. Kane *et al* (2003b) found that moderate to extreme palmar supracondylar lysis in yearling Thoroughbreds was significantly associated with a decreased chance of starting a race as a two or three year old. Palmar supracondylar lysis is described as bone loss of the distal metacarpal bone at the level of the palmar joint pouch due to chronic inflammation, usually secondary to chronic osteoarthritis (Pool 1996). Thus, it is possible that chronic inflammation and osteoarthritic changes of the fetlock joint contribute to the affected horses' decreased earnings. However, as the number affected is relatively low, further investigation would be warranted to confirm this finding.

Decreased mean earnings in three and four year old years combined was seen in cases of grade 2 lesions of the proximal SR of MTIII. Again, only a low number of horses were affected (5 of 176), limiting the statistical inferences. Other radiographic surveys have had variable findings. Jackson *et al* (2009) found that defects greater than 10mm in length in the SR of MTIII were associated with decreased likelihood of starting a race, fewer starts, decreased chance of earning money and less total prize money than unaffected horses. Cohen *et al* (2006) found a significant relationship between lesions of the proximal SR and sales price, but no relationship to performance outcome. Kane *et al* (2003b) found no relationship between abnormalities of the proximal SR and performance in Thoroughbred yearlings. However, grade 2 and 3 OCD of the fetlock has been considered by some to have a less favorable prognosis than other forms of OCD, with only a reported 57% success rate following surgery. Prognosis is influenced by confluent lesions such as articular cartilage damage and subchondral defects (McIlwraith and Vorhees 1990). Like the other findings with a relatively low number of horses affected, further investigations are indicated for better evaluation of this outcome.

Bilateral versus unilateral radiographic lesions generally were not associated with a significantly different outcome. However, in the cases where there was a significant difference, or a trend towards a difference, horses with bilateral lesions tended to have better performance outcomes than horses with unilateral lesions. A potential explanation for this finding could be that horses that have bilateral changes may be load-bearing and working more symmetrically than horses with unilateral lesions.

Interestingly, although lameness referable to the stifle, particularly the MFC, is a major concern of the cutting horse industry, no radiographic changes of the MFC were significantly associated with performance outcome. However, a shortcoming of this study is that lameness was not an outcome variable that was thoroughly examined. While an attempt was made to contact the owners of horses that did not earn money to find out why, few outcome parameters were captured on horses that earned money. Thus it is possible that there are horses with stifle lesions that were able to compete and earn money, yet still suffered from lameness. Obtaining records of individual horses' medical history may be of limited value as it is not uncommon for cutting horses to have hock and stifle injections without full lameness work-ups.

In summary, this study identified several radiographic changes associated with decreased performance outcome in cutting horses, with grade 2 osteophytes of the distal tarsus being the one change that was significantly associated with all outcome parameters. It is well accepted that tarsal disease is a common problem in cutting horses, and these results suggest that even mild changes may affect performance. Further research that included regular lameness evaluations and monitoring of joint medication would be useful to compare radiographic changes to lameness. In addition, studies that follow horses beyond their four year old year may help shed light on which radiographic changes may not affect performance in the short term but could affect the longevity of these horses' careers. For the welfare of the horse and the cutting industry, an objective understanding of the significance of particular radiographic findings is needed, and this study is an important first step in obtaining that goal.

References

Alvarado AF, Marcoux M and Breton L. (1989) The incidence of osteochondrosis in a Standardbred breeding farm in Quebec. *Proc. Am. Ass. Equine Practnrs*. **35**, 293-307.

Barclay WP, Foerner JJ and Phillips TN. (1987) Lameness attributable to osteochondral fragmentation of the plantar aspect of the proximal phalanx in horses: 19 cases (1981-1985). *J Am Vet Med Assoc* **191**, 855-857.

Becht JL and Park RD. (2000) A review of selected normal radiographic variations of the equine fetlock, carpus, tarsus and stifle. *Proc Am Ass Equine Practnrs* **46**, 362-364.

Black JB. (1999) Purchase examination of the western show and performance horse. *Proc Am Ass Equine Practnrs* **45**, 1-3.

Bladon BM and Main JP. (2003) Clinical evidence in the evaluation of presale radiography: are we in a desert on a horse with no name? *Equine Vet J* **35**, 341-342.

Blevins WE and Widmer WR. (1990) Radiology in racetrack practice. *Vet Clin North Am Equine Pract* **6**, 31-61.

Bramlage LR. (2009) Operative orthopedics of the fetlock joint of the horse: traumatic and developmental diseases of the equine fetlock joint. *Proc Am Ass Equine Practnrs* **55**, 96-143.

Butler J, Colles C, Dyson S, Kold S and Poulos P. (2008) *Clinical Radiology of the Horse 3rd ed.*, Wiley-Blackwell, Oxford.

Byam-Cook KL, Singer ER.(2009) Is there a relationship between clinical presentation, diagnostic and radiographic findings and outcome in horses with osteoarthritis of the small tarsal joints? *Equine vet J.* **41**, 118-123.

Carter GK. (2009) Purchase examination of the Western performance horse. *Proc Am Ass Equine Practnrs* **55**, 292-295.

Carlsten J, Sandgren B and Dalin G. (1993) Development of osteochondrosis in the tarsocrural joint and osteochondral fragments in the fetlock joints of Standardbred trotters. I. A radiological survey. *Equine Vet J Suppl* **16**, 42-47.

Cohen ND, Carter GK, Watkins JP,O'Connor MS. (2006) Association of racing performance with specific abnormal radiographic findings in Thoroughbred yearlings sold in Texas. J Equine Vet Sci. 26, 462-474.

Colon JL, Bramlage LR, Hance SR and Embertson RM. (2000) Qualitative and quantitative documentation of the racing performance of 461 Thoroughbred racehorses after arthroscopic removal of dorsoproximal first phalanx osteochondral fractures (1986-1995). *Equine Vet J* **32**, 475-481.

Contino EK. The prevalence of radiographic changes in yearling and two-year-old Quarter Horses. Thesis, Colorado State University, Fort Collins. 2009.

Contino EK, Park RD, McIlwraith CW. Prevalence of radiographic changes in yearling and two-year-old Quarter Horses. In: Proceedings. 55th Annu Conv Am Assoc Equine Practnrs 2009; 470.

Courcourcé-Malblance A, Leleu C, Bouchilloux M, Geffroy O. (2006) Abnormal radiographic findings in 865 French Standardbred trotters and their relationship to racing performance. *Equine vet J., Suppl* **36,** 417-422.

Dabareiner RM, Cohen ND, Carter GK, Nunn S and Moyer W. (2005a) Musculoskeletal problems associated with lameness and poor performance among horses used for barrel racing: 118 cases (2000-2003). *J Am Vet Med Assoc* **227**, 1646-1650.

Dabareiner RM, Cohen ND, Carter GK, Nunn S and Moyer W. (2005b) Lameness and poor performance in horses used for team roping: 118 cases (2000-2003). *J Am Vet Med Assoc* **226**, 1694-1699.

Dik KJ, Enzerink E and van Weeren PR. (1999) Radiographic development of osteochondral abnormalities, in the hock and stifle of Dutch Warmblood foals, from age 1 to 11 months. *Equine Vet J Suppl* **31**, 9-15.

Foland JW, McIlwraith CW and Trotter GW. (1992) Arthroscopic surgery for osteochondritis dissecans of the femoropatellar joint of the horse. *Equine Vet J* **24**, 419-423.

Foerner JJ, Barclay W, Phillips T and MacHarg M. (1987) Osteochondral fragments of the palmar/plantar aspect of the fetlock joint. *Proc Am Ass Equine Practnrs* **32**, 739-744.

Fortier LA, Foerner JJ and Nixon AJ. (1995) Arthroscopic removal of axial osteochondral fragments of the plantar/palmar proximal aspect of the proximal phalanx in horses: 119 cases (1988-1992). *J Am Vet Med Assoc* **206**, 71-74.

Grondahl AM. (1992) The incidence of bony fragments and osteochondrosis in the metacarpo- and metatarsophalangeal joints of Standardbred trotters: A radiographic study. *Equine Vet Sci* **12**, 81-85.

Grondahl AM and Engeland A. (1995) Influence of radiographically detectable orthopedic changes on racing performance in Standardbred trotters. *J Am Vet Med Assoc* **206**, 1013-1017.

Hance SR and Morehead JP. (2000) Radiographing Thoroughbred yearlings for the repository. *Proc Am Ass Equine Practnrs* **46**, 359-361.

Haynes PF, Root CR, Clabough BS and Roberts ED. (1982) Palmar supracondylar lysis of the third metacarpal bone. *Proc Am Ass Equine Practnrs* **27**, 185-193..

Hoppe F. (1984) Radiological investigations of osteochondritis dissecans in Standardbred Trotters and Swedish Warmblood horses. *Equine Vet J* **16**, 425-429..

Howard BA, Embertson RM, Rantanen NW and Bramlage LR. (1992) Survey of radiographic findings in Thoroughbred sales yearlings. *Proc Am Ass Equine Practnrs* **38**, 397-402.

Howard RD, McIlwraith CW and Trotter GW. (1995) Arthroscopic surgery for subchondral cystic lesions of the medial femoral condyle in horses: 41 cases (1988-1991). *J Am Vet Med Assoc* **206**, 842-850.

Jackman BR. (2001) Common lamenesses in the cutting and reining horse. *Proc Am Ass Equine Practnrs* **47**, 6-11.

Jackson M, Vizard A, Anderson G, Clarke A, Mattoon J, Lavelle R, Lester N, Smithenson T, Whitton C. (2009) A prospective study of presale radiographs in Thoroughbred yearlings. RIRDC: Publication No 09/082.

Jorgensen HS, Proschowsky H, Falk-Ronne J, Willeberg P and Hesselholt M. (1997) The significance of routine radiographic findings with respect to subsequent racing performance and longevity in Standardbred trotters. *Equine Vet J* **29**, 55-59.

Kane AJ, Park RD, McIlwraith CW, Rantanen NW, Morehead JP and Bramlage LR. (2003a) Radiographic changes in Thoroughbred yearlings. Part 1: Prevalence at the time of the yearling sales. *Equine Vet J* **35**, 354-365.

Kane AJ, McIlwraith CW, Park RD, Rantanen NW, Morehead JP and Bramlage LR. (2003b) Radiographic changes in Thoroughbred yearlings. Part 2: Associations with racing performance. *Equine Vet J* **35**, 366-374.

Kawcak CE and McIlwraith CW. (1994) Proximodorsal first phalanx osteochondral chip fragmentation in 336 horses. *Equine Vet J* **26**, 392-396.

Laws EG, Richardson DW, Ross MW and Moyer W. (1993) Racing performance of Standardbreds after conservative and surgical treatment for tarsocrural osteochondrosis. *Equine Vet J* **25**, 199-202.

Martin, B.B., Kimmel, J.C. and Cheney, M.W. (2003) Purchase examination of a thoroughbred sales yearling in North America. In: Diagnosis and Management of Lameness in the Horse, Eds: M. Ross and S.J. Dyson, WB Saunders, Philadelphia. pp 836-837.

Martinelli MJ and Rantanen N. (2002) The role of select imaging studies in the lameness examination. *Proc Am Ass Equine Practnrs* **48**, 161-169.

McIlwraith CW and Martin GS. (1985) Arthroscopic surgery for the treatment of osteochondritis dissecans in the equine femoropatellar joint. *Vet Surg* **14**, 105-116.

McIlwraith CW and Vorhees M. (1990) Management of osteochondritis dissecans of the dorsal aspect of the distal metacarpus and metatarsus. *Proc Am Ass Equine Practnrs* **35**, 547-550.

McIlwraith CW, Foerner JJ and Davis DM. (1991) Osteochondritis dissecans of the tarsocrural joint: results of treatment with arthroscopic surgery. *Equine Vet J* **23**, 155-162.

McIlwraith CW. (1993) Osteochondritis dissecans of the metacarpophalangeal and metatarsophalangeal (fetlock) joints. *Proc Am Ass Equine Practnrs* **39,** 63-67.

McIntosh S and McIlwraith CW. (1993) Natural history of femoropatellar osteochondrosis in three crops of Thoroughbreds. *Equine Vet J Suppl* **16**, 54-61.

Mitchell RD. (2009) Imaging considerations in the purchase examination of the performance horse. *Proc Am Ass Equine Practnrs* **55**, 296-300.

Oliver LJ, Baird DK, Baird AN, and Moore GE. (2008) Prevalence and distribution of radiographically evident lesions on repository films in the hock and stifle joints of yearling Thoroughbred horses in New Zealand. *New Zeal Vet J* **56,** 202-209.

Pool RR. (1996) Pathologic manifestations of joint disease in the athletic horse, in *Joint Disease in the Horse.* Ed: McIlwraith CW and Trotter GW. W.B. Saunders, Philadelphia pp 87-104.

Robert, C., Jacquet, S., Viennet, E., Valette, J.P. and Denoix, J.M. (2003) Correlations between the orthopaedic status and racing performances in English Thoroughbreds present at the Deauville sales. In: 29ème Journée de la recherche équine, 26 février 2003, Les Haras Nationaux Direction du Développement, Paris, France. pp 185-192.

Sandler EA, Bramlage LR, Embertson RM, Ruggles AJ and Frisbie DD. (2002) Correlation of lesion size with racing performance in Thoroughbreds after arthroscopic surgical treatment of subchondral cystic lesions of the medial femoral condyle: 150 cases (1989-2000). *Proc Am Ass Equine Practnrs* **48**, 255-256.

Smith MA, Walmsley JP, Phillips TJ, Pinchbeck GL, Booth TM, Greet TR, Richardson DW, Ross MW, Schramme MC, Singer ER, Smith RK and Clegg PD. (2005) Effect of age at presentation on outcome following arthroscopic debridement of subchondral cystic lesions of the medial femoral condyle: 85 horses (1993--2003). *Equine Vet J* **37**, 175-180.

Spike-Pierce DL, Bramlage LR. (2003) Correlation of racing performance with radiographic changes in the proximal sesamoid bones in 487 Thoroughbred yearlings. *Equine Vet J.* **35,** 350-353.

Torre F and Motta M. (2000) Osteochondrosis of the tarsocrural joint and osteochondral fragments in the fetlock joints: Incidence and influence on racing performance in a selected group of Standardbred trotters. *Proc Am Ass Equine Practnrs* **46**, 287-294.

Van Hoogmoed LM, Snyder JR, Thomas HL and Harmon FA. (2003) Retrospective evaluation of equine pre-purchase examinations performed 1991-2000. *Equine Vet J* **35**, 375-381.
.
Wallis T, Goodrich L, McIlwraith C, Frisbie D, Hendrickson D, Trotter G, Baxter G. and Kawcak C. (2008) Arthroscopic injection of corticosteroids into the fibrous tissue of subchondral cystic lesions of the medial femoral condyle in horses: A retrospective study of 52 cases (2001-2006). *Equine Vet J* **40**, 461-467.

White NA, McIlwraith CW and Allen D. (1988) Curettage of subchondral bone cysts in medial femoral condyles of the horse. *Equine Vet J Suppl* **11**, 120-124.

Whitton RC and Kannegieter NJ. (1994) Osteochondral fragmentation of the plantar/palmar proximal aspect of the proximal phalanx in racing horses. *Aust Vet J* **71**, 318-321.

Yovich JV and McIlwraith CW. (1986) Arthroscopic surgery for osteochondral fractures of the proximal phalanx of the metacarpophalangeal and metatarsophalangeal (fetlock) joints in horses. *J Am Vet Med Assoc* **188**, 273-279.