EPIDEMIOLOGICAL STUDIES INTO ORTHOPAEDIC CONDITIONS OF THE EQUINE ATHLETE

by

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ABSTRACT

The objectives of this study were to make quantitative and qualitative measurements of the frequency of occurrence of: 1) fractures among Thoroughbred (TB) flat racehorses in the United Kingdom (UK); 2) forelimb superficial digital flexor (SDF) tendinitis among National Hunt (NH) TB racehorses in the UK; and 3) developmental orthopaedic disease (DOD) among TB foals in the Hunter Valley, Australia. Several epidemiological risk factors were investigated to determine any association with the occurrence of fractures among flat racehorses. Two aspects of diagnostic ultrasonography were also investigated: 1) repeatability of the technique; and 2) the early detection acute tendinitis.

Prospective data was recorded over 12 and eight-month periods for two flat racing yards, to determine the incidence of fractures and associated epidemiological risk factors. Group 1 horses sustained 18 fractures among 209 horses (8.6%), compared with four fractures out of 82 horses in Group 2 (4.9%). Overall fracture incidence for the two groups was 7.6% of all horses. Of the 22 fractures reported, 18 (81.8%) occurred following training exercise and four (18.2%) following a race. Overall fracture rates were 0.04 cases/100 training days and 0.4 cases/100 racing days. Carpal and pelvic fractures were reported most frequently. There were no significant differences in age or gender distributions between case and control horses. Equitrack surfaces may have a protective effect in reducing the occurrence of fractures.

Ninety-six NH racehorses underwent four ultrasonographic examinations over a 12-month period, to quantify the incidence of acute and chronic SDF tendinitis. Repeat examinations of some horses by two examiners provided data to determine the repeatability of ultrasonography. A total of 41 horses (43%) showed evidence of either acute tendinitis (25 horses - 26%), chronic tendinitis (12 horses - 13%), or an acute exacerbation of a chronic injury (4 horses - 4%). Acute SDF tendinitis occurred most frequently unilaterally (17/25 horses - 68%), while 12/16 (75%) of chronic/chronic recurrent injuries were bilateral. Increasing age increased the likelihood of developing acute or chronic SDF tendinitis, while female (versus male) gender increased the likelihood of developing acute SDF tendinitis. SDF tendon cross-sectional area (CSA) values did not change significantly prior to the onset of acute tendinitis. Variation in ultrasonographic imaging occurred between operators during image measurement, but not between operators during image acquisition, or between different analytical equipment.

Retrospective and prospective data were collected from stud farms in the Hunter Valley, to determine the incidence of DOD. Retrospective data from an equine hospital was also used to determine the frequency of surgical intervention for the treatment of DOD, over a 9-year period. Angular limb deformities were the most frequently reported DOD. There was a statistically significant increase in the number of confirmed cases of osteochondrosis (OC) from 1990 - 1996. Similarly, the number of arthroscopic procedures undertaken in the diagnosis and/or treatment of OC increased from 1988 - 1996.

In conclusion, the collection of retrospective and prospective data enabled the calculation of baseline incidence rates for several orthopaedic conditions and revealed various associations between individual variables and the occurrence of the particular disease. Increasing awareness of the epidemiological investigative principles and analytical techniques available to the research community will provide the opportunity to further our understanding of equine orthopaedic disease.

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AUTHOR'S DECLARATION

I declare that this thesis describes work carried out by me, except for those matters mentioned specifically in the acknowledgements. It has not been submitted in any form for another degree or professional qualification.

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LIST OF ABBREVIATIONS

ALD	Angular Limb Deformity
ANOVA	Analysis of Variance
BAPN	Beta-aminoproprionitrile
CSA	Cross-sectional Area
CVM	Cervical Vertebral Malformation
DACB	Distal to the distal border of the Accessory Carpal Bone
DOD	Developmental Orthopaedic Disease
GLM	General Linear Model
IAc	Image Acquisition Operator
IAn	Image Analysis Operator
IEq	Analytical Equipment
MC/T	Meta-carpus/tarsus
MHz	Mega Hertz
MRT	Multiple Range Testing
MSI	Musculo-skeletal Injury
NH	National Hunt
OC	Osteochondrosis
OCD	Osteochondrosis Diseccans
PTE	Periosteal Transection and Elevation
P1	Proximal Phalanx
QH	Quarterhorse
RIRDC	Rural Industries Research and Development Corporation
SB	Standardbred
SDFT	Superficial Digital Flexor Tendon
SDF tendinitis	Superficial Digital Flexor Tendinitis
TB	Thoroughbred
TGC	Time Gain Compensation

TPB	Transphyseal Bridging
UK	United Kingdom
USA	United States of America

DEDICATION

This thesis is dedicated to all those animals which, in the future, may benefit from the knowledge and experience that I have gained during my time spent undertaking this project.

CHAPTER I

A REVIEW OF THE LITERATURE OF RELEVANCE TO EPIDEMIOLOGICAL RISK FACTORS FOR MUSCULOSKELETAL INJURIES, THE ASSESSMENT OF SUPERFICIAL DIGITAL FLEXOR TENDINITIS AND THE AETIO-PATHOGENESIS OF DEVELOPMENTAL ORTHOPAEDIC DISEASE

CHAPTER I

A REVIEW OF THE LITERATURE OF RELEVANCE TO EPIDEMIOLOGICAL RISK FACTORS FOR MUSCULOSKELETAL INJURIES, THE ASSESSMENT OF SUPERFICIAL DIGITAL FLEXOR TENDINITIS AND THE AETIO-PATHOGENESIS OF DEVELOPMENTAL ORTHOPAEDIC DISEASE

1.1 GENERAL INTRODUCTION

The equine industry is a complex organisation beginning with the continual production of new crops of foals year after year, destined to undertake countless activities in countless destinations around the globe. A large number of Thoroughbred (TB) foals enter the horse racing sector, racing on the flat and over obstacles, either over collapsible hurdles or fixed steeplechase jumps. Generally speaking young horses' racing careers start on the flat as two year olds, where they may remain until they retire, while some progress to hurdle and steeplechase racing. A smaller number enter as slightly older horses directly into competing over obstacles.

From the very first steps taken by each new foal, illness and injury can delay, interrupt, prevent or terminate the athletic career of the individual. Horses destined for, or already involved in, racing careers undergo demanding physical training programs from an early age, placing great demands on the still immature musculo-skeletal system. Individuals with congenital defects or weaknesses frequently fail to withstand these pressures and ultimately fall short of their anticipated and desired level of achievement. Those individuals that compete either on the flat or over obstacles continue to risk injury while racing and while undertaking training exercise.

A thorough understanding of the aetio-pathogenesis of "failure" at all levels is essential if interventions directed at reducing the failure rate are to be successful. Central to the understanding of all illnesses is the ability to quantify their incidence, thereby providing baseline data and allowing the effect of future interventions to be determined and measured.

This project undertook to investigate three areas of "failure" among TB horses destined for or already part of the racing industry. These included: developmental orthopaedic disease (DOD) among the foal population; fracture injuries sustained by racehorses competing on the flat; and superficial digital flexor (SDF) tendinitis among National Hunt (NH) racehorses competing over fences.

1.2 Musculoskeletal Injuries and associated Epidemiological Risk Factors in Thoroughbred Racehorses

1.2.1 Summary

Many horses participating in racing, either on the flat or over obstacles, suffer injuries to the musculoskeletal system at some stage in their career, resulting in either temporary withdrawal, or permanent exclusion from competition. Fractures, particularly those involving the forelimbs, are one of the most frequently recorded serious injuries.

The incidence of musculoskeletal injury (MSI) is influenced by variables known as epidemiological risk factors, which can be associated with an increase or decrease in the likelihood of sustaining an injury. Employing modern epidemiological principles and methodology, many variables have been assessed to determine their role in the occurrence of injury. However, as the effect of risk factors is often highly complex, with variables exerting their effects simultaneously and often interacting with other variables, research findings hitherto have had a very limited impact on reducing the incidence of MSI in racehorses.

1.2.2 Introduction

The equine racing industry suffers from high levels of wastage at all stages in the continuous provision of replacement athletes (Jeffcott and others, 1982; Bourke, 1990). Even after racehorses have reached competition age, wastage occurs throughout their training (Lindner and Dingerkus, 1993) and racing (Rossdale and others, 1985; Bourke, 1995a; Bourke, 1995b) careers. The identification and quantification of these losses has been the focus of research, assessing all levels of the Industry (Jeffcott and others, 1982; Bourke, 1990; Bourke, 1995a). Other investigations have focussed on particular aspects of wastage, such as racecourse fatalities (Gelberg and others, 1985; Johnson and others, 1994a; Johnson and others, 1994b) and fatality incidence (McKee and Clarke, 1993; Wilson and others, 1993; Bourke, 1995b; McKee, 1995; Wilson and others, 1996).

The situation in the United Kingdom (UK) TB racing industry has been the focus of research for nearly two decades (Jeffcott and others, 1982; Rossdale and others, 1985; McKee and Clarke, 1993; McKee, 1995). Jeffcott and others (1982) collated information concerning horse performance and the reasons for absence from flat racing competition, either temporarily or on a permanent basis, calculating an overall loss of 72.8%. However, this figure was calculated from all the horses that could have theoretically competed between these ages. Consequently, it included an unknown number of surviving animals, such as those unnamed, untrained or unraced, some of which would have been retained as store horses for NH competition, never participating in flat racing. Other horses within this latter category could have been used for a variety of other activities such as hunting, eventing and general purpose riding horses and would not be wasted *per se*.

Recent studies have quantified the situation in the North American Standardbred (SB), TB and Quarterhorse (QH) flat racing industry (Wilson and others, 1993; Peloso and others, 1994a; Peloso and others, 1994b; Wilson and others, 1996). The TB flat racing industry in Australia has also been the focus of attention over recent years (Bourke, 1990; Bourke, 1995a; Bourke, 1995b; Bailey and others, 1997c), as have the Japanese and South African TB flat racing industries (Ueda and others, 1993; MacDonald and Toms, 1994). Bailey and others (1997c) surveyed 40 trainers from the three major race centres in Sydney, Australia, collating their views on the major areas of wastage affecting the Industry. The findings contrasted with those of earlier UK studies, where the musculoskeletal system and reproductive tract were the most frequently affected body systems resulting in wastage of horses (Jeffcott and others, 1982; Rossdale and others, 1985). Bailey and others (1997c) found that trainers perceived respiratory tract disease as the most significant cause of interruption to exercise. These investigators concluded that MSI were considered to be of a lesser importance, although the high incidence of dorsal metacarpal disease was a frequently cited concern and was considered to be much more of a problem than was reported in the earlier UK studies. Bourke (1995a) also identified shin soreness as one of the most frequent actual or perceived causes of interruption to athletic activity.

Variations in study design make valid comparisons between published data difficult. However, there are reports highlighting similar areas of wastage. Jeffcott and others (1982) reported that almost a third of horses racing only as two-year olds and 38.1% of horses racing less than five times at two to three years old, were retired through "lack of ability". Bourke (1995a) confirmed this high level of drop-out from competition after the first and second season of racing, irrespective of age at start of first racing season, suggesting that the main reason for this was horses failing to show adequate racing potential or ability. Both investigations identified a considerable number of named horses that subsequently failed to race, Bourke (1995a) calculating a figure of 17%, compared to the figure of just over 26%

reported by Jeffcott and others (1982), the majority eventually leaving flat racing for other activities. A significant number of horses left flat racing, destined for export or retention for NH racing (Jeffcott and others, 1982).

1.2.3 Wastage among Horses which have Raced

Many racehorses fail to start training, or make a single start even when training has been undertaken. Once racehorses have shown promise and competed in at least one race, many have their careers terminated prematurely or their training programs temporarily interrupted. Jeffcott and others (1982) suggested that if a filly raced up to three years of age, then many owners would be satisfied with the performance and retire them to stud. This hypothesis concurs with the findings by Bourke (1995a), where males competed for an average of three to four racing seasons, compared with two to three for females.

Lindner and Dingerkus (1993) reported that 57% of training failures, defined in their study as "...the inability to undertake galloping exercise...", resulted from lameness. Similarly, Jeffcott and others (1982) identified lameness as the most important cause of "...permanent disability, reduction in performance potential or number of race starts and interruption of training programme...". Fifty three percent of the horses in this study experienced a period of lameness, with 21% failing to return to racing after the lameness. Jeffcott and others (1982) also reported that MSI accounted for 45% of cases where a horse failed to make a start. Comparatively, 53% of horses being withdrawn from races in Australia were due to MSI and one fifth of horses experiencing a period of lameness "...did not race in the 12 months after lameness was diagnosed " (Bourke, 1985).

1.2.4 The Role of Clinical Epidemiology

Jeffcott and others (1982) acknowledged the need for epidemiological surveillance of lameness, in an effort to identify predisposing risk factors. Rossdale and others (1985) undertook an "epidemiological" study of wastage, extending the earlier work by Jeffcott and others (1982). Both studies reported on the identification and quantification of specific MSI resulting in wastage, although risk factors *per se* were not investigated.

As well as quantitative assessment of racehorse lameness, research efforts are increasingly focusing on identifying specific epidemiological risk factors associated with MSI occurrence, which may increase or decrease disease incidence. These include, amongst many others, variables such as horseshoe characteristics (Kane and others, 1996b) and the work by Estberg and others (1994), who investigated the effect of cumulative exercise distance on the risk of fatal MSI. Peloso and others (1994a) examined no less than 35 variables, while Bailey and others (1997a) assessed 19, ranging from position of the horse at the start barrier, to mean rest period between races.

The use of epidemiological study designs has become increasingly widespread, replacing the traditionally employed **case series, surveillance** or **prevalence studies**. The two most frequently utilised are the **case-control study** (Robinson and Gordon, 1988; Robinson and others, 1988; Mohammed and others, 1991; Estberg and others, 1993; Estberg and others, 1994; Bailey and others, 1996; Kane and others, 1996a) and the **cohort study** (Robinson and Gordon, 1988; Robinson and others, 1988; Kobluk and others, 1989; Kobluk and others, 1990; Bailey and others, 1997a; Bailey and others, 1997b). A case-control study involves selection of diseased and non-diseased animals and compares the exposure of each group to each risk factor variable. A cohort study involves defining a cohort or group of animals without disease, but all exposed to a variety of risk factors and monitoring the cohort over a period of time. Individuals that develop disease are then compared with those that remain free of disease.

1.2.5 Categorisation of MSI – The Importance of Case Definition

1.2.5.1 Fatal Injuries

Horse fatality whilst racing (Bourke, 1995b; McKee, 1995) or racing/training (Gelberg and others, 1985; Johnson and others, 1994a; Johnson and others, 1994b) has frequently been used as a selection criterion for inclusion in a study, although non-MSIs were also included in some of these studies. The cause of death was usually elective euthanasia on humane or financial grounds, as the majority of MSIs were not themselves fatal.

Racing fatality data are relatively straightforward to collect, as most racetracks, trainers and/or veterinary surgeons keep records of horses that have died or have been euthanased as a result of an injury sustained while competing, although the quality of information may vary. Injuries sustained while **training** are harder to collate, as are the number of deaths unrelated to racing or training. Death is a useful case definition due to its unambiguous nature, unlike the myriad definitions used to define injury or lameness, allowing comparison between different data sets to be undertaken more readily. McKee (1995) summarised seven years of racetrack fatality data for the UK racing industry and found the fatality rates, expressed as a percentage of starts for the different types of TB racing, varied considerably: flat 0.08%; hurdling 0.49%; steeplechase 0.70%; and NH flat 0.47%. Bourke (1995b) reported slightly different values for the Australian racing industry, although the relative proportions between disciplines was similar: flat 0.03%; hurdling 0.6%; and steeplechase 1.1%. A more recent Australian retrospective case-control study reported incidence rates for fatal MSI, of 0.06%, 0.63% and 1.43% for flat, hurdle and steeplechase, respectively (Bailey and others, 1998). Peloso and others (1994a) calculated a fatality rate of 0.14% for TB racing on the flat at four tracks in Kentucky.

The percentage of racehorse fatalities has been shown to result from MSI in a high proportion of cases. Estberg and others (1993) found catastrophic MSI to account for

73% of all deaths or 88% of exercise related injuries. Further post mortem investigations by Johnson and others (1994a), reported similar findings. This latter study reported 83% of injuries resulting in the death of the horse involved the MSI, although this figure included exercise and non-exercise related injuries. Fatal injuries occurring during exercise totalled 81% in this study.

The proportions of non-MSI also showed some similarities: Bourke (1995b) calculated that over 10% of fatalities were due to either acute thoraco-abdominal haemorrhage or heart attack/collapse; McKee (1995) did not include abdominal haemorrhage and consequently found a slightly lower prevalence, ranging from 0% among NH flat racehorses to 8.3% in steeplechasers. A post-mortem study investigating deaths among TB and QH over a two-year period on a California racetrack found cardiac and respiratory disease to account for 6.5% of deaths (Johnson and others, 1994a). Excluding infectious pulmonary disease this was reduced to approximately 3%, which is comparable to the figure of 3.7% calculated by McKee (1995) for flat racing fatalities caused by heart attack/collapse or pulmonary haemorrhage.

1.2.5.2 Non-fatal Injuries

Although calculating fatal MSI is a convenient method of estimating the incidence of serious injury, not all serious MSI are invariably fatal and a broad range of injury severities occur. Non-fatal injuries range from superficial wounds, that may not affect the training or racing program, to serious tendon and ligament injuries, or fractures that are amenable to repair. To quantify such a diversity of injuries accurately would be extremely difficult, so inclusion/exclusion criteria are clearly defined to eliminate subjectivity.

1.2.6 Terminology of Selection Criteria

1.2.6.1 Lameness

- Jeffcott and others (1982) defined lameness as "...resulting in permanent disability, a reduction in performance potential, and interruption of training programme or the number of race starts".
- Peloso and others (1994a) defined lameness as "...any obvious change in soundness immediately before, during or after a race...".

1.2.6.2 Musculo-skeletal Injury

- Clanton and others (1991) defined a breakdown as "...an acute injury (horse was removed from the track by ambulance) that prevented a horse from racing or training for six months or longer, forced the horse to retire from racing, or caused the horse to be euthanased".
- Mohammed and others (1991) defined a breakdown as "...a horse that had not raced within six months following a muscular or skeletal injury on the racetrack". This was expanded to include "...an injury which led to the humane destruction of the horse..." for fatal injuries by Mohammed and others (1992), sub-dividing the injuries into "severe" and "less severe" categories.
- Oikawa and others (1994) defined racing injuries as "...acute locomotor injuries that prevented a horse from being trained for three months or longer, or resulted in permanent retirement or euthanasia of the horse".
- Bailey and others (1996) defined an MSI as the failure to "...race or trial for six months from the date of injury".
- Cohen and others (1997) defined a career ending injury as occurring when "...an obvious onset of lameness became apparent during a race...but the horse was not euthanatized...the injury necessitated restricting the horse from racing for a period of greater than or equal to six months...".

1.2.6.3 Failure to Train and/or Race

- Rossdale and others (1985) defined the time lost from training or racing as every "...day on which the horse did not canter for reasons of injury or disease". The number of days lost, due specifically to particular causes of lameness was then calculated.
- Lindner and Dingerkus (1993) defined training failure as "...the failure to be trained at a galloping pace", based on a weekly census with lameness of any cause recorded.

Clearly there would be considerable variation in the type and severity of injury included in, or excluded from each study. Taking a random cohort of horses from the equine population and applying each selection criteria would almost certainly result in different conclusions. For example, those studies which included all causes of lameness (Jeffcott and others, 1982; Peloso and others, 1994a), would have a greater number of recorded lamenesses than those only recording MSI preventing a return to work within six months of injury (Mohammed and others, 1991; Bailey and others, 1996). However, the latter studies would have excluded a number of mild injuries that only resulted in a short break in training or racing. Peloso and others (1994a) recognised the need for standardisation of definitions used for MSI or breakdowns, thereby allowing more meaningful comparisons of data.

1.2.7 Injury Site

1.2.7.1 Limb Location

Reports on the anatomical location and musculoskeletal tissue most commonly injured found the forelimbs to be the more frequently affected limbs and fractures to be the most common MSI resulting in the death or euthanasia of the horse (Bourke, 1995b; McKee, 1995). The mean values for all four race types in the UK, including forelimb (28%), hindlimb (10%) and vertebral/pelvic (14%) fractures accounted for over half of the total injuries in one study (McKee, 1995). This study found that forelimb and hindlimb fractures accounted for a higher percentage of fatalities on the flat compared with over jumps, where spinal injuries were more common than on the flat. Forelimb fractures were singularly the most frequently recorded fatal injury in all four race types in this study. Bourke (1995b) reported that 54% of racing fatalities involved forelimb MSI and 16.5% hindlimb MSI among Australian racehorses. These values were higher than reported by McKee (1995), but included soft tissue injuries such as articular luxation and tendon rupture.

1.2.7.2 Location of Injury on Limb

Jeffcott and others (1982) identified the foot as the site of 15.4% of lameness in horses racing on the flat in the UK, followed by the fetlock (15.0%), carpus (12.6%) and metacarpus (16.6%). However, these figures include both fatal and non-fatal injuries and all tissue types in the respective anatomical regions. Another report on racing in the UK found fatal flat racing fractures involved the metacarpus (8.6%), carpus (6.8%), pastern (6.8%) and fetlock (6.4%) regions most frequently, expressed as a percentage of all fatal injuries (McKee, 1995). This was in contrast to hurdlers and steeplechasers, which sustained fractures to the humerus or scapula/shoulder more commonly (5.7% and 8.7%, respectively). The lower figures obtained by McKee (1995) may be a result of the exclusion of non-fatal injuries from this study, a good example of the difficulty in making accurate and meaningful comparisons.

Ueda and others (1993) reported the proximal sesamoid bones (22%) and metacarpal bones (17.1%) to be the most frequent site of fatal or non-fatal fracture, followed by fracture of the proximal phalanx (14.6%). Similar figures were reported by Bathe (1994) in a UK study, who identified the proximal phalanx (15%), third metacarpus/tarsus (15%) and tibia (14%) as the most frequently fractured bones, not differentiating between training and racing components and including both fatal and non-fatal fractures. These figures appear high in comparison to the results obtained by McKee (1995), possibly because Ueda and others (1993) excluded all injuries other than fractures and dislocations, increasing the relative percentage of each injury in proportion to the total number of injuries, while Bathe (1994) included only fractures.

Johnson and others (1994a) found the most common fatal fractures sustained by TB racing on the flat involved the proximal sesamoid and third metacarpal bones while racing (50%; 30%), or training (30%; 26%) respectively. These figures only included fatal fractures, excluding any non-fatal fractures and all non-fracture injuries, explaining the high values compared to the previous results.

There are also a number of undiagnosed conditions that account for a considerable percentage of injuries. Bourke (1985) reported that the cause of lameness was not diagnosed in a mean of 14.5% of cases over a two-year period. Nearly 8% of injuries reported by Bourke (1995b) were grouped as "unspecified", while 8.5% of lamenesses were classified as miscellaneous or undiagnosed by Jeffcott and others (1982). Over a two-year period, a mean of 31.2% of lamenesses were undiagnosed in the study by Rossdale and others (1985). These injuries may be due to a range of conditions and specific diagnoses may not have been possible at the time.

1.2.8 Activity at Time of Injury

The incidence of all types of both fatal and non-fatal injuries occurring while racing has been well documented. However, there is evidence to suggest that injuries sustained while training are equally or even more common and just as serious. Nearly half of 25 cases of sudden death in TB racehorses examined by Gelberg and others (1985) occurred while the horses were undertaking training exercise. A diagnosis was not made in 17 of the cases. Musculoskeletal injury was not associated with any of the sudden deaths, most of the animals showing gross thoracic or abdominal pathology. Johnson and others (1994a) found that 42% of fatal injuries affecting TB racing on the flat occurred while racing, 39% during training, 12% were non-exercise related illness and 7% resulted from an accident. The majority of these injuries were of a musculoskeletal origin (83%). Further results from this ongoing investigation (Johnson and others, 1994b) highlighted similar relative proportions: racing 34%; training 33%; non-exercise 14%; and accident 4.2%. Including other breeds in the calculation, the racing to training injury ratio was approximately equal.

Robinson and Gordon (1988) derived similar figures from a mixture of TB and QH flat racing: racing 39%; training 45% and stabled 16%. In contrast with Johnson and others (1994a), these results included fatal and non-fatal, MSI and non-MSI, although the majority were non-fatal MSI. Reporting on the incidence of fractures sustained by flat racehorses in the UK, Bathe (1994) calculated that 84% of fractures occurred spontaneously while training, with only 9% being sustained during a race and 7% as a consequence of accidental trauma. Wilson and others (1996) summarised data previously reported to the Japan Racing Association, relating to injuries at ten Japanese racetracks and three training centres. Fifty five percent of all fractures were sustained while training. However, a higher percentage of fatal fractures were sustained while racing compared to training: 64% and 36% respectively.

1.2.9 Epidemiological Risk Factors Associated with MSI

Many variables have been investigated in an attempt to identify an association with the occurrence of MSI. Although there is both agreement and discrepancy between reports, any conclusions must be interpreted with caution: differences in study design, subject selection and racetrack structure are just a few of the variables making direct comparison between results difficult and conclusions potentially erroneous. If one study finds an association between a particular variable and the subsequent development of a MSI, any inference can only be appropriately applied to horses exposed to the same conditions. Recent review papers summarised most of the work that has been published to date relating to the identification of epidemiological risk factors associated with racing injuries (Wilson and Robinson, 1996; Mundy, 1997).

For the purposes of this review, the variables have been broadly categorised into **racetrack, racing, racehorse** and **environmental** factors, although there is a degree of overlap between groups.

1.2.9.1 Racetrack

1.2.9.1.1 Turf versus Dirt

The ground surface conditions of racetracks have been scrutinised in an effort to determine the nature of the ideal surface on which to race and identify surfaces with a higher incidence of injury. Racetrack ground surface composition varies considerably, with most racing in the United Stated of America (USA) taking place on dirt surfaces, with some turf tracks, while in the UK the major surface is turf, although three all-weather surfaces are also used for winter racing on the flat. A number of courses previously investigated, comprised of both dirt and turf tracks (Hill and others, 1986; Mohammed and others, 1991; Mohammed and others, 1992; Oikawa and others, 1994). Mohammed and others (1992) found that racing on firm, turf tracks was associated with a lower risk of severe MSI than racing on the normal dirt surface at three New York racetracks. These findings were consistent with earlier work by Mohammed and others (1991), where turf was found to have a lower risk than dirt. Similarly, Wilson and others (1993) reported a higher percentage of fatal injuries were sustained during racing on dirt compared to turf surfaces: 27% and 23% respectively. These findings are in contrast to several studies, which found no significant difference in the risks between competing on turf and dirt tracks (Hill and others, 1986; Robinson and others, 1988; Estberg and others, 1998). Analysis of seven years of data from the UK racing population suggested that the incidence of fatalities among hurdlers and steeplechasers increased on firm, turf tracks compared to softer turf surfaces, although no statistical analysis was undertaken (Herbert, 1994; Wright, 1994). This study did not identify any significant difference in death rate between different turf surface conditions for horses racing on the flat. Despite training injuries being reported to occur with a similar or even greater frequency to racing injuries in some investigations (Gelberg and others, 1985; Robinson and

Gordon, 1988; Bathe, 1994; Johnson and others, 1994a), there is a paucity of information pertaining to the use of different training surfaces.

1.2.9.1.2 Track Design

Racetrack design has been implicated as a risk factor in the occurrence of breakdown. Rooney (1983a) measured the forces acting on the limbs on various parts of the racetrack. There was a strong association between breakdown in the left forelimb and the calculated impulse, a measure of the forces acting on the limb multiplied by time, in horses travelling in an anti-clockwise direction. The lateral forces acting on the left forelimb were approximately twice that compared to the right limb. It was hypothesised that poorly designed or inadequately banked turns could result in increased forces acting on the inside leg, increasing the risk of injury.

Hill and others (1986) examined racetrack conditions, including curvature of turns and stage of race, finding no association between either variable and the incidence of MSI. Oikawa and others (1994) reported on considerable structural changes to a racetrack in Japan, including increasing the graduation of bends, which resulted in a drop in the number of severe, but not mild injuries. As several other features of the track were also changed, such as the surface composition and the introduction of inclines and declines, no single alteration was solely credited with the improvement.

1.2.9.1.3 Track Identity

Mohammed and others (1991) and Mohammed and others (1992) showed that three New York racetracks were associated with differing relative risks of sustaining an injury, in contrast to Bailey and others (1997a), who could find no difference in injury rate between two tracks in Sydney. This also contrasts with the results from four Melbourn tracks, where racing on one particular course was associated with an increased risk of fatal MSI (Bailey and others, 1998). Racetracks around the world differ greatly in many respects and many variables influence the surface conditions of tracks, making identification of specific risk factors very difficult.

1.2.9.1.4 Stage of Race

Clanton and others (1991) found that three quarters of all injuries occurred at either the entrance to, or exit from the final turn: 27% and 50% respectively. Similarly Ueda and others (1993) reported 64% of injuries occurred at some stage in a turn and the remaining 36% on the straight regions of the track. The findings by Robinson and Gordon (1988) suggested that nearly half the injuries occurred in the middle of or as the horse left the final turn, while Peloso and others (1994a) found significantly more catastrophic injuries occurred in the final turn or the previous straight. These findings differ from those by Mohammed and others (1992), who concluded that a severe injury was 13 times more likely to occur during the first six furlongs of a race, than in the seventh or greater furlongs. However, the results of research summarised by Herbert (1994) and Wright (1994), found the time of injury occurrence to be evenly distributed throughout the race, suggesting that fatigue may not be strongly associated with breakdown, as suggested in other reports (Clanton and others, 1991).

Peloso and others (1994a) proposed that the higher numbers of catastrophic injuries occurring in shorter races might be related to the speed of the race. The slower race times recorded after restructuring a track in Japan (Oikawa and others, 1994), which resulted in a decrease in injuries, lends credence to this hypothesis.

1.2.9.2 Racing Factors

1.2.9.2.1 Pre-race Inspection

Pre-race veterinary examination has been shown to aid in the identification of horses at risk of sustaining certain MSI (Peloso and others, 1996; Cohen and others, 1997). Cohen and others (1997) applied four different criteria in the assessment of TB horses racing on the flat and used the information to predict whether or not each horse was at an increased risk of injury. The criteria included both physical findings and previous records. The investigators reported that horses identified as being at increased risk of MSI were 5.5 and 13.5 times more likely to sustain an injury to the suspensory apparatus and superficial digital flexor tendon, respectively. The findings of this study are a good example of the potential for intervention in an effort to reduce MSI.

1.2.9.2.2 Jockey

There is considerable variation in the fatality rate between different race types in the UK, in particular between flat and NH flat racing. Changes made by the Jockey Club in 1994 allowed professional jockeys to compete in NH flat races, no longer restricting the field to amateur and conditional jockeys, with the aim of reducing the incidence of racehorse injury (McKee, 1995). No significant differences were observed between jockey status (apprentice or veteran) by Peloso and others (1994a), who examined a large number of variables for two groups of injured horses: catastrophic versus non-catastrophic, although other investigators reported the incidence of MSI to be greater among amateur jockeys compared with professionals (Herbert, 1994).

Ueda and others (1993) used video footage to review the activity of the jockey and horse immediately prior to injury. The investigation found the most common activities at this time to include lead change, use of the whip and an oblique movement by the horse, all possibly resulting in a shift in balance or sideways movement. Observations relating change in lead leg to time of injury are consistent with other findings in this study, showing injuries to be most frequently associated with a turn rather than a straight portion of the track (64% and 36%, respectively). However, it was not possible to determine whether the change in lead leg resulted in, or was a consequence of the injury. Clanton and others (1991) also found that if the entry into or exit from a bend was associated with a change in lead leg, then the likelihood of injury at that point was increased. Ueda and others (1993) also observed that the lead foreleg was the most at risk of injury: 70.8% of left fore and 72.7% of right fore injuries occurred while the respective leg was leading.

1.2.9.2.3 Race Length

In order to obtain an indicator of fatigue during a race, Rooney (1982a) measured the reduction in velocity of the lead horse between the last two sections of a race. Turf and dirt were found to result in similar levels of fatigue, although the turf surface appeared to have a slightly lower mean drop in velocity at most distances. However, the statistical significance of this was not determined. Certain race lengths were associated with a greater reduction in velocity, notably 5.5 to 7 furlongs and 1 1/16 miles. These race lengths were considered to represent high-risk distances. Peloso and others (1994a) found a higher risk of catastrophic injury in shorter races.

1.2.9.2.4 Class of Race

Robinson and Gordon (1988) found a significantly greater risk of injury in claiming versus non-claiming races (odds ratio 1.86, 95% C.I.). Estberg and others (1998) calculated a similar figure for two to five-year-old horses in claiming versus maiden races. Stakes races were reported by Bailey and others (1997a) to have a 2.3 times increased risk of involving a MSI, compared to non-stakes races. In contrast, Peloso and others (1994a) found no significant difference between racing classes.

1.2.9.2.5 Exercise Level

The intensity of exercise in relation to the occurrence of MSI was the focus of work by Kobluk and others (1990), who found a negative correlation of -0.51 between subjective scales of the "...level of daily exercise..." and the "...incidence of MSI of all severity...". The investigators concluded that horses with fewer MSI were exercised harder, suggesting that the presence or absence of MSI were used by trainers as one factor in the decision to select an appropriate level of exercise. High total cumulative exercise distance and a high rate of accumulation of exercise distance, during a two-month period, were found to increase the risk of fatal MSI by 3.9 and 1.8 times, respectively, in a retrospective case-control study of TBs racing on the flat in California (Estberg and others, 1996).

1.2.9.2.6 Others

Many other variables such as the number of seasons raced, number of starts to date, position in starting gate and speed of race when injury occurred have been investigated for their involvement. Mohammed and others (1991) found that horses with more starts per season and a greater number of seasons raced, were at a lower risk of MSI. This finding could be a result of the horses suffering injuries making fewer starts and racing for fewer seasons than horses free of injury, rather than high racing frequencies over several seasons having a protective effect *per se*. Severe injuries were more common in the first or second racing season in the study by Mohammed and others (1992), possibly due to an age effect, but no correlation between MSI and number of starts per season was identified.

Although differences in fatality rates for different race types i.e. flat, NH flat, hurdles and steeplechase, have been reported (Peloso and others, 1994a; Bourke, 1995b; McKee, 1995), multivariable logistic regression has only recently been employed in the data analysis. Bailey and others (1998) reported jumping races i.e. hurdles and steeplechase, as being risk factors for fatal MSI, when compared to flat racing.

1.2.9.3 Racehorse Factors

1.2.9.3.1 Gender

Rooney (1983b) showed that more MSIs, defined as fractures, in particular third metacarpal bone fractures, occurred in entire males, than would be expected from the gender ratio in the study sample population, although numbers involved were small and no statistical significance was demonstrated. This study also found geldings to be at a decreased risk of MSI. In contrast, Estberg and others (1998) found male horses to be at an increased risk of fatal MSI compared to female horses. The conflicting results obtained may be explained by the difference in case definition, the latter study including only MSI that resulted in the euthanasia or natural death of the horse. A greater proportion of horses euthanased as a result of injury would be expected to be male, as the option to salvage for breeding purposes applies mainly to females. Both Peloso and others (1994a) and Bailey and others (1996) found no association between gender and the risk of injury, as defined in the individual studies.

1.2.9.3.2 Age

Age has been associated with the occurrence of severe injury. Mohammed and others (1992) found a negative association between age and severe injury, suggesting that as age increased, the risk of severe injury decreased. Investigations undertaken at Canterbury Downs, Minnesota by Robinson and Gordon (1988) found that severe injuries were over two times and nearly five times more likely to occur in three and four-year-old horses, respectively, compared with two-year-olds. Bailey and others (1997a) reported that horses over four years old were 1.8 times more likely to suffer a MSI while racing, when compared to animals less than four years old. Mohammed and others (1991) also found a positive association between increasing age and the risk of MSI. Similarly, Bailey and others (1998) found the risk of fatal MSI to increase in horses older than three years of age. No relationship was demonstrated between the age at first race and the risk of fatal MSI by Estberg and others (1996).

1.2.9.3.3 Shoeing

Horseshoe characteristics have been compared between TB racehorses that died or were euthanased as a result of a MSI affecting the appendicular skeleton and those which died for other, unrelated reasons. The risks of certain features of shoe design were also assessed for specific MSIs, namely suspensory apparatus failure and condylar fracture of the meta-carpus/tarsus, using a case-control study design (Kane and others 1996a). The findings of this study suggested that the use of regular toe grabs increased the risk of suspensory apparatus failure or condylar fracture by factors of 15.6 and 17.1, respectively. Rim shoes decreased the risk of both the aforementioned injuries to one third of the levels in horses not shod with rim shoes.

A smaller cohort study undertaken by Kobluk and others (1989) compared several aspects of racehorse conformation and shoe type with the occurrence of MSIs. Although there were no statistically significant conclusions, possibly due to the relatively small sample size, the results were suggestive of an association between higher hoof angles and a decreased risk of MSI.

1.2.9.4 Environment

1.2.9.4.1 Season

Rooney (1982b) identified the period between June and November as a time during which there was an increased number of fractures and superficial digital flexor tendon injuries, suggesting a seasonal influence, although no statistical analysis of the data was undertaken. A three-fold increase in the risk of MSI associated with racing during summer, compared with winter racing on three New York racetracks was reported by Mohammed and others (1991). However, Hill and others (1986) could find no significant seasonal variation in fracture or non-fracture injuries on the same tracks studied by Mohammed and others (1991) five years later. A temperature range of 40°F through the racing season was not associated with any increase or decrease in injuries by Hill and others (1986).

1.2.10 Conclusions

Lameness in all forms and severities frequently results in both the temporary or permanent exclusion of racehorses from training and competition. Injuries occurring on exercise surfaces and during competition range from the very mild, through varying degrees of severity but not life threatening injuries, to those that warrant the humane destruction of the animal. Injuries involve ligamentous, muscular, tendinous, articular and osseous components of the appendicular and axial musculoskeletal system and may occur spontaneously or in association with a traumatic event.

The likelihood of sustaining a particular injury is influenced by numerous variables, acting alone or in combination through complex interactions, often making direct comparisons between results difficult. A number of epidemiological risk factors have been reported to either increase or decrease the incidence of injury, the role of others remaining poorly understood. The application of epidemiological principles has allowed the simultaneous analysis of a large number of variables irrespective of their interrelationships, allowing quantification of individual effects and eliminating confounding influences.

As each period of exercise and competition undertaken by a given individual is unique and involves the complex interactions of numerous variables, the identification of all risks and prevention of all injuries is virtually impossible. However, by identifying risk factors with the potential for human modification by some form of intervention, the current high frequency of injuries sustained by equine racing athletes could be reduced.

1.3 THE ULTRASONOGRAPHIC INVESTIGATION OF THE NORMAL AND DISEASED EQUINE SUPERFICIAL DIGITAL FLEXOR TENDON

1.3.1 Introduction

Tendinitis of the equine forelimb superficial digital flexor tendon (SDFT) is a common cause of temporary and permanent exclusion from training and competition, affecting all types of equine athletes, particularly TB, SB and QH racehorses. Of these, the NH hurdlers and steeplechasers are most frequently affected.

Diagnostic ultrasonography has proven to be the most useful of a number of diagnostic imaging modalities employed in the initial assessment and monitoring of acute and chronic tendinitis. Treatment of SDF tendinitis is controversial and a wide range of medical and surgical procedures are currently utilised. Given the limited success in treatment of acute tendinitis and relatively high recurrence rate, recent research efforts have focused on the early detection of changes within the tendon prior to gross fibre disruption.

1.3.2 Incidence of Superficial Digital Flexor Tendinitis

SDF tendinitis affects horses involved with all types of activities, but it is most frequently reported as an injury of racehorses. The injury has been recognised and documented for many years (Peters, 1940), although the aetio-pathogenesis is still not fully understood. All ranges of severity exist, from mild, diffuse inflammation of the tendon through to complete rupture or traumatic laceration of the tendon body (Adams, 1987).

Although not a life-threatening injury *per se*, horses with complete rupture or traumatic laceration of the SDFT are frequently euthanased, while many with SDF tendinitis are forced to retire from racing prematurely. Peloso and others (1996) reported that horses with SDFT injuries accounted for 42% of non-fatal, but career ending injuries at racetracks in Kentucky, USA, over a two-year period. In contrast, only 4.6% of fatal injuries involved the SDFT. However, the injury severity in each category was not reported. An investigation into the fatalities occurring at Australian racetracks, found 14% resulted from flexor tendon injuries of all types, the higher figure possibly due to the inclusion of deep digital flexor tendon injuries. Ruptured or severed tendons accounted for 12.3% of fatalities among horses racing on the flat in the UK (McKee, 1995). The proportion of horses racing over jumps was even higher, at 14.9% and 25.0% for steeplechase and hurdles, respectively.

Due to the nature of fatality studies, only the most severe injuries tend to be included, involving rupture or laceration of one or both forelimb SDFTs. An investigation into the cause of wastage amongst young flat TB racehorses by Jeffcott and others (1982), reported 5.7% of diagnosed lamenesses during one season to be attributable to tendinitis, although which tendons were affected was not stated. Rossdale and others (1985) reported the findings of an extension of Jeffcott's survey and found that an average of 10% of lamenesses, over two years, were the result of tendinitis, again not specifying which tendons were involved. Wilson and others (1993) reported 28% of forelimb injuries involved SDF tendinitis among a group of mainly flat TB racehorses in the USA, while a recent symposium highlighted the importance of SDFT injuries of all severities, reporting a frequency of between 0.58 and 0.94 injuries per 1000 starts on USA racetracks in 1992 (Wilson and others, 1996).

Although present at these frequencies among flat racehorses, SDF tendinitis is generally considered to be of greater importance to horses racing over obstacles. A survey of trainers in Sydney, Australia, involving horses competing on the flat, found tendon and ligament injuries to be ranked only 12/35 in order of significance by trainers (Bailey and others, 1997c).

Once a horse has sustained an injury of the SDFT, the increased risk of re-injury adds to the difficulty in returning horses to racing long term. A survey of SDF tendinitis among North American horses racing on the flat reported an incidence of 7% of horses developing an initial acute injury during one season, with a further 6% of the horses suffering a recurrence of a previous tendon injury (Rooney and Genovese, 1981). From a group of 73 NH and point to point racehorses in the UK, 35% suffered a recurrence of the initial injury (Marr and others, 1993a). Long-term follow up of 164 cases of SDF tendinitis identified high rates of recurrence, depending on the severity of the initial injury, treatment protocol and timing of return to racing/full training (Genovese and others, 1996). The rate of recurrence among the horses that were not returned to full race training for at least six months post-injury varied between 55% and 82%.

1.3.3 Diagnostic Imaging of the Superficial Digital Flexor Tendon

The primary means of assessing SDF tendinitis has, until fairly recently relied on thorough physical examination and palpation of the affected tendon(s). However, prior to the advent of diagnostic ultrasonography, a number of imaging modalities were used to investigate the normal and abnormal SDFT.

1.3.3.1 Contrast Radiography

Verschooten and De Moor (1978) reported the application of air tendography to aid in both confirming a clinically suspected diagnosis of tendinitis and also attempted to quantify the severity of injury by measuring the diameter of the tendons and related tissues at different levels.

1.3.3.2 Thermometry/Thermography

Webbon (1978a) reported the use of limb thermometry as a method of plotting distal limb thermal profiles of normal horses, showing a high degree of similarity between contra-lateral limbs. Palmer (1981) investigated the influence of coat pigment on thermometric measurements, finding no significant difference between black and white limb shades. The use of both infrared and microwave thermography has been reported in the literature in the assessment of normal and diseased SDFTs (Stromberg and Norberg, 1971; Stromberg, 1973; Marr, 1992; Turner, 1996). Stromberg (1971) reported the occurrence of thermographic "hot spots" in horses with acute tendinitis and also in clinically normal horses that subsequently developed acute tendinitis. However, two horses with no clinical evidence of tendinitis also developed equivalent temperature elevations, but did not subsequently develop signs of injury. Unfortunately these horses were withdrawn from training at this time. Had other imaging modalities been available, a more complete assessment may have been possible, although the presence of sub-clinical tendon changes, as identified from post-mortem studies of clinically normal SDFTs could in part explain Stromberg's findings (Webbon, 1978b).

Microwave thermography has been used to document the profile of normal tendons (Marr, 1992) and was found to have a sensitivity of 81% for the detection of SDFT injury. However, as with limb thermometry a number of horses with no clinical evidence of tendinitis also returned abnormal thermographic profiles.

1.3.3.3 Diagnostic Ultrasonography

Since the early 1980s equine diagnostic ultrasonography has become an increasingly valuable tool for the assessment and quantification of soft tissue injuries involving both internal and external body systems (Rantanen, 1986; Reef, 1991). In the context of the equine SDFT, the ultrasonographic anatomy of both normal and diseased tendons has been well documented (Pharr and Nyland, 1984; Spaulding, 1984; Genovese and others, 1986; Hauser, 1986; Reimer, 1998). The ultrasonographic appearance of the SDFT has been found to correspond well with different histological and histo-pathological findings (Reef and others, 1989; Spurlock and others, 1989; Nicoll and others, 1992; Marr and others, 1993b). The primary features of diagnostic ultrasonography utilised in the assessment of the SDFT include cross-sectional area (CSA) measurements and echogenicity (Genovese and others, 1997; Reef and others, 1997). CSA measurements of normal and diseased SDFTs have allowed the calculation of baseline values for normal tendons (Smith and others, 1994; Gillis and others, 1995a) and quantification of the effect of exercise on SDFT size (Gillis and others, 1993; Gillis and others, 1995b).

Gray scale analysis of SDFT echogenicity has also been used in combination with CSA measurement, in the examination of normal tendons (Martinoli and others, 1993; Wood and others, 1993), quantifying SDFT injuries (Tsukiyama and others, 1996) and during healing, as an aid in the management of injuries (Yovich and others, 1995; Genovese and others, 1997).

Using multiple 2-dimensional ultrasound images of diseased tendons, Wood and others (1994) reported the development of a technique for producing a 3-

dimensional image of the SDFT. The resultant images gave excellent visualisation of the extent of the lesions identified in both transverse and longitudinal planes, although the practical application of this technique may be limited by the relative complexity of 3-dimensional image construction.

1.3.3.4 Others

Although more commonly used in the imaging of bone and peri-articular soft tissues, nuclear scintigraphy has proven useful in the assessment of certain ligament and tendon injuries (Turner, 1996). The low specificity of nuclear scintigraphy, combined with the superior soft tissue imaging ability of diagnostic ultrasonography over scintigraphy, have limited its use in the investigation of SDF tendinitis. Magnetic resonance imaging is another imaging modality that has been shown to be an effective means of imaging acute tendon injuries, although imaging during the healing phase of injury failed to identify in-complete repair of damaged fibres detected ultrasonographically (Crass and others, 1992). Although used to image injuries to equine limbs such as carpal bone fractures (Rantanen, 1996), the use of computed tomography in the assessment of SDF tendinitis has not been reported.

1.3.4 Post-mortem Investigations

The accuracy of ultrasonography in the determination of tendon CSA and identification of changes associated with tendon injury have been investigated. Results of the comparison between ultrasonographic and post-mortem measurements of normal SDFTs have shown good correlation (Smith and others, 1994; Gillis and others, 1995a).

Marr and others (1993b) documented the ultrasonographic changes present in a group of horses with both normal and injured SDFTs, reporting consistent changes in echogenicity in areas of injured tissue, different stages of injury having different patterns of echogenicity. Other studies using collagenase-induced tendinitis have also reported good consistency between ultrasonographic and histologic findings

(Spurlock and others, 1989). Quantitative assessment of injured tendons has also been achieved using gray scale analysis of ultrasonographic images (Nicoll and others, 1992), tendons with areas of fibre damage having a reduced mean gray scale value.

Prior to the development of diagnostic ultrasonography in equine practice, the gross and histologic appearance of the SDFT was documented (Webbon, 1977; Webbon, 1978b). Webbon (1977) reported evidence of discoloration, changes in fascicular pattern and increases in tendon CSA in clinically normal horses. Further investigation of the structural and biochemical composition of the tendon within the areas of discoloration identified structural damage to collagen fibres, an increase in type III collagen and increased sulphated glycosaminoglycan levels compared to the peripheral regions of the same tendons (Miles and others, 1994; Birch and others, 1998). It has been hypothesised that degenerative changes occurring within the central core region of the SDFT predispose to injury of the tendon, although no attempt has been made to correlate the gross and histological appearance of tendons with the occurrence of clinical disease.

1.3.5 Age-related Changes in the Superficial Digital Flexor Tendon

Webbon (1978b) reported histological differences in the SDFT with age, including a decrease in cellularity around the mid-metacarpal region and changes in the extra-cellular composition with age and between levels in the same tendon. More recent investigations have confirmed the presence of age related changes in the SDFT extra-cellular matrix, proposing that the appearance of different proteins in adults, when compared to neonates, was in part influenced by functional requirements (Jones and Bee, 1990).

Further investigations into age related differences have identified alterations in both the physical and mechanical properties of the SDFT. The central core region most frequently associated with the development of inflammatory lesions was reported to have a reduction in the crimp angle of collagen fibres with increasing age (Wilmink and others, 1992; Patterson-Kane and others, 1997). These findings were thought to be the result of the greater number of loading cycles undergone by the SDFTs of an older horse. No statistically significant similar changes were detected in the tendon periphery. *In vitro* studies of the biomechanical properties of the equine SDFT failed to identify any relationship between age and CSA or echogenicity (Gillis and others, 1995c). However, the investigators did conclude that an increase in age was associated with an increase elastic modulus of the tendon.

1.3.6 The Response of the Superficial Digital Flexor Tendon to Physical Exercise

Shadwick (1990) reported the results of an investigation into the mechanical properties of porcine flexor tendons. An increase in the elastic modulus of the digital flexor tendons was found with age and also relative to the ipsilateral extensor tendon, hypothesising an association between changes in mechanical properties of tendons and exposure to different strains. The modulus of elasticity, a measure of the ability of a tendon to increase in length in response to strain, was found to be fairly consistent along the length of the SDFT in ten horses with clinically normal tendons (Crevier and others, 1996). The effect of exercise on tendon metabolic activity was investigated by Curwin and others (1988), the results suggestive of an increase in collagen turnover, but not collagen content, in the gastrocnemius tendon of chickens, in response to high level exercise. The workers concluded that this resulted in a reduction in overall tendon collagen maturation. Similarly, exercised rats did not have any detectable increase in tendon collagen content compared to non-exercised controls (Tipton and others, 1975).

Changes identified in mice tendons in response to exercise included, in the short term, an increase in tendon fibre CSA and number, although only the increase in fibre numbers remained statistically significant in the long-term when compared to the controls (Michna and Hartmann, 1989). In contrast, Patterson-Kane and others

(1997) reported a decrease in fibril diameter in the central region of the SDFT, in horses subjected to an extended period of training. These workers concluded that the changes were the result of micro-trauma resulting from the exercise regime. Ultrasonographic monitoring of a group of young TB racehorses revealed a trend towards an increase in SDFT CSA and decrease in mean echogenicity during the first four months of training (Gillis and others, 1993). Histological examination of these tendons revealed an increase in fascicle diameter, relative to controls, as the possible cause for the changes in CSA and echogenicity (Gillis, Meagher, Pool and Stover 1992).

1.3.7 The Early Detection of Superficial Digital Flexor Tendinitis

Identification of alterations in the biochemical or ultrastructural composition and appearance of the SDFT might allow the modification of an individual horse's exercise schedule in an effort to prevent the progression to acute fibre disruption. Although no reliable method of achieving this goal has been developed, a number of investigators have reported alterations in tendon parameters that were found to be related to the subsequent development of tendinitis. Dow and others (1991) reported the use of force plate analysis of the weight distribution between limbs of NH racehorses. Alterations in weight distribution were detected among horses which subsequently developed clinical evidence of tendinitis.

Microwave thermographic imaging of NH racehorses by Marr (1992) identified abnormal patterns in the SDFT of two horses prior to the development of acute tendinitis. However, a number of horses with no evidence of tendinitis during the period of investigation also showed abnormal thermographs. More recently, Cohen and others (1997) reported on the use of pre-race inspection of TB flat racehorses as a means of identifying "at risk" horses. Using a combination of the results of physical examination, historical information pertaining to previous injury and changes from earlier examinations, Cohen and others (1997) found a strong association between abnormal pre-race parameters and the subsequent occurrence of acute tendinitis. The odds of finding an abnormality prior to racing associated with the SDFT, were 15 times higher among horses that subsequently developed acute tendinitis compared to those horses that did not develop tendinitis in this study.

1.3.8 Bio-mechanical Investigation of the Superficial Digital Flexor Tendon

Increasing interest in the biomechanics of lameness has lead to the development of equipment to determine the strains placed on the SDFT *in vivo* and *in vitro*. Lochner and others (1980) implanted strain gauges into the SDFT and measured the effect of changing hoof angle on the strain through the tendon, reporting no increase in strain with increasing hoof angle. This study also documented the change in strain through the phases of the stride, the peak strain being detected during full weight bearing with the limb perpendicular to the ground. In contrast, Stephens and others (1989) reported a slight increase in SDFT strain with increasing hoof angle, although this was only detected at the trot. This and other studies reported an increase in maximum strain in the SDFT with increasing level of exercise (Riemersma, van den Bogert, Jansen and Schamhardt 1996). The maximum values of strain reported by Stephens and others (1989), were 10.1% at the trot and 16.6% at the gallop. Comparatively, Jansen and Savelberg (1994) reported total failure of the SDFT occurred at a strain of 10.9%. These findings indicate that horses exercising at high speed may be close to the limits of the ability of the SDFT to withstand strain.

The use of a pressure sensitive plate for the identification of changes in the pattern of limb loading has also been investigated (Dow and others, 1991). As well as finding a similar pattern in the distribution of forces through the limbs of un-injured horses, these investigators also reported alterations in the pattern of force distribution within limbs that subsequently developed clinically detectable evidence of SDF tendinitis.

1.3.9 Conclusions

The economic impact of SDF tendinitis to the equine industry results from extended periods of absence from training and competition following injury, permanent exclusion from competition, in some cases involving humane destruction of individuals and the cost of veterinary therapies and rehabilitation. With all these expenses the likelihood of recurrence upon re-commencing training and competition is still high.

Improvements in diagnostic imaging equipment, in particular ultrasonography, have allowed prompt and objective initial assessment of injuries. Ultrasonographic monitoring of healing tendons has provided valuable information in determining the optimal time to return to training and competition.

Although there is some evidence to suggest that changes occur in the SDFT prior to the development of acute tendinitis, the identification of a reliable indicator or marker has yet to be achieved. Ultimately, the prevention of acute tendinitis is the ideal goal. However, the current situation dictates that objective initial assessment combined with prompt treatment be achieved, followed by regular monitoring of the healing process, throughout the long period of rehabilitation necessary for this type of injury.

1.4 DESCRIPTIVE EPIDEMIOLOGY OF EQUINE DEVELOPMENTAL ORTHOPAEDIC DISEASE IN THE HUNTER VALLEY

1.4.1 Introduction

DOD is the term used to encompass a number of conditions affecting the axial and appendicular bones of skeletally immature foals (Pool, 1993). Recent forums (American Quarter Horse Association, 1986; Jeffcott and others, 1993; McIlwraith, 1993a) have highlighted the need to define those diseases considered to be examples of DOD (Pool, 1993) and also to standardise terminology for these conditions (Jeffcott, 1993).

1.4.2 Aetiology

Currently, the aetiopathogenesis of DOD is not fully understood and opinions differ regarding the nature of the primary lesion. The relative importance of the several putative epidemiological risk factors is also debated and these issues have been investigated by a number of researchers. The American Quarter Horse Association (1986) included a total of six disorders in their classification of DODs, including osteochondrosis diseccans (OCD), physitis, acquired angular limb deformities, subchondral cystic lesions, flexural deformities and cuboidal bone malformations. However, this grouping excludes a number of conditions considered by others to be manifestations of osteochondrosis (OC), such as cervical vertebral malformation, juvenile arthrosis of the pastern joint, juvenile spavin and palmar/plantar proximal phalanx (P1) fragments in SBs (Pool, 1993).

Probably the most widely studied DOD is OC in its different forms. The two current hypotheses for the development of OC, irrespective of location or type, are that it occurs due to the application of abnormal mechanical forces on normal or abnormal physes, or due to the application of normal mechanical forces on abnormal physes (Pool, 1993).

Heredity (Philipsson and others, 1993), nutrition (Cymbaluk and Smart, 1993; Hurtig and others, 1993; Savage and others, 1993a; Savage and others, 1993b; Savage and others, 1993c), birth date (Sandgren and others, 1993a) and foal growth/size (Sandgren and others, 1993b), are factors implicated in the pathogenesis of OC. Distinction has been made between idiopathic and acquired OC (Pool, 1993), the former involving lesions of unknown aetiology, probably multi-factorial, the latter resulting from known disturbances such as nutritional imbalances.

Despite previous work, a major hurdle in the development to a greater understanding of DODs is this confusion resulting from the classification of the number of arguably distinct conditions under the same umbrella terms, such as DOD or OC.

Attempts to identify patterns in the incidence of disease or determine associations with possible risk factors can produce conflicting information where case definition is inadequate. Confounding between different conditions or between factors which may have an effect upon one, but not another DOD or manifestation of OC, can lead to erroneous conclusions.

1.4.3 Investigative Techniques

To date, a number of study designs have been used in the investigation of DOD. These include retrospective studies of clinical case material (Lindsell and others, 1983; Hoppe, 1984), cross-sectional studies of samples from a clearly defined population (Grondahl, 1991), and prospective studies monitoring animals at specific points during a study period (Carlsten and others, 1993; Sandgren and others, 1993b) and assessing the long-term outcome (McIntosh and McIlwraith, 1993). Retrospective and prospective studies have also been combined to identify associations between historical information relating to the disease and future performance as an athlete (Laws and others, 1993; McIlwraith, 1993b).

Case series are a frequently used method of collecting and presenting the results of various treatment options for the different DODs. However, there is a paucity of case-control or clinical trial/intervention studies, comparing the efficacy of one treatment with another, or between surgical and conservative treatments.

Prospective cohort studies are an effective technique for assessing both the incidence of DOD in a sample population and also for determining the long-term outcome of the condition, irrespective of the treatment employed. This design also allows the simultaneous monitoring of a number of potential risk factors over an extended time period. However, because of the apparent relatively low incidence of some DODs, such as OCD, and the inevitable loss of animals from the cohort, it would be necessary to monitor a large sample of animals in order to identify a sufficient number of cases for such a study to have sufficient power and for the findings to be of statistical as well as biological significance. This results in greater costs in terms of finance and manpower.

1.4.4 Conclusions

DOD has been the subject of many small and large scale research investigations, involving considerable financial investment over several decades, allowing a more thorough understanding of the complex, multi-factorial aetiology and numerous clinical manifestations of the disease.

Although some aspects of the occurrence of DOD are well documented, relatively little data exists pertaining to the actual incidence of the various forms of DOD. In order to ultimately reduce the incidence of a disease it is essential to have both a thorough understanding of the aetiology and also to be able to quantify the extent of the disease. In view of the reported perceived increase in incidence of DODs over the last decade, it is imperative that future investigations are directed at quantifying both the actual incidence and any change in the incidence of DODs, thereby allowing the effect of any intervention on the incidence to be determined.

CHAPTER II

MUSCULOSKELETAL INJURIES AND ASSOCIATED EPIDEMIOLOGICAL RISK FACTORS AMONG THOROUGHBRED RACEHORSES

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2.1 INTRODUCTION

The occurrence of fractures among TB flat racehorses is frequently the subject of investigation. However, the relationship between fractures and racing conditions is usually the main focus of interest, with little consideration for the conditions under which the horses train. As racehorses spend considerably more time undertaking training exercise than actually racing, a prospective cohort study was designed to investigate fracture injuries among TB flat racehorses while both training and racing, focussing on variables associated with the training environment. The two areas of investigation involved:

1. Quantifying the incidence of fractures among flat TB racehorses during training and racing over a specific time period;

2. Identification of epidemiological risk factors associated with the occurrence of fractures and in particular the effect of exercise conditions on the occurrence of fractures in young flat racehorses.

The horses at two flat racing yards were monitored and records of all fractures occurring during the period of investigation were obtained. Group 1 horses were monitored for a one-year period from the 1st January 1997 to the 31st December 1997 inclusive, while Group 2 horses were followed from the 17th February 1997 to the 30th September 1997, inclusive.

2.1.1 Cohort Selection

The cohort was selected from the population at risk of fracture injury whilst flat race training or competing in the UK on turf and/or all-weather surfaces. The population was defined as all TB racehorses registered for flat race training and eligible to compete in 1997. Information was collated for all horses resident at each yard and participating in the respective training program.

2.1.2 Case and Control Definition

Cases were defined as those horses sustaining fracture injuries during the period of investigation whilst in residence at the respective yards. Fracture injuries were defined as those diagnosed during the period of investigation resulting in lameness sufficient to cause: the temporary exclusion from training and racing or permanent retirement from racing competition or euthanasia on humane grounds, at any stage within the study period following diagnosis of the fracture. Only those fractures resulting directly from training and racing activities were included, those involving accidental injuries sustained outwith the activities of the normal exercise programme were reported, but were excluded from subsequent calculations.

Control horses were those horses that, during the period of study, did not develop evidence of a fracture injury, as defined above, while resident and in training at the respective yards. Some horses did not arrive at the yards until after the start of the study period, and some departed prior to the end of the period. Some horses were also absent from the yard for variable periods during the course of the investigation. All these horses were included in the control group if they did not sustain a fracture injury during the study period while resident at the yard.

2.2 MATERIALS AND METHODS

Due to differences in established data recording systems, training methods and individual compliance of the trainers, there was some variation in the data collection and recording systems employed and the detail of data recorded at each yard. All information was entered and stored in a computer spreadsheet program, which was also used during subsequent data analysis[1].

2.2.1 Measures and Statistical Methods Employed

2.2.1.1 Descriptive Statistics

Signalment and fracture injury data collected from each group was summarised in tabular format and expressed graphically where appropriate. Calculations were made from the total number of case and control days of exposure i.e. days in training at each yard. Cases were included until the time of injury. All fractures were diagnosed on the basis of a combination of clinical, radiographic and/or scintigraphic examinations. As the method of confirming each diagnosis varied between cases, the exact details relating to injury description and location showed some variation, e.g. in some carpal bone fractures the actual bone(s) injured was not specified. The distribution of injuries between racing, training and other activities was also determined.

2.2.1.2 2-sample t-test and Odds Ratios

In order to determine the effect of age and gender on the occurrence of fracture injuries in each group, 2-sample t-test analyses were performed and odds ratios were calculated on each group's data using proprietary software[1,2].

2.2.1.3 Comparison of cases and controls on different exercise regimes

Due to the summary nature of the data provided by the yards and because of sparsity of data, it was only possible to present summary descriptive statistics. The average time per horse expressed as a percentage of total time for each of the two groups for cases and controls was calculated and compared by inspection; no suitable test exists for these kind of summary frequency data.

2.2.2 Signalment

Name, official age on the 1st January 1997 and gender were reported for each horse. All males were included in the same category irrespective of castration status, as in some cases this changed during the period of investigation.

2.2.3 Distribution of Fracture Location

The location of each individual fracture was reported, differentiating between fore and hindlimbs and identifying the region affected, although specific details regarding the exact nature of the fracture were not reported in some cases. Some fractures involving the small carpal bones were classified as "carpal" fracture where the specific bone involved was not reported.

2.2.4 Date of Injury

The total number of fractures sustained in each group during each calendar month was calculated. The results were plotted together on the same graph, showing the individual and combined totals and highlighting the difference in duration of each study period.

2.2.5 Activity Prior to Lameness

From the records of each case, the activity immediately prior to the onset of lameness, subsequently confirmed to be the result of a fracture injury, was determined. This activity was classified as racing, training or any other activity. The results from each group were tabulated and plotted graphically separately and compared with the total number of cases and controls in each group and each group total.

2.2.6 Injury Rate

The frequency of occurrence of fracture injuries per exercise day and per horse was calculated for Groups 1 and 2 separately and when combined, by dividing the number of fractures in each group by the total number of exercise days, or by the total number of horses in the group. All pre-injury exercise days were included for cases within the limits of each respective study period. Exercise days included both racing and training days. The incidence of fractures sustained while either racing or training was also calculated for the two groups separately and when combined (number of fractures per racing or training day).

2.2.7 Frequency of Each Activity

A record of the daily exercise program for each individual was maintained by the trainer. Information pertaining to the nature of the exercise surface, level of exercise and distance or length of exercise period were recorded. For each of the two yards a system of codes was designed to categorise the information recorded by each trainer.

At the end of each period of study the information was converted into numerical format using the coding system for Groups 1 and 2 separately (Tables 1 and 2).

On a number of days some subjects undertook more than one type of exercise, resulting in a total of 20 different combinations of different exercise types. In view of the small number of exercise days in each pair, some containing zero values, the following combinations were grouped together in Table 1 (category 25): 1/8; 1/9; 2/8; 2/9; 4/9; 5/8; 7/9; 8/3; 8/4; 8/7; 8/9; 8/10; 8/21; 8/22; 8/23; 8/24; 8/28; 11/8; 12/8; and 19/9.

Using this daily exercise coding system, the total number of horse days recorded for each exercise type and level was determined for the cases and controls in Groups 1 and 2. An exercise day included all activities that the horse undertook while present at the respective yard, excluding being confined to the stable. The total number of exercise and non-exercise days for **cases** was calculated for the period up to the time of fracture injury. For the **controls**, the calculation included the full duration of the respective study periods.

Table 1. Daily activity/exercise categories and description of activity undertaken, during the investigation of fracture injury occurrence, among a cohort of Thoroughbred flat racehorses, while training and racing (Group 1).

Category	Surface	Description
1#	---	Absent from yard
2	E1	2 x 7 furlong canters
3	E1	2 x 5 furlong canters
4	E1	2 x 2.5-5 furlong canters (2 year old horses only), slower than "3", distance increased through season
5	E1,E2	1 x 7 furlong hack/canter, 1 x 12 furlong canter, 2 miles walk/trot
6	E1,E2	1 x 7 furlong hack/canter, 1 x 10 furlong canter, 2 miles walk/trot
7	E1,E2	1 x 7 furlong hack/canter, 1 x 5 furlong canter, 2 miles walk/trot
8	---	Up to 30 circuits of a circular pool, 40 minutes on horse walker
9	---	One hour on horse walker
10	E1	1 x 7 furlong canter on Sundays (2 year olds do 1 x 3-7 furlong canter, increasing through season)
11	G1	2 x 7 furlong canters
12	G1	2 x 5 furlong canters
13	G1	2 x 2.5-5 furlong canters (2 year old horses only), slower than "3", distance increased through season
14	G1,G2	1 x 7 furlong hack/canter, 1 x 12 furlong canter, 2 miles walk/trot
15	G1,G2	1 x 7 furlong hack/canter, 1 x 10 furlong canter, 2 miles walk/trot
16	G1,G2	1 x 7 furlong hack/canter, 1 x 5 furlong canter, 2 miles walk/trot
17	---	Walking exercise while training to wear tack
18	---	Walking and trotting exercise on lunge line for approximately 45 minutes
19	---	Free exercise in pen
20	E1	2 x 7 furlongs (1 canter/1 fast canter)
21	E1,E2	1 x 7 furlong hack/canter, 1 x 12 furlong fast canters (working speed), 2 miles walk/trot
22	G1	2 x 7 furlongs (1 canter/ 1 fast canter)
23	G1,G2	1 x 7 furlong hack/canter, 1 x 12 furlong fast canter (working speed), 2 miles walk/trot
24	+	Walking and trotting exercise for one hour (one/two year olds only), roads/dirt tracks
25	---	Multiple exercises
26	*	Race day
27#	---	Sunday (confined to stable)
28	+	Walking/trotting exercise, 1 hour on roads/dirt tracks

Key: E1 = equitrack one E2 = equitrack two G1 = grass one G2 = grass two

+ = dirt track/roads * = grass or all weather surface

= category excluded from total number of exercise days

Table 2. Daily activity/exercise categories and description of activity undertaken during the investigation of fracture injury occurrence among a cohort of Thoroughbred flat racehorses while training and racing (Group 2).

Category	Surface	Description
1#	---	Absent from yard
2#	---	Confined to stable
3	---	30 minutes on horse walker
4	---	Trot/hack
5	---	Swim
6	---	Pen
7	---	Paddock
8	Wc	1x5f canter
9	Wc	2x5f canters
10	G	1x3f canter
11	G	1x 4f canter
12	G	1x 4.5f canter
13	G	1x5f canter
14	G	1x6f canter
15	G	1x7f canter
16	G	1x8f canter
17	G	1x9f canter
18	G	2x5f canters
19	G	2x3f canters
20	E	1x4f canter
21	E	1x5f canter
22	E	1x6f canter
23	E	1x7f canter
24	G/E	2x5f canters
25	Wc/E	2x5f canters
26	*	Race day
27	Wc/G	2x5f canters

Key: Wc = woodchip G = grass E = equitrack * = grass or all weather
G/E = grass/equitrack Wc/E = woodchip/equitrack Wc/G = woodchip/grass
= category excluded from total number of exercise days

2.3 RESULTS

2.3.1 Descriptive Statistics

The period of time spent in training and at the respective yard varied between horses, ranging from a few days for some horses, to those present for the duration of the study period.

2.3.1.1 Group One

The period of study extended for 365 days, involving 209 horses. A total of 18 fractures were reported among 209 horses during the 12-month study period (Table 3). Two year-old horses and male horses were most frequently reported to sustain fractures. Training exercise was more frequently associated with the occurrence of a fracture when compared with racing. Forelimb fractures were slightly more frequently reported than hindlimb fractures. All reported fractures involved bones of the appendicular skeleton, including the pelvis. No vertebral fractures or fractures of the calvarium were reported.

The age and gender distributions for the case and control groups were determined as individual variables (Figures 1 and 2) and when combined (Figure 3). The female to male ratio, mean and median age, age range and standard deviation among case and control groups were calculated (Table 4). The female to male ratio was less than one in both case and control groups, the smallest proportion of females being present in the case group, while mean age was similar between groups.

2.3.1.2 Group Two

The study period covered 227 days and included 82 horses. A total of five fractures were reported among the 82 horses during the period of investigation (Table 5). Four of the five injuries were sustained during or shortly after a period of training exercise and one occurred when the horse became cast while stabled. The case suffering an injury in the stable was included in the control sample for statistical calculations as occurrence of the injury was not directly associated with exercise. Female horses were injured more frequently than male horses. Excluding the stable injury, forelimb and hindlimb fractures occurred with a similar frequency. However, in view of the small number of cases reported among horses in Group 2, the significance of these findings is questionable.

The age and gender distributions were compared between case and control groups individually and when combined (Figures 4 - 6). The female to male ratios, mean and median age, age range and standard deviation were calculated for case and control groups (Table 6). The female to male ratio was found to be greater than one in both groups. Mean age was similar between case and control groups.

Table 3. Case signalment and description of fracture injuries sustained by Thoroughbred flat racehorses, while either racing or training during the period of study in 1997 (Group 1).

No.	Fracture	Age (years)	Gender	Activity	Limb
1	Humerus – shaft	3	F	T	F
2	Pelvis – ilial wing	3	F	R	H
3	Proximal phalanx – fissure	2	M	T	F
4	Carpus – chip	3	F	R	F
5	MC3 – lateral condyle	2	M	T	F
6	Pelvis	2	M	T	H
7	Proximal sesamoid – apical	4	F	R	F
8	Radio-carpal	2	M	R	F
9	Pelvis	2	M	T	H
10	Distal phalanx – articular wing	3	M	T	H
11	Third carpal	2	M	T	F
12	Proximal sesamoid	3	M	T	F
13	Pelvis – ilial wing	4	M	T	H
14	MT3 – medial condyle	2	M	T	H
15	Third tarsal	3	M	T	H
16	Second metacarpal	3	M	T	F
17	Carpal	2	F	T	F
18	Proximal phalanx – chip	2	M	T	F

Key: MC3 = third metacarpal bone MT3 = third metatarsal bone
M = male F = female T = training R = racing
F = forelimb H = hindlimb

Table 4. Summary of signalment of case and control Thoroughbred flat racehorses during a 12-month study period through 1997, investigating the incidence of fracture injuries (Group 1).

Group	Female	Male	F/M ratio	Mean age (years)	s.d.	Median age (years)	Age range (years)
Case	5	13	0.38	2.6	0.70	2.5	2 - 4
Control	74	117	0.63	2.5	1.14	2	1 - 7

Key: F/M ratio = female to male number ratio s.d. = standard deviation

Table 5. Case signalment and description of fracture injuries sustained by Thoroughbred flat racehorses while either racing, training or involved in other activities during the study period in 1997 (Group 2).

No.	Fracture	Age (years)	Gender	Activity	Limb
1	Humerus - stress	3	F	T	F
2	Pelvis	2	F	S	H
3	Proximal phalanx	5	M	T	F
4	MT3 - plantar	3	F	T	H
5	Tibia - stress	4	F	T	H

Key: MT3 = third metatarsal bone T = training S = stabled
F = forelimb H = hindlimb F = female M = male

Table 6. Summary of signalment for case and control Thoroughbred racehorses included in Group 2 during a seven-month study period investigating the incidence of fracture injuries.

Group	Female	Male	F/M ratio	Mean age (years)	s.d.	Median age (years)	Age range (years)
Case	3	1	3	3.8	0.96	3.5	3 - 5
Control	40	38	1.05	3.4	1.57	3	2 - 10

Key: F/M ratio = female to male number ratio s.d. = standard deviation

2.3.2 Age and Gender Distribution

2.3.2.1 Group One

T-test analysis showed there to be no statistically significant difference between the age distributions of the case and control horses ($p = 0.71$). The results of odds ratio calculations concurred with the findings of the 2-sample t-tests, there being no statistically significant difference in age distributions between case and control horses in Group 1 (Tables 7 and 8) when age was treated as a categorical variable. Similarly, there was no statistically significant difference in gender distributions between case and control horses.

2.3.2.2 Group Two

No statistically significant difference was detected in the age distributions of case and control horses using t-test analysis ($p = 0.68$). Due to the presence of individual cell counts of less than five in both the age and gender calculations, the results of the Fisher exact test are reported from odds ratio calculations (Tables 9 and 10). Age categories were defined as less than or equal to three years of age and older than three years of age, to avoid any cells containing zero values. The results of odds ratio calculations were consistent with the 2-sample t-test result, finding no statistically significant difference between case and control group age distributions. There was also no statistically significant difference between case and control group gender distributions.

Table 7. Odds ratio calculation to determine the effect of age on the occurrence of fracture injuries among Thoroughbred flat racehorses in Group 1, comparing case and control horses two years of age or younger with older horses.

		Disease	No disease	
		Case	Control	Total
Exposure	≤2 years old	9	108	117
No exposure	>2 years old	9	83	92
	Total	18	191	209

Odds ratio (95% C.I.): 0.27 < O.R.0.77 < 2.22

Uncorrected p - value: p = 0.59 (Yates corrected p = 0.77)

Table 8. Odds ratio calculation to determine the effect of gender on the occurrence of fracture injuries among Thoroughbred flat racehorses in Group 1, comparing case and control male and female horses.

		Disease	No Disease	
		Case	Control	Total
Exposure	Male	13	117	130
No Exposure	Female	5	74	79
	Total	18	191	209

Odds ratio (95% C.I.): 0.52 < O.R. 1.64 < 5.54

Uncorrected p - value: p = 0.36 (Yates corrected p = 0.51)

Table 9. Odds ratio calculation to determine the effect of age on the occurrence of fracture injuries among Thoroughbred flat racehorses in Group 2, comparing case and control horses three years of age or younger with older horses.

		Disease	**No Disease**	
		Case	Control	Total
Exposure	≤3 years old	2	50	52
No exposure	>3 years old	2	28	30
	Total	4	78	82

Odds ratio (95% C.I.): 0.05 < O.R. 0.56 < 5.97

Two tailed Fisher exact test: $p = 0.62$

Table 10. Odds ratio calculation to determine the effect of gender on the occurrence of fracture injuries among Thoroughbred flat racehorses in Group 2, comparing case and control male and female horses.

		Disease	**No Disease**	
		Case	Control	Total
Exposure	Male	1	38	39
No Exposure	Female	3	40	43
	Total	4	78	82

Odds ratio (95% C.I.): 0.01 < O.R. 0.35 < 4.07

Two tailed Fisher exact test: $p = 0.62$

2.3.3 Distribution of Fracture Location

Although the duration of the study periods differed, the results obtained from Groups 1 and 2 were combined (Table 11), as the periods ran concurrently within the same calendar year. Fifty nine percent of the fractures involved the forelimbs, while 41% involved the hindlimbs/pelvis. Carpal fractures were the most frequently reported forelimb fracture (30.8%), accounting for 18.1% of all fractures, while pelvic fractures were the most frequently reported hindlimb fracture (44.4%), also accounting for 18.1% of all fractures. Proximal phalangeal (13.6%) and third meta-carpal/tarsal (MC/T) (13.6%) fractures were also reported with a greater frequency than other fracture types. No fractures of the vertebral column or calvarium were reported. Similarly, no fractures of the navicular bone, middle phalanx, radius, ulna, scapula, patella or femur were identified.

Table 11. Fracture injury classification and distribution between fore and hindlimbs among Thoroughbred flat racehorses while undertaking racing and training exercise[1] (Groups 1 and 2 combined).

Fracture	Forelimb	F%[2]	T%[3]	Hindlimb	H%[4]	T%[3]	Total	T%[3]
Carpus	4	30.8	18.1	--	--	--	4	18.1
Humerus	2	15.4	9	--	--	--	2	9
MC/T 2/4	1	7.7	4.5	0	0	0	1	4.5
MC/T 3	1	7.7	4.5	2	22.2	9	3	13.6
Proximal phalanx	3	23.1	13.6	0	0	0	3	13.6
Distal phalanx	0	0	0	1	11.1	4.5	1	4.5
Pelvis	--	--	--	4 (1)[1]	44.4	18.1	4 (5)[1]	18.1
Proximal sesamoid	2	15.4	9	0	0	0	2	9
Tarsus	--	--	--	1	11.1	4.5	1	4.5
Tibia	--	--	--	1	11.1	4.5	1	4.5
Total number	**13**	--	--	**9**	--	--	**22**	--
Total percentage	--	**100**	**59**	--	**100**	**41**	**100**	**100**

Key: 1 = Stable injury excluded

2 = Percentage of all forelimb fractures

3 = Percentage of all fractures (forelimb plus hindlimb)

4 = Percentage of all hindlimb fractures

MC/T 2/4 = Second/fourth meta-carpal/tarsal bone

MC/T 3 = Third meta-carpal/tarsal bone

2.3.4 Date of Injury

The peak months when the maximum number of fractures were reported for Groups 1 and 2 were July (4) and June (2), respectively (Figure 7). However, it appears from the graph that there were three periods during which the monthly injury rate peaked: February/March; June/July; and September/October. The June/July peak corresponds with the busiest racing period during the season and might be expected to yield the most fracture injuries.

2.3.5 Activity Prior to Lameness

The majority of fractures were sustained during or following a period of training exercise; 13 of the 18 fractures (72.2%) in Group 1 and four of the five fractures (80%) in Group 2 (Tables 3 and 5; Figure 8). The remaining five fractures reported among Group 1 horses occurred during or following a race. In contrast, no fracture injuries were reported in association with racing among horses in Group 2, the fifth fracture injury occurring following the horse becoming accidentally cast while stabled. This latter accidental injury was excluded from fracture incidence calculations.

2.3.6 Injury Rate

The rate of occurrence of fractures per exercise day (racing and training) was similar between groups; Group 1 - 0.05% and Group 2 - 0.03% (Table 12). However, the fracture rate per horse was nearly twice that among horses in Group 1 (8.61%) compared with Group 2 horses (4.88%). The fracture incidence per 100 training days was the same for Groups 1 and 2 (0.03 cases), while the incidence per 100 racing days differed between groups, possibly because of the small number of cases in Group 2; 0.5 and 0 cases for Groups 1 and 2, respectively. In contrast to the total numbers of fractures sustained when either racing (5) or training (17), the combined fracture incidence when racing was 10 times greater compared with training; 0.4 cases per 100 race days versus 0.04 cases per 100 training days.

Table 12. Fracture injury rate per exercise day and per horse, among two groups (1 and 2) of Thoroughbred flat racehorses undertaking racing and training exercise during 12 and seven month study periods, respectively, in 1997.

Group	1	2
Total fractures	18	4
Total no. of horses	209	82
Total days of exercise*	2615 + 33262 = 35877	367 + 12941 = 13308
Total race days	38+815 = 853	7+170 = 177
Total training days	2577 + 32447 = 35024	360 + 12771 = 13131
Fracture incidence per horse	= 18/209 = 0.0861 (x 100) = **8.61%**	= 4/82 = 0.0488 (x 100) = **4.88%**
Fracture incidence per exercise day*	= 18/35877 = 5.02×10^{-4} (x100) = **0.05%**	= 4/13308 = 3.01×10^{-4} (x100) = **0.03%**
Fracture incidence per race day	= 4/853 = 0.005 = 0.5% = **0.5 cases/100 race days**	= 0/177 = 0 = 0% = **0 cases/100 race days**
Fracture incidence per training day	= 14/35024 = 0.0003 = 0.03% = **0.03 cases/100 training days**	= 4/13131 = 0.0003 = 0.03% = **0.03 cases/100 training days**
Combined incidence per race day	= (4 + 0) / (853 + 177) = 4/1030 = 0.004 = 0.4% = **0.4 cases/100 race days**	
Combined incidence per training day	= (14 + 4) / (35024 + 13131) = 18/48155 = 0.0004 = 0.04% = **0.04 cases/100 training days**	

Note: See Tables 13 - 15 (Group 1) and 16 - 17 (Group 2) for source data.
* = includes all racing and training days

2.3.7 Frequency of Each Activity

Using the daily exercise coding system previously described, the total number of horse days recorded for each activity type and level was determined for the cases and controls in Group 1 (Tables 13 - 15) and Group 2 (Tables 16 - 17). The total number of activity days for **cases** was calculated for the period up to the time of fracture injury. For the **controls,** the calculation included the full duration of the respective study periods.

2.3.8.1 Group One (Tables 13a,b - 15)

In respect of the summary data presented in table13b, two observations are of note. First that cases spent proportionately more time undertaking walking/trotting exercise on roads and dirt tracks than did controls. Second that controls were exercised more on Equitrack than were cases. The summary nature and the resolution of these data given that there were only 18 cases makes further analysis questionable although direct comparison of the individual categories does allow a comprehensive picture of the training programme to be built up.

Table 13a. Time spent for case and control Thoroughbred flat racehorses in Group 1 exercising, on different surfaces over different distances.

Category[1]	Case[2]	Control	Percentage of time per horse (cases)	Percentage of time per horse (controls)
28	722	8219	23	12
1	318	35877	10	51
2	148	3134	5	4
3	75	1157	2	2
4	530	5352	17	8
5	79	1716	3	2
6	32	576	1	1
7	187	1681	6	2
8	148	1778	5	3
9	108	1698	3	2
10	163	2265	5	3
11	11	487	0	1
12	16	213	1	0
13	70	633	2	1
14	0	9	0	0
15	0	2	0	0
16	4	15	0	0
17	36	177	1	0
18	4	82	0	0
19	73	415	2	1
20	62	790	2	1
21	38	602	1	1
22	37	397	1	1
23	26	344	1	0
24	3	532	0	1
25[3]	5	173	0	0
26	38	815	1	1
27	182	576	6	1

Key: 1 = see Table 1 for full description of individual activity/exercise

2 = total number of case days up to time of fracture injury

3 = see Table 14 for individual pairs of multiple exercise days

Table 13b Summary data from Table 13a showing percentage of time per horse on different surface types.

Predominant Surface	Percentage of time per horse (cases)	Percentage of time per horse (controls)
Road/Dirt track	23	12
Grass	5	3
Equitrack	52	76
Other	12	6

Table 14. Total days of multiple activities for each combination of daily multiple activity among case and control Thoroughbred flat racehorses in Group 1 during the study period.

Category[1]	Case[2]	Control	Category[1]	Case[2]	Control
1,8	2	43	**8,10**	0	9
1,9	2	1	**2,8**	0	39
8,4	0	6	**8,23**	0	1
8,3	0	6	**8,24**	0	7
7,9	1	0	**18,9**	0	1
8,9	0	22	**11,8**	0	6
8,20	0	4	**8,22**	0	3
8,7	0	1	**8,21**	0	3
2,9	0	2	**4,9**	0	2
5,8	0	17			

Key: 1 = see Table 1 for full description of individual activity/exercise

2 = total number of case days up to time of fracture injury

Table 15. Summary calculations from different activities undertaken by case and control Thoroughbred flat racehorses from Group 1 during the study period.

Description	Case[1]	Control
1 Total number of horses	18	191
2 Total days of study	3115	69715
3 Total horse days present at yard	2797	33838
4 Total horse days absent from yard	318	35877
5 Total horse days of exercise[2]	2615	33262
6 Total horse days rest at yard (Sunday)	182	576
7 Mean days exercise per horse	145	174

Key: 1 = Includes case data up to the time of each fracture injury

2 = sum of 1-28 in respective columns of Table 13a except numbers 1 (absent) and 27 (Sunday rest)

2.3.8.2 Group Two (Tables 16a, b and 17)

As a result of the small number of cases in Group 2 (4) direct comparison of the different categories was considered unreliable It is of interest to note that cases spent more time exercising on woodchip than controls.

Table 16a. Time spent for case and control Thoroughbred flat racehorses in Group 2 exercising, on different surfaces over different distances.

Category[1]	Case[2]	Control	Percentage of time per horse (cases)	Percentage of time per horse (controls)
1	74	3219	15	18
2	43	1546	9	9
3	75	2555	15	14
4	0	1316	0	7
5	0	63	0	0
6	0	29	0	0
7	0	11	0	0
8	102	2980	21	17
9	98	3213	20	18
10	0	10	0	0
11	0	81	0	0
12	0	10	0	0
13	3	213	1	1
14	6	378	1	2
15	0	3	0	0
16	0	77	0	0
17	0	12	0	0
18	6	81	1	0
19	0	201	0	1
20	0	58	0	0
21	19	389	4	2
22	0	2	0	0
23	0	3	0	0
24	0	11	0	0
25	49	922	10	5
26	7	170	1	1
27	2	153	0	1

Key: 1 = see Table 2 for full description of individual activity/exercise

2 = number of case days up to time of fracture injury

Table 16b Summary data from Table 16a showing percentage of time per horse on different surface types.

Predominant surface	Percentage of time per horse (cases)	Percentage of time per horse (controls)
General	40	49
Woodchip	55	44
Grass	3	6

Table 17. Summary calculations from different activities undertaken by case and control Thoroughbred flat racehorses from Group 2 during the study period.

Description	Case[1]	Control
1 Total number of horses	4	78
2 Total days of study	484	17706
3 Total horse days present at yard	410	14487
4 Total horse days absent from yard	74	3219
5 Total horse days of exercise[2]	367	12941
6 Total horse days of rest at yard	43	1546
7 Mean days exercise per horse	92	166

Key: 1 = Includes case data up to the time of each fracture injury

2 = sum of 1-27 in respective columns of Table 16a except numbers 1 (absent) and 2 (stabled)

2.4 DISCUSSION

2.4.1 Fracture Location

Previous reports of racing and training fracture injuries have identified a wide variety of fracture orientations involving bones of the axial and appendicular skeleton (Bathe, 1994, McKee, 1995; Wilson and others, 1996). Although there are an infinite number of possible fracture orientations, a relatively small number of well-defined fracture injuries are reported to occur most frequently. These vary with the activity undertaken, but fatal fracture injuries included the metacarpal, proximal sesamoid, carpal and phalangeal bones in the forelimbs and the metatarsus, pelvis and phalanges in the hindlimbs among TB racehorses competing on the flat in reports from the UK, Australian and North American populations (Johnson and others, 1994a; Johnson and others, 1994b; Bourke, 1995b; McKee, 1995). These findings are consistent with the cases reported here, where the most frequent forelimb fractures included those involving the carpus and phalanges, while hindlimb fractures most frequently involved the pelvis and metatarsus. Bathe (1994) reported the fetlock, carpus, tibia and pelvis to be the most frequent sites of fractures in fore and hindlimbs among TB racehorses assessed at one clinic, with a 10.2% initial fatality rate.

Variations between published reports could be due to differences in case definition, i.e. the most severe or disabling injuries would have a higher incidence in fatal injury reports. Similarly, the relatively high incidence of tibial stress fractures reported by Bathe (1994), may have resulted from the inclusion of all fractures diagnosed during lameness investigations with the aid of nuclear scintigraphy, thereby increasing the proportion of stress fractures diagnosed with a similar reduction in the number of more severe fractures. The results of the investigation reported here identified a similar pattern of fracture distribution, among the bones of the appendicular skeleton, to that previously reported.

2.4.2 Forelimb versus Hindlimb Fractures

Among the cases reported here, 59% of fractures involved forelimbs while 41% involved the hindlimbs and pelvis. Peloso and others (1994a) reported 90.2% of racing injuries to involve the forelimbs, while Mohammed and others (1991) and

(1992) reported similar figure of 88% and 93.1%, respectively, although these higher figures included soft tissue injuries such as tendon and suspensory ligament injuries, both being more frequently reported injuries of the forelimbs compared to the hindlimbs. Fatal equine injury studies reported by Johnson and others (1994a) and Bourke (1995b) found that 90% of fatal **fractures** and 54.6% of fatal **injuries** involved the forelimbs, respectively. The frequent inclusion of "fatal fracture" as criteria for inclusion in the calculations and the variable use of "fracture" and "injury" in different investigations makes the direct comparison of percentage values inappropriate. Despite this, the results reported here are consistent with the overall impression in the literature that forelimb fractures occur with a greater frequency than hindlimb fractures.

2.4.3 Racing versus Training Fractures

Although the frequently dramatic occurrence of acute fractures during a race are both distressing for spectators to see and often the subject of high profile media attention, the actual proportion of fractures sustained while racing when compared with training or accidental injury has not been widely reported. Unfortunately, racehorse injury investigations almost invariably focus on injuries sustained at the racetrack (Bourke, 1985; Mohammed and others, 1991; Peloso and others, 1994a; McKee, 1995; Bailey and others, 1998), rather than while training (Lindner and Dingerkus, 1993).

The importance of fractures sustained away from the racetrack is highlighted by the relative proportion of activities related to the occurrence of the 23 fractures reported here. Seventeen (73.9%) occurred during or following a period of training exercise, compared with only 5 (21.7%) occurring during or following a race and 1 (4.3%) involving an accidental injury. A well established, large-scale, ongoing investigation of California racetrack fatalities reported 42% of fatal injuries to occur while racing, compared with 39% during training sessions and 7% involving accidental injuries, the remainder resulting from non-exercise related conditions (Johnson and others, 1994a). However, the inclusion of only fatal injuries, the inclusion of axial and appendicular fractures and both fractures and soft tissue injuries in Johnson's study, precludes a direct comparison of the reported values with those obtained in this investigation. If only fatal limb fractures are included in the calculation, 139/272 (51.1%) and 133/272 (48.9%) occurred while training and racing, respectively, emphasising the high frequency of fractures sustained while training. Another example, reported by Bathe (1994), found that of 245 fractures examined at a large equine hospital, 206 (84.1%), 21 (8.6%) and 18 (7.3%) fractures occurred while training, racing and accidentally, respectively. These latter figures are more consistent with the findings of this report, the two populations of horses being more similar than that reported by Johnson and others (1994a).

Although the majority of fractures identified in the study reported here were sustained during training exercise, the actual fracture incidence was 10 times greater when racing (0.4 cases per 100 racing days) compared with training (0.04 cases per 100 training days). This implies that there was a greater risk of sustaining a fracture while racing compared with training. During a race, horses usually compete at speeds greater than when training. All body systems are pushed closer to their physiological limit, increasing the likelihood of any weakness being exposed to excessive forces or a fatigued horse making an error, leading to the development of a fracture with the associated clinical signs. The risks of sustaining a fracture during these periods of extreme activity are therefore greater than when training, although, because considerably more time is spent training, a greater absolute number of fractures are sustained undertaking training activities (Bathe 1994). However, the conditions resulting in an inherent weakness within a bone, i.e. stress remodelling, thereby predisposing to fracture occurrence, may be related to the conditions under which the horse is trained, the racing conditions simply providing suitable conditions for exposure to the forces necessary to fracture the weakened bone.

The high number of fractures sustained and, importantly, diagnosed during training compared with racing emphasises the importance of regular assessment of horses in training for evidence of lameness, or reduction in performance for no obvious reason. The increasing use of nuclear scintigraphy has undoubtedly aided the early detection of metabolic changes in bone that is failing to adapt to increasing workloads sufficiently rapidly, or is suffering sub-clinical cumulative damage creating a weak point in the bone. The topographic patterns reported for long bone stress fractures are frequently similar to that of complete, catastrophic fractures (Stover and others, 1992).

It is being increasingly recognised and acknowledged that the occurrence of an acute fracture on the racetrack or while training is a reflection of a failure to identify a gradual deterioration in bone structure over the weeks preceding the injury. The importance of early intervention and modification of exercise programs in horses with evidence of stress fractures cannot be overemphasised. The traditional view that most fractures occur acutely while racing at maximal speeds is no longer a valid justification for the continued occurrence of racing fractures, as many occur during training when the vast majority of racehorses exercise at lower speeds and over shorter distances in a more controlled environment.

2.4.4 Fracture Incidence

Previously reported methods of calculating the incidence rate of MSI have varied depending on the study design, but are frequently reported as percentage values relative to the number of race starts. McKee (1995) calculated the number of fatal injuries per 10000 race starts and expressed the results as percentage values, while Bailey and others (1998) calculated the number of serious MSI per 1000 race starts, subsequently calculating percentage values. Peloso and others (1994a) and Bourke (1995b) also used number of race starts as the denominator variable to calculate injury incidence rates. This method is useful in standardising incidence rates between investigations.

As the focus of this investigation was the incidence of training fracture injuries, the results reported here involved the calculation of incidence rates relative to number of exercise days rather than race starts, precluding comparison of the results with other investigations, but providing baseline data for future projects. The number of injuries per horse was also calculated. The incidence rate per exercise day was similar between the two groups, 0.05% versus 0.03% for Groups 1 and 2 respectively, but Group 1 horses had nearly twice the number of fractures per horse compared with Group 2 horses, 8.61% versus 4.88%. The small number of injuries reported from Group 2 (5) makes the significance of this difference questionable.

Calculation of the incidence of fractures per horse allowed comparison with some other investigations. Estberg and others (1998) reported an incidence of 1.66 catastrophic musculoskeletal injuries per 1000 race entrants (0.166%). Although considerably lower than the results reported here from Groups 1 and 2, 8.61% and 4.88%, respectively, the figure only included severe injuries resulting in euthanasia of the horses, while most of the fractures reported here were not fatal injuries. McKee (1995) also reported an injury rate of between 0.03% - 0.21% of all runners at 39 flat racetracks in the UK, again including only fatal injuries.

2.4.5 Age and Gender Effects

The relationship between both age and gender and the occurrence of MSI has been previously reported (Mohammed and others, 1991; Johnson and others, 1994a; Peloso and others, 1994a; Bourke, 1995b; Bailey and others, 1997a; Bailey and others, 1998; Estberg and others, 1998). Although the results have been conflicting, the majority of reports identified a significant relationship between age and the occurrence of injury. This is in contrast to the results reported here where no significant difference was found between case and control age distributions, a finding also reported by Peloso and others (1994a) when comparing all horses with racing MSIs with horses competing at the same four racetracks over the same period. The specific positive relationships previously reported have varied. Bourke (1995b) reported an "over-representation" of horses with fatal racetrack injuries older than six years of age compared to the population, while Johnson and others (1994a) reported an increase in fatal training injuries among two year old TB horses compared with older horses. Estberg and others (1998) and Mohammed and others (1991) both reported older horses to be at greater risk of injury, but only in certain race categories in the former report. As the age of any particular population is likely to be influenced by numerous factors, the relationship with injury occurrence is likely to vary. Differences in age categorisation between reports may also influence the results obtained.

The results reported here are one of the few investigations that did not identify a significant relationship between age and the occurrence of MSI. Given that the majority of injuries were sustained while training, the results contradict the findings of Johnson and others (1994a) described above. It is frequently reported that increased frequency of injury with increasing age results from accumulation of micro-trauma to tissues over time, resulting in the eventual failure of the tissue. It is possible that the failure to identify any relationship between age and injury reported here could be due to the relatively young age group of horses included, the vast majority being two and three year old horses. Any accumulation of injuries with time would not be detected as only a small number of horses over the age of four years were included in the study.

Reports of the relationship between gender and the occurrence of MSI are equally conflicting. As with the results reported here, Peloso and others (1994a) and Bourke (1995b) did not identify any relationship between gender and severe racing injury. In contrast, both Bailey and others (1998) and Estberg and others (1998) found males to be 1.7 times more likely than females to sustain an MSI, although the definition of MSI differed between studies. This male propensity for injury could be due to managemental factors, resulting in male horses continuing to race after mild injuries when a female might be retired to stud. Recurrences of mild injuries, that may not be included in some investigations, might be much more severe and be recorded in the results of studies such as that reported by Estberg and others (1998), which included only those injuries resulting in the euthanasia of the horse.

2.4.6 Exercise Surface/Distance

The incidence of MSI at different racetracks, on different racing surfaces and under different environmental conditions has been the subject of numerous investigations (Hill and others, 1986; Clanton and others, 1991; Oikawa and others, 1994), as either the main focus or as part of an epidemiological risk factor assessment for the occurrence of MSI (Mohammed and others, 1991; Peloso and others, 1994; Bourke, 1995b; Bailey and others, 1998; Estberg and others, 1998). Hill and others, (1986), Peloso and others (1994) and Bourke (1995b) did not find any significant relationship between injury and different surface conditions. In contrast, Bailey and others (1998) reported a higher risk of injury on harder, faster surfaces, while Mohammed and others (1991) found turf surfaces to have a lower risk of injury compared with dirt. The results reported here compared different training surfaces used for exercising at speed. Cases in Group 1 were found to undertake less training exercise on two equitrack surfaces compared with controls. In view of the absence of a positive association between fracture injury and other surfaces, these findings could be interpreted as meaning that training on equitrack surfaces might have a protective effect in reducing the likelihood of sustaining a fracture injury. The results of Group 2 horses are difficult to interpret, as there was no consistent relationship between the exercise surface and frequency of exercise. Given that a significant number of MSI occur while training, further investigation into the effect of different surfaces and surface conditions on the occurrence of injury should at least include an individual's training surfaces.

2.4.7 Limitations of Investigation

A number of features inherent in the study design created certain difficulties during the period of data collection. As both racing yards were geographically distant from the research centre, regular visits and meetings with the lay staff involved in the day to day recording of data were difficult. This resulted in the success of the project being greatly dependent on the diligence of the lay staff. Each of the yards already maintained certain records prior to the start of the study, the previous recording systems being modified and enhanced to allow more information to be recorded in a relatively simple manner, without creating an unreasonable workload. The final method and quantity of data collection and storage at each yard was greatly dependent on previous systems used, but was made easier by the use of computer databases and spreadsheets.

The categorisation of each exercise undertaken proved difficult, mainly due to different surfaces used, variable distances covered and alterations in speed and distance over the racing season and with increasing age. This resulted in a relatively large number of categories in both groups. This became a problem in two of the Group 1 categories and 15 of the Group 2 categories where zero values were recorded. Combining categories was difficult due to the variations previously described.

Prior to the start of the investigation both yards already recorded all injuries that were sustained both soft tissue and boney in origin. As it proved difficult to identify the exact time of occurrence of some of the soft tissue injuries, only fracture injuries were included in the case group, as they generally had a more readily identifiable time of occurrence, although stress fractures could be an exception. This resulted in horses with non-fracture injuries being included in the control group, although their exercise regimen would probably have been modified following the injury. Some of the fracture injuries may also have occurred some time before the diagnosis of the injury. However, as the comparison of timing of fracture occurrence was between training and racing, rather than between different exercise categories, this probably did not have much influence on the racing to training injury ratios reported.

The number of horses in training at the yard and their movement during the season may have influenced the occurrence of injuries. Some horses were only present at either yard for a short period and may have subsequently sustained injuries after leaving the yard to train elsewhere, resulting in artificially low injury rates, possibly explaining the lower rate recorded in Group 2.

Although the results reported here give an indication of the frequency of occurrence of fracture injuries among TB racehorses while racing and training, the inclusion of only two yards means that any extrapolation to the general racing population should be interpreted with caution. This is particularly the case in the UK where horses train and race on many different surfaces. The day to day exercise program of racehorses also varies between racing yards, making inter-yard comparisons difficult. Although the identification of epidemiological risk factors may be of relevance to one particular yard, such factors may not be significant under different conditions.

2.5 CONCLUSIONS

Fractures sustained by TB flat racehorses are a significant cause of wastage among the population, resulting in temporary or permanent exclusion from competition and in some cases the death or euthanasia of the horse on humane grounds. Forelimbs were affected more frequently than hindlimbs and certain bones in both fore and hindlimbs appear to be predisposed to injury. Racing fractures are well recognised and reported and were found to have a higher incidence rate than training fractures. However, the total number of fractures sustained while training was found to be considerably higher than when racing, yet such injuries are poorly documented in the literature.

Among two groups of flat TB racehorses, including a total of 291 horses, investigated over a combined total period of 19.5 months, 7.6% sustained fractures, the majority occurring while training. Financial and manpower constraints often result in the research focus of equine MSI being restricted to racing injuries. Epidemiological risk factor assessment also frequently involves the investigation of racetrack variables, to which large numbers of horses from different sources compete under similar conditions. Consequently, the influence of the training environment on the occurrence of injuries at the racetrack is ignored. Practical difficulties in standardising training variables makes inter-yard comparison and the analysis of potential risk factors complicated.

The results of this study were suggestive of a protective effect of training horses on equitrack surfaces. The increased use of such a surface might reduce the incidence of both racing and training injuries and might be useful in horses with unexplained poor performance or mild lameness of unknown origin, reducing the likelihood of the progression of a sub-clinical injury to an acute clinical injury. Further investigation of this finding is necessary, involving the direct comparison with other high-speed surfaces.

In conclusion, this study found a high incidence of fractures among TB flat racehorses, mostly occurring while training, with no age or gender predilection. Horses in Group 1 not developing a fracture during the study period spent more time exercising on an equitrack surface compared with those horses that sustained a fracture.

Key 1 - Microsoft Excel, Microsoft Corporation, Redmond, WA, USA.

2 - Epi-info 6.04b, Brixton Books, New Orleans, LA, U.S.A.

2.6 FIGURES

Figure 1. Age distribution among case and control Thoroughbred flat racehorses under investigation for a 12-month period, to determine the incidence of fracture injuries while racing and training (Group 1).

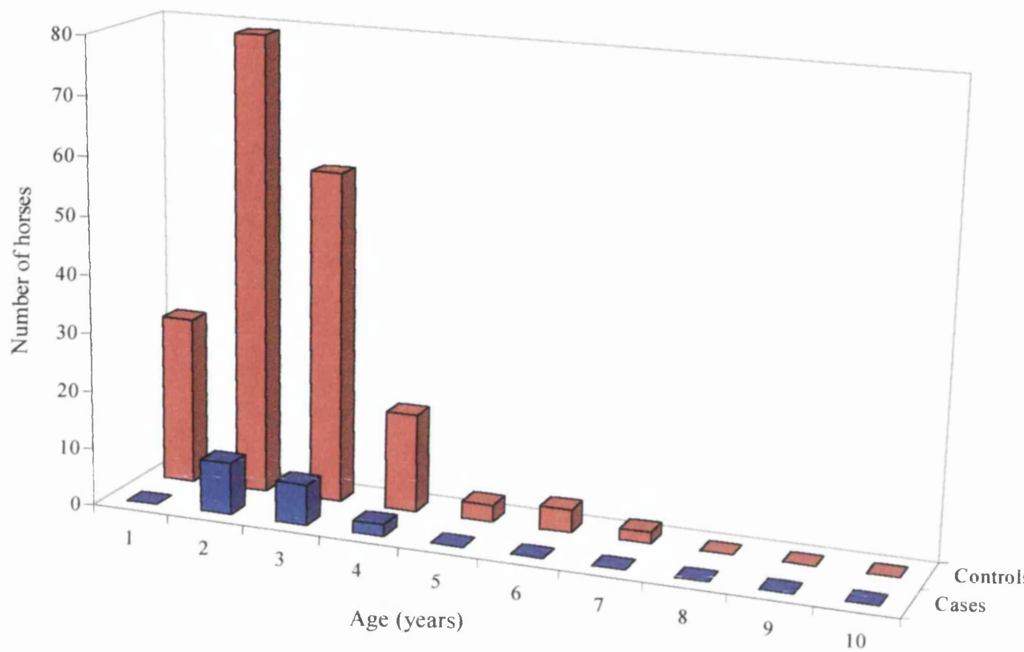


Figure 2. Gender distribution among case and control Thoroughbred flat racehorses under investigation for a 12-month period, to determine the incidence of fracture injuries while racing and training (Group 1).

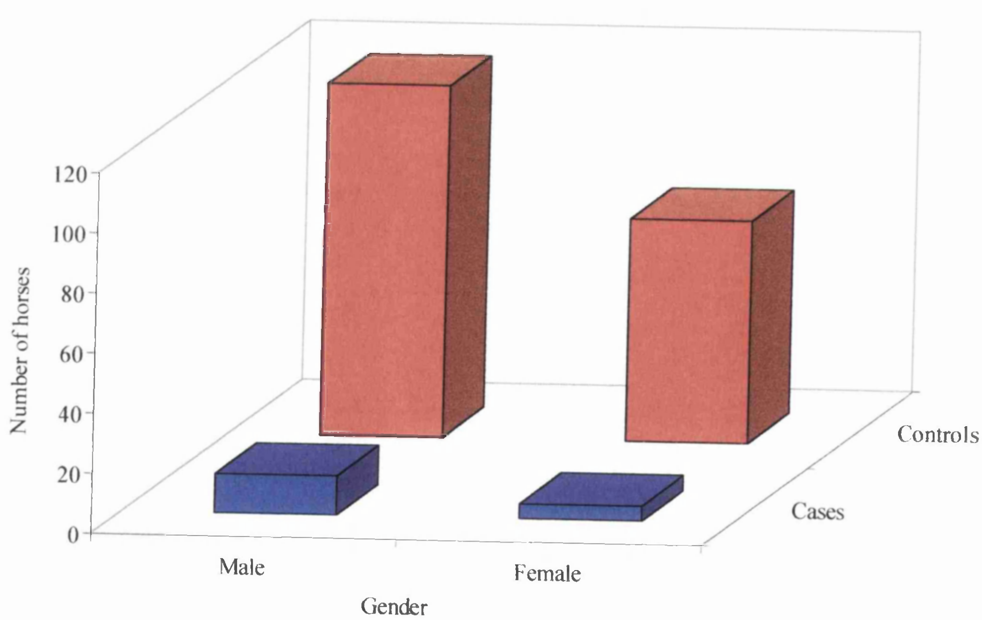


Figure 3. Combined age and gender distribution among case and control Thoroughbred flat racehorses under investigation for a 12-month period, to determine the incidence of fracture injuries while racing and training (Group 1).

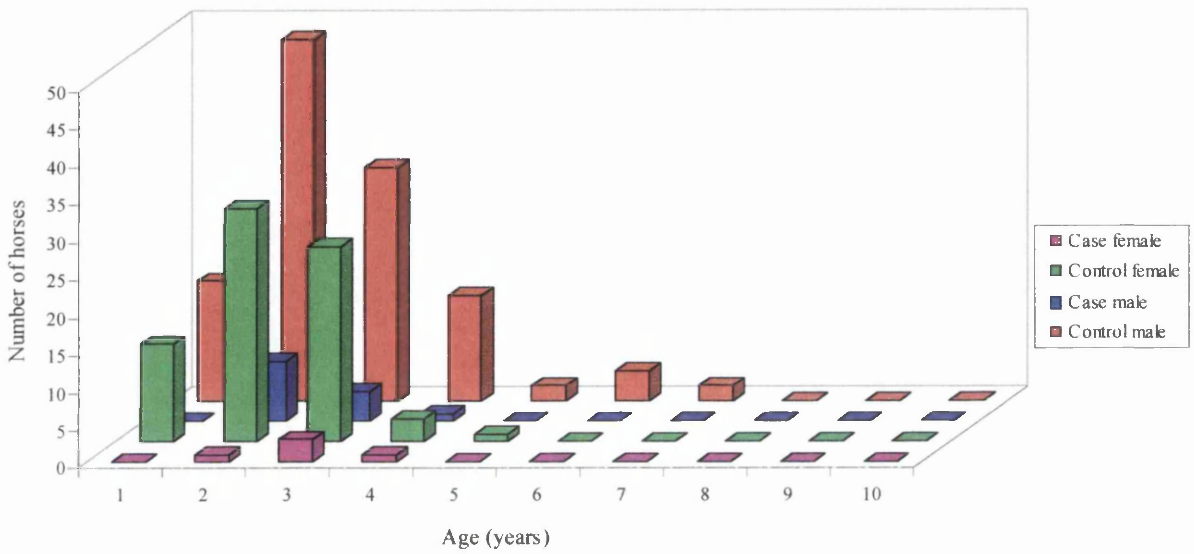


Figure 4. Age distribution among case and control Thoroughbred flat racehorses under investigation over a seven month period, to determine the incidence of fracture injuries while training and racing (Group 2).

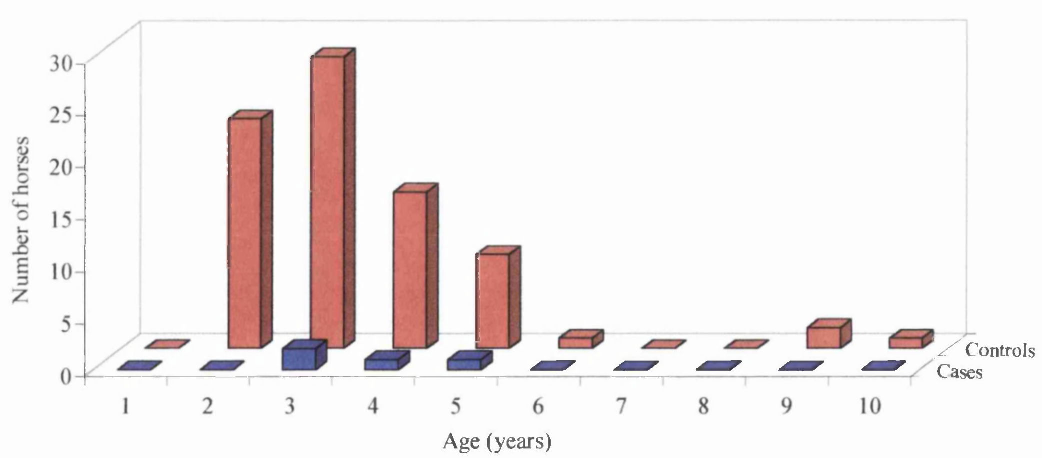


Figure 5. Gender distribution among case and control Thoroughbred flat racehorses under investigation over a seven-month period, to determine the incidence of fracture injuries while training and racing (Group 2).

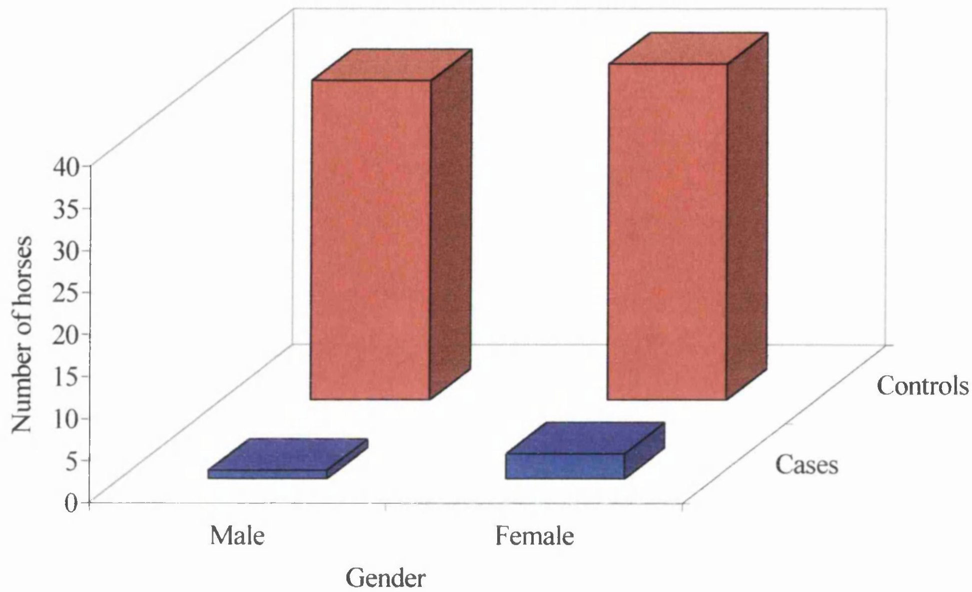


Figure 6. Combined age and gender distribution among case and control Thoroughbred flat racehorses under investigation for a seven-month period, to determine the incidence of fracture injuries while racing and training (Group 2).

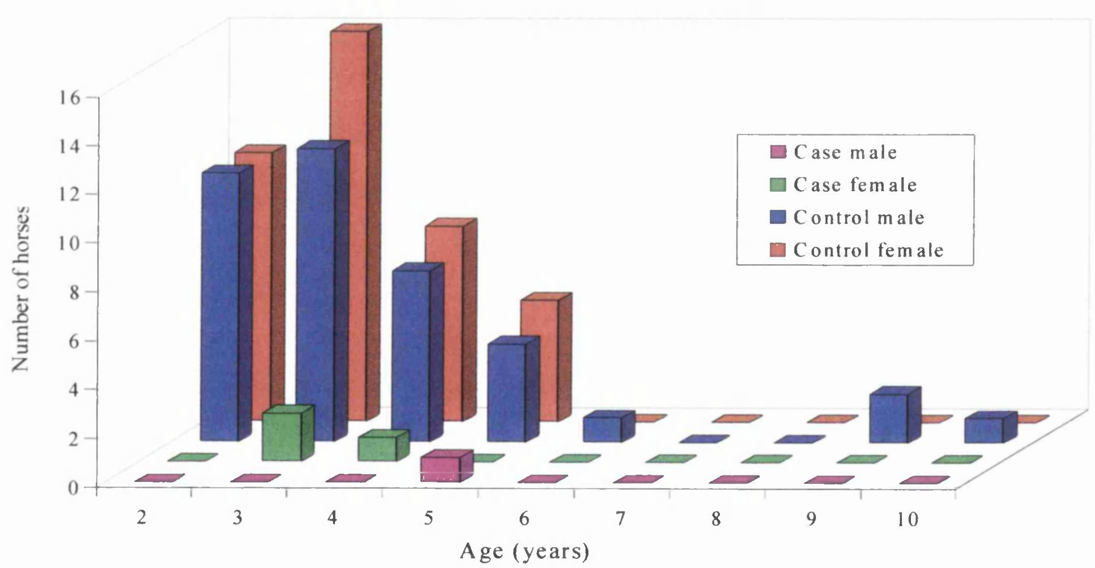


Figure 7. Distribution of fracture injuries by calendar month during each study period during 1997 among Thoroughbred flat racehorses from Groups 1 and 2 while undertaking racing and training exercise.

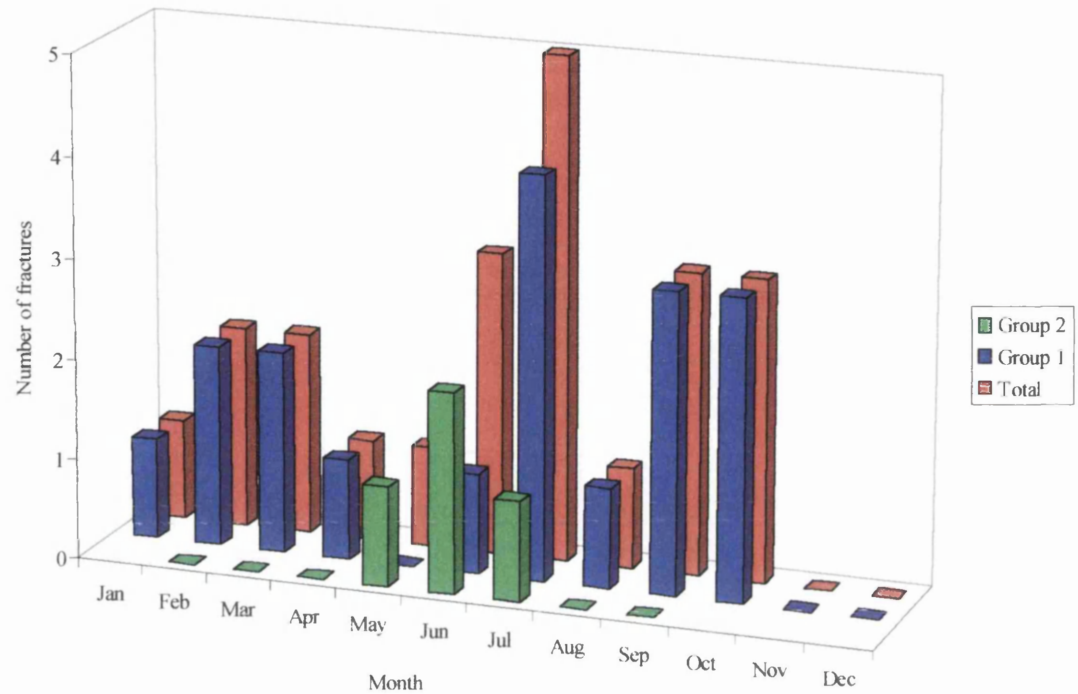
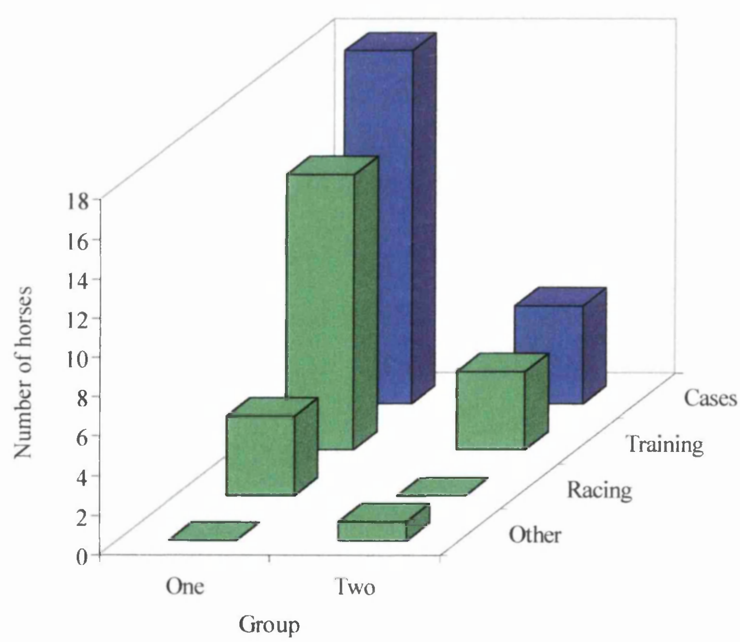


Figure 8. Proportion of case horses and their distribution in relation to activity immediately prior to the onset of lameness among two groups of Thoroughbred flat racehorses in training.



CHAPTER III

REPEATABILITY OF DIAGNOSTIC ULTRASONOGRAPHY IN THE ASSESSMENT OF THE EQUINE SUPERFICIAL DIGITAL FLEXOR TENDON

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REPEATABILITY OF DIAGNOSTIC ULTRASONOGRAPHY IN THE ASSESSMENT OF THE EQUINE SUPERFICIAL DIGITAL FLEXOR TENDON

3.1 INTRODUCTION

Diagnostic ultrasonography has, over the last decade, become an essential imaging modality in the assessment of equine soft tissue injuries, particularly those involving the distal limbs. Despite this dramatic increase in popularity, qualitative and quantitative assessment of the repeatability of diagnostic ultrasonographic examination of body tissues has not been reported.

Ultrasonographic assessment of soft tissues usually involves quantification of the structures under investigation, using both objective and subjective scales of measurement (Reef and others, 1996; Genovese and others, 1997). Clearly, objective measurement would be less susceptible to bias and should provide more reliable and consistent results. Variables suitable for an objective ultrasonographic assessment of the equine SDFT include, determination of total tendon and lesion CSA at various pre-determined levels in the tendon (Gillis and others, 1995a), usually involving contra-lateral limb comparisons and subjective assessment of gray scale analysis of echogenicity of areas of tendon perceived to be damaged (Wood and others, 1992; Martinolli and others, 1993; Nicoll, Wood and Martin 1993; Wood and others, 1993; Tsukiyama and others, 1996). Various ordinal scales have been developed to subjectively quantify the proportion of injured SDFT CSA in relation to the total SDFT CSA at various locations along the tendon, the echogenicity of injured SDFT, and the linear echo pattern of areas of injured SDFT (Reef and others, 1996; Genovese and others, 1997). Variation in the values obtained using any of the above measurements could occur at a number of points during the course of image acquisition and analysis.

A source of possible variation during objective and subjective assessment involves the selection of the exact location from which the image is obtained.

Sources of possible variation during objective assessment include:

1. Selection of the boundary for measurement of total SDFT CSA;
2. Selection of the boundary for measurement of total lesion CSA;
3. Selection of the boundary for measurement of total echogenicity using gray scale analysis.

Sources of possible variation during subjective assessment include:

1. Assignment of numerical value to individual fibre pattern;
2. Assignment of numerical value to proportion of SDFT injured;
3. Selection of the boundary for measurement of total echogenicity using ordinal scale.

The aim of this investigation was to use an objective measure, namely the measurement of CSA, to quantify the variability occurring during the course of the ultrasonographic assessment of the equine SDFT. The effects of three variables on the CSA measurements were determined, including:

1. Image acquisition operator (IAc): Two different operators undertaking the ultrasonographic examination;
2. Image analysis operator (IAn): Two different operators undertaking the calculation of CSA values from previously stored images;
3. Analytical equipment (used during CSA measurement) (IEq): The use of two different sets of equipment during calculation of CSA values.

3.2 MATERIALS

3.2.1 Experiment Hypothesis

A study was designed to investigate the effect of each variable. The experimental hypothesis was that different operators undertaking either the ultrasonographic examination, or the subsequent analysis, were not associated with a statistically significant difference in the mean CSA values obtained and that there was no significant difference in results when different equipment was used to calculate the CSA.

3.2.2 Study Design

A randomly selected cohort of 16 NH racehorses was selected from those residing at a training yard. Eligible horses were those animals registered in NH race training in 1996-7. Horses were selected irrespective of SDFT injury status. All eligible horses underwent ultrasonographic examination of both forelimb SDFTs by both operators.

Two experiments were designed to determine the effect of individual variables on the CSA values obtained. Experiment one involved the comparison of data obtained when different operators undertook either image acquisition (IAc) or image analysis (IAn), using only the CSA values obtained using the first set of analytical equipment (IEq) (Figure 9).

The second experiment again involved the comparison of data obtained when different operators undertook image acquisition (IAc). This was combined with a comparison of the values obtained when different equipment was used during calculation of CSA values (IEq), involving only those values obtained when operator one undertook image CSA measurement (IAn) (Figure 10).

3.2.3 Ultrasonographic Examination

Each horse underwent an ultrasonographic examination of both forelimb SDFT. Each horse was assigned an identification number, which corresponded with the number on all subsequent ultrasonographic video recordings. This was necessary to maintain anonymity and also because some horses were named or re-named during the period of the study.

The examination was undertaken in a set of purpose built restraining stocks, already installed in a building at the yard and used for routine procedures that required minimal restraint of the horse e.g. clipping, physiotherapy and veterinary examinations. The open steel frame design allowed easy and safe access to the horses' limbs, while the swinging side and rear panels provided a quick release route if the horse panicked. A non-slip rubber mat surface covered the floor. As the horses were in training during the study, clipping the hair over the area of interest was not possible. Prior to entry into the stocks the palmar surface of both forelimbs was hosed with cold water until it was thoroughly soaked, usually approximately five minutes. Echolucent gel was then applied to the area against the direction of hair growth and massaged in thoroughly. The gel was left *in situ* for a further five minutes prior to the ultrasonographic examination. Any foreign material, scale and debris present on the limbs were removed during hosing.

The region of the SDFT under examination was restricted to the forelimb palmar metacarpal region, extending from immediately distal to the distal border of the accessory carpal bone to the proximal sesamoid bones. The examination was undertaken from the left side of the horse, starting proximally on the left SDFT and finishing distally on the right SDFT. Each limb was divided into five levels, at 4cm intervals, extending from 8cm to 24cm distal to the distal border of the accessory carpal bone (DACB). With the probe contacting the most palmar aspect of the limb, perpendicular to its palmar surface, a transverse plane image of the SDFT was obtained at each pre-determined level. The probe was manipulated in both proximo-distal and medio-lateral planes to obtain an optimal image and ensure consistent perpendicular and palmar probe placement. A transverse plane image of the SDFT was obtained at each pre-determined level. The images were subsequently used to calculate the SDFT CSA values at each level of each tendon.

3.2.4 Image Processing

3.2.4.1 Image Acquisition

The same ultrasound machine and variable frequency linear transducer (7.5 - 10.0 megahertz (MHz)) set at 7.5 MHz and a field depth of 5cm, with standoff, were used for all examinations. Initially, maximum power and time gain compensation (TGC) settings were used. If the images were excessively echogenic then the settings were reduced accordingly. The identification number, the limb under examination (left -

L, right - R) and the level of the examination (1[8cm] - 5[24cm]) were all recorded on the screen adjacent to the images, allowing identification of individual images during subsequent image analysis. Field depth was fixed at 5cm, as this centred the SDFT on the screen, providing an image of sufficient size to allow subsequent CSA measurement. The probe head was applied perpendicular to the skin surface to produce a good quality, representative image of the SDFT at each level.

3.2.4.2 Image Storage

A representative image was obtained at each level, sufficient to allow accurate identification and tracing of the outer margin of the SDFT. Each level was determined with the aid of a ruler placed against the side of the limb. The examinations were recorded with an SVHS video recorder and cassettes. Each image was frozen for several seconds while the video player continued to record, facilitating later reviewing of the images during the analysis. The two operators undertook image acquisition out of direct sight of each other.

3.2.4.3 Image Analysis

The CSA values were determined from the ultrasonographic video images using two methods. The first involved reviewing the recordings using the pre-installed image analysis software, incorporated into the machine used for image acquisition. A frozen image was obtained at each level in each limb and the SDFT CSA determined by tracing the outline with the cursor. The tracing was repeated twice more, resulting in three measurements for each level of each tendon. The second method, used only by operator one, involved digitisation of the frozen images using image analysis software, conversion to bitmap files and calculation of the CSA in a manner similar to that described for the first technique[1]. All subsequent analysis of CSA measurements involved the mean CSA value calculated for each level of the tendon.

3.3 STATISTICAL METHODS

3.3.1 Descriptive Statistics

A total of six sets of data were obtained and categorised according to which operator undertook the image acquisition and/or image CSA measurement and which set of equipment was used during CSA measurement (Figures 9 and 10). As the effect of "limb" was not under investigation, the values for corresponding levels in the left and right limbs were combined and the mean at each level for the 16 horses in each data set was calculated. A spreadsheet program was used to generate a graphical representation of the data.

3.3.2 Analysis of Variance (ANOVA), General Linear Modelling (GLM) and Multiple Range Testing (MRT)

ANOVA and GLM statistical techniques were used to determine the effect of individual variables on the results obtained. ANOVA was used for balanced data sets containing an even number of values, while GLM was used for uneven numbers of values in unbalanced data sets. The statistically significant results were investigated further using a Newman-Keuls MRT to identify the respective differences between data sets. As a result of inadequate image quality, accurate determination of the SDFT CSA was not possible in a small number of cases, at levels 4 - 5. ANOVA was therefore used to determine the effects of each variable at levels 1 - 3 inclusive, while a GLM technique was applied to levels 4 - 5. The null hypothesis was that there was no significant difference between the means of the data sets, with the significance level set at 5%. MRT was applied to the significant result to determine the pairwise difference between means.

3.4 RESULTS

3.4.1 Descriptive Statistics

The values for corresponding levels in the left and right limbs were combined and the mean at each level for the 16 horses in each data set calculated (Figure 11). Six horses had no evidence of SDF tendinitis, six had evidence of acute SDF tendinitis, while four horses had evidence of chronic SDF tendinitis. Inter-group variation gradually increased from level 1 - 5. Overall mean CSA values increased from level 1 - 4 and then decreased to level five. Groups 1 - 4 and 5 - 6 formed separate clusters, following similar patterns, the former cluster having higher mean CSA values at all five levels. The two clusters represented the CSA measurements determined by the two operators.

3.4.2 ANOVA, GLM and MRT

The results of the ANOVA or GLM at each level of the SDFT for the variables under investigation in each of the two experiments are shown in Tables 18 and 19. At all levels, there was no significant difference in the SDFT mean CSA values obtained when different operators undertook image acquisition. Similarly, at levels 1 - 4 there was no significant difference in the values obtained when different equipment was used during image analysis. However, at level five a significant difference was identified. The comparison between operators undertaking CSA measurements revealed a significant difference in the values obtained at all five levels. MRT of this difference revealed that operator one consistently returned larger measurements compared with operator two at all levels of the SDFT.

Table 18. Experiment 1 analysis of variance (ANOVA), general linear model (GLM) and multiple range test (MRT) results for mean forelimb superficial digital flexor tendon cross-sectional area values determined ultrasonographically, from 16 Thoroughbred National Hunt racehorses in training.

Level	Variable	P value	Comments
1	IAc	N	--
	IAn	$<0.01^*$	1>2
2	IAc	N	--
	IAn	0.01^*	1>2
3	IAc	N	--
	IAn	$<0.01^*$	1>2
4	IAc	N	--
	IAn	$<0.01^*$	1>2
5	IAc	N	--
	IAn	$<0.01^*$	1>2

Table 19. Experiment 2 analysis of variance (ANOVA), general linear model (GLM) and multiple range test (MRT) results for mean forelimb superficial digital flexor tendon cross-sectional area values determined ultrasonographically, from 16 Thoroughbred National Hunt racehorses in training.

Level	Variable	P value	Comments
1	IAc	N	--
	IEq	N	--
2	IAc	N	--
	IEq	N	--
3	IAc	N	--
	IEq	N	--
4	IAc	N	--
	IEq	N	--
5	IAc	N	--
	IEq	0.01*	1>2

Key to Tables 18 and 19:

IAc = Image acquisition

IAn = Image analysis (measurement of CSA)

IEq = Analytical equipment (equipment used to calculate CSA)

N = Not statistically significant ($p > 0.05$) * = Statistically significant

1>2 = Operator 1 values greater than operator 2

3.5 DISCUSSION

3.5.1 Repeatability of Diagnostic Ultrasonography

Previously reported measurements for SDFT mean CSA in TBs covered a wide range of values at all levels in the tendon (Smith and others, 1994). Although the levels at which measurements were taken differed slightly from those used in this study, the mean values calculated appeared to be considerably smaller than those reported by Smith and others (1994), despite the fact that ten horses in the study reported here had evidence of acute or chronic tendinitis. The wide range of values reported by Smith and others (1994) and identified in this study could result in considerable differences in values and profiles between studies. The SDFT cross-sectional area profile reported for a group consisting of mainly TBs (Gillis and others, 1995a) was similar to that reported here at levels 1 - 4, although the mean values were lower than obtained in this report. These findings concur with the aforementioned possible explanation for inter-study variation.

For the purposes of this study the SDFT mean CSA values for left and right limbs were combined. Smith and others (1994) found no significant difference between left and right forelimb SDFT mean CSA values in any of several groups of horses, ranging from heavy horses to ponies. Similarly Gillis and others (1995b) reported no significant difference between the left and right forelimbs in each of a group of 50 TBs.

The consistency in CSA values obtained through different operators undertaking image acquisition has considerable clinical and research significance. This is particularly relevant in the context of repeat ultrasonographic examinations of the same individual(s). Gillis and others (1993) identified a trend towards an increase in SDFT mean CSA in TBs in training. The study involved approximately fortnightly ultrasonographic examinations over a period of four months. If more than one operator had been involved in image acquisition, then any inter-operator variability could have introduced a confounding influence with consequences on the results obtained. Despite a considerable difference in the level of ultrasonographic experience of the two operators involved in the report described here, no significant difference in image acquisition was identified.

Comparison between two different sets of equipment during image analysis suggested that different image analysis software and hardware could be used to determine CSA with considerable consistency. Although using the same equipment to undertake repeat examinations would be preferable, particularly in relation to clinician familiarity with equipment, in clinical practice this is not always possible.

However, the similar results obtained between the two sets of equipment reported here cannot be extrapolated to all available equipment. Many published reports used the same equipment for the duration of the study, eliminating any possible influence of this variable.

The different sets of equipment were used only by operator one. The absence of any significant difference apart from level five is suggestive, although not conclusive of a high degree of intra-operator consistency. This finding is relevant to repeat examinations of the same animals. Genovese and others (1997) reported the quantitative assessment of healing SDFT injuries, where objective measurement of CSA and echogenicity were used to prognosticate for return to competition. Although small changes in these parameters could be detected, which may have altered the prognosis given, any intra-operator variability could have lead to erroneous results and a premature return to competition, with potentially devastating consequences.

The differences identified in this study between operators during image analysis were significant at all five levels of the tendon, operator one consistently returning values greater than operator two. The most likely explanation for this finding was differences in interpretation of the SDFT external border location. The relative inexperience of operator one may have led to over-estimation of the SDFT mean CSA. Image analysis in clinical practice is usually undertaken at the time of examination. The results reported in this study suggest that in sequential examinations or during the examination of a group, then differences in measurement of cross-sectional areas could occur if different operators undertook the image analysis.

With the increasing availability of diagnostic ultrasonographic equipment and the trend from subjective towards objective ultrasonographic assessment of SDFT injuries (Genovese and others, 1997; Reef and others, 1997), the possibility of operator and equipment related variability should be considered when interpreting CSA in clinical cases and research investigations.

3.5.2 Limitations of Investigation

As the horses examined were in training during the study period, the hair could not be removed prior to ultrasonographic examination. Although both examiners were exposed to the same conditions, the difficulty in obtaining good quality ultrasonographic images, particularly at the more distal sites in the limb, may have influenced the accuracy of subsequent measurements undertaken by either examiner. Had this project been undertaken out of season or when the limbs were less hairy, this could have been avoided.

Although a clearly defined protocol was planned prior to the first examination, it is possible that during the examination period either operator may have refined the technique, as they became more familiar with the routine. Although difficult to quantify, the accuracy during the measurement of the appropriate level of the tendon at which to obtain each image could vary, as could the quality of each image obtained.

Due to equipment location it was only possible for one of the operators to undertake image analysis (measurement of CSA) on both sets of equipment, resulting in an incomplete data set. Although a number of comparisons were still possible, the investigation would have been more complete had both operators completed image analysis using both sets of equipment. Although limited by time constraints, another dimension of data analysis could have involved intra-operator comparisons, if each operator had repeated the data analysis of their own and the other operator's data using one set of equipment.

3.6 CONCLUSIONS

A variety of quantitative and qualitative measures have been developed to allow the subjective and objective assessment of diagnostic ultrasonographic images. Although there are an ever increasing number of reported uses of ultrasonography, along with more in depth assessment of frequently examined soft tissues, the repeatability of an ultrasonographic examination has not been previously reported. The results of this investigation found that different operators undertaking the image acquisition stage of the procedure were able to produce consistent results, as did the use of two different sets of analytical equipment by one operator. However, different operators undertaking image analysis i.e. actual measurement of the SDFT CSA, returned significantly different values. Operator variability, occurring during image analysis, is therefore, one potential source of variation.

Consideration should be given to this variability during the design of ultrasonographic investigations involving multiple operators. To avoid any confounding effects, the same operator should undertake analysis of all images obtained from the study group during the investigation and at subsequent examinations if serial assessment is being undertaken.

Key 1 - Image PC for Windows, National Institute of Health, USA.

3.7 FIGURES

Figure 9. Study design for experiment one, involving a comparison of the mean forelimb superficial digital flexor tendon cross-sectional area (CSA) values obtained between different operators undertaking ultrasonographic image acquisition (IAc) and between different operators undertaking calculation of CSA values (IAn) from the acquired ultrasonographic images.

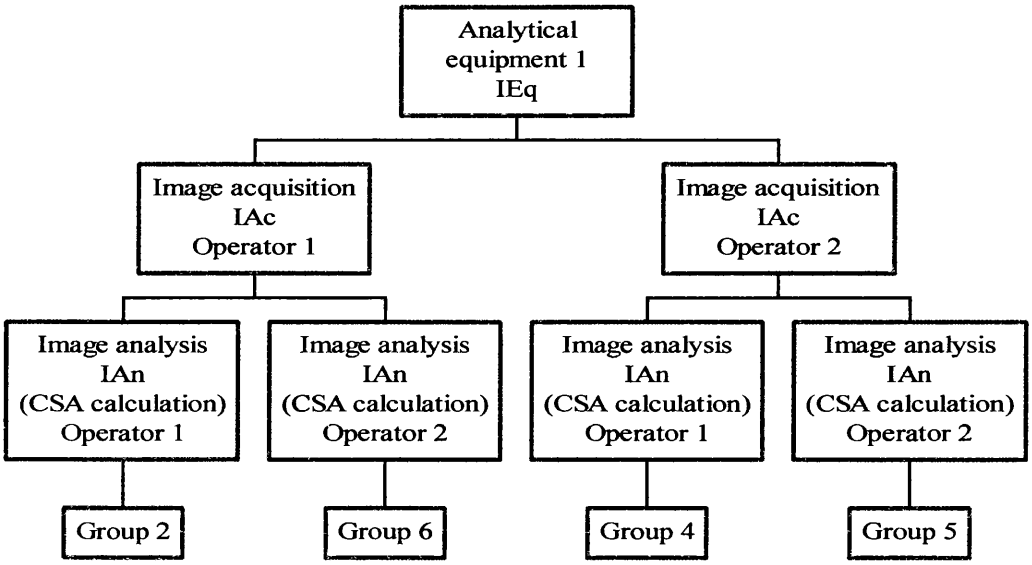


Figure 10. Study design for experiment two, involving a comparison of the mean forelimb superficial digital flexor tendon cross-sectional area (CSA) values obtained between different operators undertaking ultrasonographic image acquisition (IAc) and between different analytical equipment (IEq) used to calculate CSA values from the acquired ultrasonographic images.

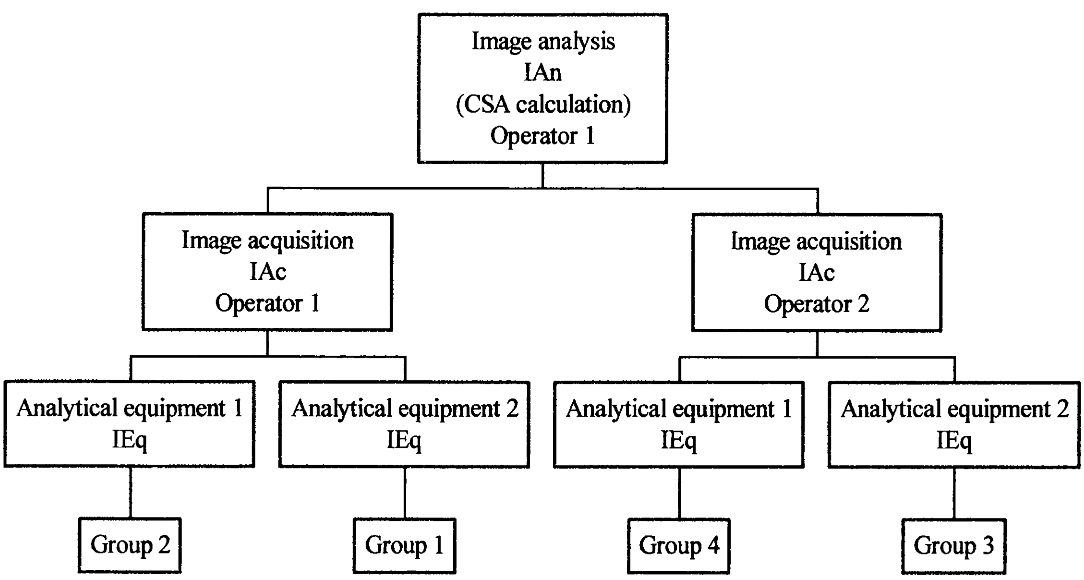
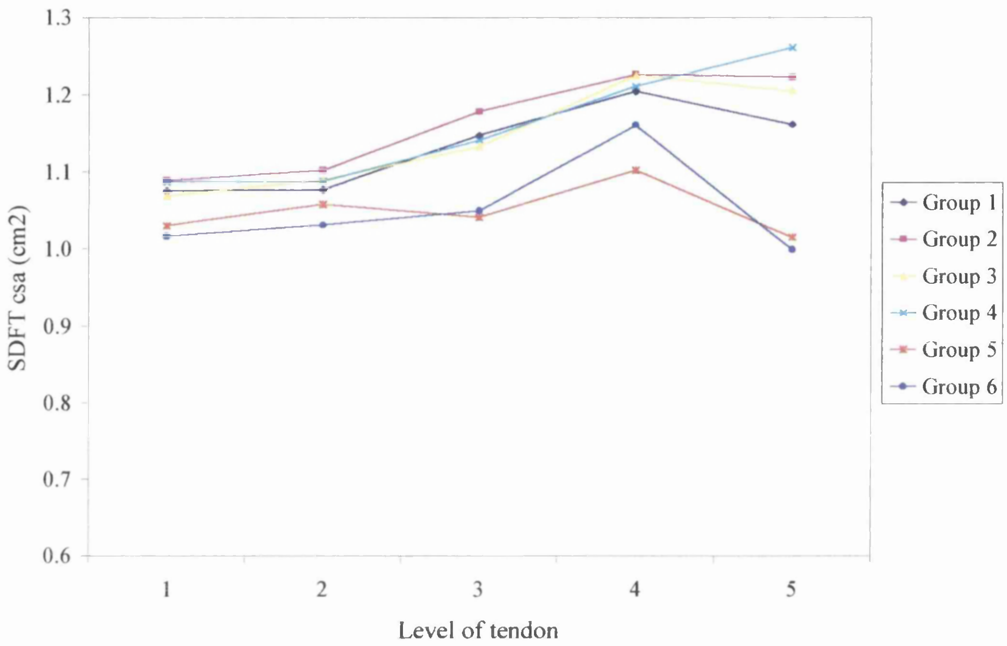


Figure 11. Mean forelimb superficial digital flexor tendon cross-sectional area values of 16 Thoroughbred National Hunt racehorses determined ultrasonographically and measured by different operators and using different analytical equipment to undertake measurements from the stored ultrasonographic images.



CHAPTER IV

THE ULTRASONOGRAPHIC INVESTIGATION OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IN NATIONAL HUNT RACEHORSES

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THE ULTRASONOGRAPHIC INVESTIGATION OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IN NATIONAL HUNT RACEHORSES

4.1 INTRODUCTION

Although SDF tendinitis is a widely recognised condition in racehorses of all types, there is sparse information relating to the incidence among those most frequently affected, namely NH hurdlers and steeplechase horses. The aim of this study was to monitor, both clinically and ultrasonographically, a cohort of NH racehorses over a 12-month period with the following objectives:

1. Quantify the incidence of acute and chronic SDF tendinitis within the cohort;
2. Identify and measure changes in CSA, determined ultrasonographically, within in the SDFT over the 12-month period in both normal and damaged tendons;
3. Identify any changes in the SDFT CSA prior to the development of acute tendinitis.

The prevalence of SDF tendinitis was determined from historical information, records maintained during the course of the investigation and from the results of the ultrasonographic examinations. The changes in SDF CSA were determined by repeat ultrasonographic examination, on four occasions over a 12-month period.

4.2 MATERIALS AND METHODS

4.2.1 Study Design

4.2.1.1 Cohort Selection

Horses were selected from those residing at a NH training yard during the period of study, from December 1996 - 1997. During the course of the investigation, the population of horses fluctuated, as horses moved to and from the yard on both a temporary and permanent basis. Consequently, the number of individuals undergoing ultrasonographic examination varied at each session, as did the number of overall examinations each horse received. Due to the nature of the Industry, there is a steady movement of horses between racing yards, although a core of horses usually remains at the yard for an extended period of time. These movements result from horses being sold, retired from racing or following death/euthanasia, as well as the purchase of new horses and transfer to another yard at the owner's preference. Any individuals arriving after the start of the study were included in subsequent examinations.

The failure to carry out subsequent ultrasonographic examination of all the horses present at the initial examination resulted from a number of factors. During the course of the study some of these horses sustained injuries, necessitating an extended period of rest, permanent retirement from NH racing, or euthanasia on humane grounds. At the owner's discretion others were either moved to another yard or retired from training due to lack of ability or for personal reasons, while others were receiving treatment for a recently sustained injury at the time of some subsequent examinations. These individuals were either receiving treatment elsewhere at the time of examinations or were boxed at the yard but were not available for examination. A small number of individuals were considered unsafe, due to their temperament, to examine ultrasonographically without risk to the horse, handler and equipment.

4.2.1.2 Ultrasonographic Examination

The SDFT of both forelimbs were examined ultrasonographically on four occasions over a 12-month period, at 0, 4, 8 and 12 months. At the time of each initial examination, a record of signalment, including name, age, gender and historical information pertaining to previous forelimb SDF tendinitis was collected. Each horse was assigned an identification number, which corresponded with the number on all subsequent ultrasonographic video recordings. This was necessary to maintain anonymity and also because some horses were named or re-named during the study period.

The region of the SDFT under examination was restricted to the forelimb palmar metacarpal region, extending from immediately distal to the distal border of the accessory carpal bone to the proximal sesamoid bones. This region was divided into five levels at 4cm intervals, extending from 8cm to 24cm DACB. A transverse and longitudinal plane image of the SDFT was obtained at each pre-determined level and the images obtained were subsequently used to calculate the SDFT CSA. During the course of the investigation, all information pertaining to cases of forelimb SDF tendinitis, including previous, new and recurrent episodes was recorded by the trainer. These records were collated with the ultrasonographic examinations, allowing the quantification of frequency of occurrence of each injury type.

4.2.1.3 Categorisation of SDF Tendinitis

Each horse was categorised according to historical, clinical and ultrasonographic findings. All horses were included in one of four mutually exclusive categories: acute tendinitis; chronic tendinitis with no recurrence during the study period; chronic tendinitis with acute recurrence during the study period; and those with no evidence of tendinitis. The information obtained was used to determine frequency of injury according to age, gender, limb and overall incidence of each injury type.

4.2.1.3.1 Acute SDF Tendinitis (Figure 12)

Horses in this group were found to have ultrasonographic evidence of acute tendinitis, with the presence of either a single central or peripheral core lesion, or multi-focal smaller, more diffuse lesions. The lesions appeared as either hypo- or an-echoic regions. On longitudinal plane imaging there was a variable degree of linear fibre disruption. There was also no history of clinical or ultrasonographic evidence of tendinitis while resident at the yard.

4.2.1.3.2 Chronic and Chronic-Recurrent SDF Tendinitis (Figure 13)

This group included all horses showing evidence of previous SDF tendinitis of one or both forelimbs at the time of initial ultrasonographic examination, but with no evidence of a recent acute lesion. Ultrasonographic changes associated with previous tendinitis included an increase in SDF CSA, along with a heterogeneous pattern consisting of mixed hypo- and hyper-echoic fibres on the transverse view. Longitudinal plane imaging abnormalities included echogenic, but irregular, or poorly aligned linear fibres. A sub-division of this group, chronic-recurrent tendinitis, included those horses with chronic injuries that developed signs of acute tendinitis within the course of the study. For some of the data analysis, these were grouped together. The historical records were not sufficient to categorise horses within this group according to the time of the original injury or most recent recurrence prior to the start of the period of study.

4.2.1.3.3 No SDF Tendinitis

All horses within this group were found to be free of any clinical or ultrasonographic evidence of SDF inflammation, at any time during the course of the study and had no history of SDF tendinitis while at the yard or prior to arrival.

4.2.2 Ultrasonographic Examination Technique

The examination was undertaken in a set of purpose built restraining stocks, already installed in a building at the yard. As the horses were in training during much of the study period, clipping the hair over the area of interest was not possible. Prior to entry into the stocks the palmar surface of both forelimbs was hosed with cold water for five minutes until it was thoroughly soaked, removing any foreign material, scale or debris. Echolucent gel was then applied to the area against the direction of hair growth and massaged in thoroughly. The gel was left *in situ* for a further five minutes prior to the ultrasonographic examination. The examination was undertaken from the left side of the horse, starting proximally with the left SDFT and finishing distally with the right SDFT.

4.2.3 Image Processing

4.2.3.1 Image Acquisition

One ultrasound machine[1] and variable frequency linear transducer (7.5 - 10.0 MHz) with detachable standoff were used for all examinations. Each examination was started using a frequency of 10 MHz to provide optimal resolution. However, in some horses and at certain times of the year, this resulted in insufficient tissue penetration. For these examinations the frequency was reduced to 7.5 MHz, which proved adequate in most cases to obtain representative images. Initially, maximum power and time gain compensation settings were used. If the images were excessively echogenic then the settings were reduced accordingly. The identification number, the limb under examination (left - L, right - R) and the level of the examination (1[8cm] - 5[24cm]) were all recorded on the screen adjacent to the images, allowing identification of individual images during subsequent image analysis.

Field depth was fixed at 5cm, as this centred the SDFT on the screen, providing an image of sufficient size to make subsequent CSA measurement relatively straightforward. The probe head was applied perpendicular to the skin surface to produce a good quality, representative image of the SDFT at each level. Due to the presence of hair on the limbs there was some variation in the quality of images produced, resulting in the failure to acquire images of sufficient quality at the more distal levels in a small number of cases.

4.2.3.2 Image Storage

A representative image was obtained at each level, sufficient to accurately identify and trace the outer margin of the SDFT. Each level was determined with the aid of a ruler placed against the side of the limb. The examinations were recorded with an SVHS video recorder and cassettes. Each image was frozen for several seconds while the video player continued to record, facilitating later reviewing of the images during the analysis.

4.2.3.3 Image Analysis

The CSA values were determined from the ultrasonographic video images by reviewing the recordings using the pre-installed image analysis software, incorporated into the ultrasound machine. A frozen image was obtained at each level in each limb and the SDFT CSA determined by tracing the outline with the cursor. The tracing was repeated twice more, resulting in three measurements for each level of each limb. All subsequent analysis of CSA measurements involved the mean CSA value calculated for each level of each tendon.

4.3 STATISTICAL METHODS

4.3.1 Descriptive Statistics

The mean CSA values were used to calculate the variation in tendon CSA over the course of the four examinations, using a spreadsheet program[2] to generate graphical representations of the data. Information relating to the frequency of ultrasonographic examinations, cohort signalment and features of SDF tendinitis were also reported graphically.

4.3.2 Odds Ratio

The relationship between injury occurrence and age and gender was determined by calculating odds ratios using appropriate statistical software[3]. For each injury type the ratio of disease to no-disease in the exposed group was compared with the same ratio in the unexposed group. In the assessment of age related injury, those horses greater than seven years old were classified as the exposed group and those less than eight years of age were the unexposed group. In determining the effect of gender, the exposed group included all females, while the unexposed group included all male horses. The odds ratios, 95% confidence intervals and probability values (p - value) were calculated, the latter using the Fisher exact test, due to the low value of some of the cells.

4.3.3 ANOVA, GLM and MRT Calculations

These statistical techniques were applied in the quantification of the variation that occurred in CSA values between left and right limbs and between ultrasonographic examinations. The data sets analysed in this way included the total cohort (96 horses), the group of horses undergoing all four ultrasonographic examinations irrespective of injury status (17 horses) and the group of horses undergoing all four examinations with no clinical or ultrasonographic evidence of tendinitis (11 horses). ANOVA was used for balanced data sets containing even numbers of values and GLMs were used for data with uneven, unbalanced numbers of values. The statistically significant results were investigated further using Newman-Keuls MRT to identify the respective differences between data sets.

ANOVA and GLM statistical techniques were used to determine the effect of individual variables on the results obtained. As a result of inadequate image quality, accurate determination of the SDFT CSA was not possible in a small number of cases, at levels 4 - 5. ANOVA was therefore used to determine the effects of each variable at levels 1 - 3 inclusive, while a GLM technique was applied to levels 4 - 5. The null hypothesis was that there was no significant difference between the data sets, with the significance level set at 5%. MRT was applied to a significant result to determine which means were significantly different.

4.3.4 Multivariable Logistic Regression

The effect of age and gender on the occurrence of each category of tendinitis was determined using a multivariable logistic regression model in proprietary statistical software[4]. The significance of each variable was determined alone and when combined in each model. Odds ratios were calculated for each category.

4.3.5 Two-Sample t-tests

In order to identify any significant change in SDFT CSA prior to the development of acute tendinitis, the mean CSA values obtained from these horses at the examination immediately before that at which the tendinitis was first identified ultrasonographically were obtained. These values were then compared with equivalent measurements from those horses that remained free of any clinical or ultrasonographic evidence of tendinitis during the course of the investigation. As a result of the movement of horses into and out of the yard, only a proportion of horses in the acute injury and no injury groups were included in this analysis. As the acute injury group contained only four horses, a Mann-Whitney analysis of the data was undertaken.

4.4 RESULTS

4.4.1 Descriptive Statistics

A total of 96 horses underwent between one and four ultrasonographic examinations during the period of investigation: one – 24 horses; two – 39 horses; three – 16 horses; four – 17 horses. The total number of horses undergoing an ultrasonographic examination on each occasion also varied slightly: 1^{st} – 55; 2^{nd} – 51; 3^{rd} – 53; 4^{th} – 59.

4.4.1.1 Age Distribution

The age distribution for all individuals examined at each of the four ultrasonographic examinations is shown in Figure 14. The mean and median age of the population was six years (±s.d.1.84), with a range of three to 12 years.

4.4.1.2 Gender Distribution

Gender distribution was determined for each of the four ultrasonographic examinations (Figure 15). Colts and geldings were grouped together for this calculation, as the number of entire males was very small. There were 84 geldings, two colts and ten females. The male to female ratio varied between the four ultrasonographic examinations; 1^{st} – 6.9:1; 2^{nd} – 5.4:1; 3^{rd} – 16.7:1; 4^{th} – 18.7:1; cohort – 8.6:1.

4.4.1.3 Age and Gender Distribution

The combined age and gender distribution of the cohort is shown in Figure 16. The mean age of the females was slightly higher than the males, at 6.3 years and 6 years, respectively.

4.4.1.4 Population SDFT CSA Values

The SDFT mean CSA profile was determined for each of the four ultrasonographic examinations for the left and right limb values combined (Figure 17). The mean values fluctuated between 1.0 - 1.18cm^2 over the four examinations. The variation in mean CSA between examinations was least at level one, increasing to level five. The least variation in mean CSA between levels 1 - 5 occurred at the second examination, with the first examination returning the greatest variation in CSA values between levels.

The SDFT mean CSA values obtained for the population over all four examinations were categorised into 0.1cm^2 divisions and the total number of values falling into each category determined over all ultrasonographic examinations (Figure 18). Almost half (43%) of mean CSA values fell within the range 0.91 - 1.10cm^2, with only 2% of values greater than 1.70cm^2 and none greater than 2.71cm^2 or less than 0.60cm^2.

4.4.1.5 Quantification of Population SDFT CSA Variation

The variation in SDFT mean CSA values obtained for the population over the course of all four examinations was determined, p - values were calculated from ANOVA and GLMs and any differences between values identified (Table 20). At all levels apart from level five, there was no significant difference in the values obtained between left and right limbs at any of the four ultrasonographic examinations. At level five the values obtained for the right limb were consistently larger than those for the left limb at all four examinations.

The difference in CSA values obtained was less clearly defined when the effect of "time" was considered. At levels one and three, there was no significant difference in values obtained over the four examinations. However, at levels two, four and five, there was a statistically significant difference between the CSA values. Those from the first examination were consistently larger than those obtained at the second and fourth examinations, at all three levels. Similarly, the values from the third examination were consistently larger than those obtained at the second and fourth examinations, at all three levels.

Table 20. Probability values and multiple range test results for the effect of "limb" and "time" on the mean forelimb superficial digital flexor tendon cross-sectional area values among a cohort of National Hunt Thoroughbred racehorses in training during 1997-1998, examined ultrasonographically on four occasions.

Level	Variable	P-value	Significance
1	Limb	0.56	NS
	Time	0.76	NS
	Limb/Time	0.07	Borderline
2	Limb	0.91	NS
	Time	**0.0003**	1>2&4, 3>2&4
	Limb/Time	0.06	Borderline
3	Limb	0.68	NS
	Time	0.15	NS
	Limb/Time	0.67	NS
4	Limb	0.73	NS
	Time	**0.0036**	1>2&4, 3>2&4
	Limb/Time	0.32	NS
5	Limb	**0.0121**	R>L
	Time	**0.0002**	1>2&4, 3>2&4
	Limb/Time	0.14	NS

Key: NS = not statistically significant ($P > 0.05$)

BOLD = statistically significant ($P \leq 0.05$)

Column 4: **Limb**: L = left, R = right **Time**: 1 - 4 = 1st - 4th examination

4.4.2 Horses Undergoing All Four Ultrasonographic Examinations

Horses undergoing all four ultrasonographic examinations had a mean age of 6.1 years (median 6 years; ± s.d.2.7; range 4 - 10 years) and all were geldings. The group contained 11 horses with no clinical or ultrasonographic evidence of tendinitis, two with evidence of acute tendinitis and four with chronic tendinitis. Although the SDFT CSA profiles were determined (Figure 19), there was considerable variation in the results obtained due to the inclusion of horses from different injury categories.

4.4.2.1 Variation in SDFT CSA

The effect of the two variables "time" and "limb" on the SDFT mean CSA values was determined. Each of the five levels in each limb were analysed separately (Table 21). There was no significant difference in the mean CSA between left and right limbs at all levels of the tendons. When considering the effect of time, a significant difference was detected in the values obtained over the four examinations at all levels except level three. The values at levels four and five were greater at the third and first ultrasonographic examinations respectively, than at the fourth examination.

When the effect of "limb" and "time" was considered together, at levels one and two there was a significant difference in the values obtained for left and right limbs over the course of the four examinations, although this was of borderline significance. There was no reported difference for levels three to five in terms of the "limb*time" interaction. As the "limb*time" effect was significant at levels one and two, the individual effect of "time" could not be quantified.

Table 21. Analysis of variance, general linear model and multiple range test results for the effect of "limb" and "time" on the superficial digital flexor tendon mean cross-sectional area values of 17 horses examined ultrasonographically.

Level	Variable	P-value	Significance
1	Limb	0.32	NS
	Time	**0.03**	--
	Limb/Time	**0.05**	Borderline
2	Limb	0.17	NS
	Time	**0.03**	--
	Limb/Time	**0.05**	Borderline
3	Limb	0.35	NS
	Time	0.19	NS
	Limb/Time	0.74	NS
4	Limb	0.28	NS
	Time	**0.03**	3>4
	Limb/Time	0.10	NS
5	Limb	0.56	NS
	Time	**0.03**	1>4
	Limb/Time	0.28	NS

Key: NS = not statistically significant ($p > 0.05$)

BOLD = statistically significant ($p \leq 0.05$)

Column 4: **Time**: 1 - 4 = 1st - 4th examination

4.4.3 Horses With No Evidence of SDF Tendinitis

The age distribution of those horses with no evidence of tendinitis during the course of the investigation was determined and is shown together with the total cohort and the three tendinitis categories combined in Figure 20. The category of tendinitis free horses included a total of 55 horses which received between one and four ultrasonographic examinations, 11 of which underwent all four examinations. The age distribution of the 55 horses was found to be significantly different from the three injury groups combined ($p < 0.001$), where, despite the "no injury" group resembling the population distribution over the younger ages, there were no horses in the "no injury" group over eight years of age. The mean CSA profiles for the groups of 55 and 11 horses were determined (Figures 21 and 22, respectively). No significant difference was identified in the values obtained for left and right limbs at each of the five levels of the tendon in either group.

4.4.3.1 Variation in SDFT CSA in Horses Free From Tendinitis

For the group of 11 horses, there was no significant difference between left and right limbs when considering each of the five levels individually (Table 22). There was also no significant difference between CSA measurements obtained over the four examinations at levels one and two. However, at levels three to five, a significant difference was detected, which was further investigated using MRT (See column 4 of Table 22 for relative significant differences between four examinations). No interaction was identified.

Table 22. Analysis of variance, general linear model and multiple range test results for the mean superficial digital flexor tendon cross-sectional area values obtained over four ultrasonographic examinations for 11 Thoroughbred racehorses.

Level	Variable	P-value	Significance
1	Limb	0.77	NS
	Time	0.47	NS
	Limb/Time	0.42	NS
2	Limb	0.9	NS
	Time	0.13	NS
	Limb/Time	0.17	NS
3	Limb	0.38	NS
	Time	**0.01**	1>4
	Limb/Time	0.31	NS
4	Limb	0.2	NS
	Time	**0.000**	1>2,3,4 2>4, 3>4
	Limb/Time	0.35	NS
5	Limb	0.46	NS
	Time	**0.000**	1>4, 2>4, 3>4
	Limb/Time	0.21	NS

Key: NS = not statistically significant ($p > 0.05$)

BOLD = statistically significant ($p \leq 0.05$)

Column 4: **Time**: 1 - 4 = 1st - 4th examination

4.4.4 Horses with Superficial Digital Flexor Tendinitis

4.4.4.1 Age Distributions

The age distribution of horses in each SDF tendinitis category was determined and is shown compared with the uninjured horses and the total cohort (Figure 23). The mean values for cases with acute and chronic tendinitis were 6.68 years (s.d. ± 2.51) and 7.5 years (s.d. ± 1.71), respectively.

The horses with acute tendinitis were more evenly distributed across the age range, compared with the higher proportion of horses in the 4 - 6 year age range in the uninjured group and in the cohort. The effect of age on the occurrence of acute SDF tendinitis was determined. The cases with acute tendinitis were included in the disease group and those with no evidence of tendinitis were in the no disease group. Exposure was defined as those horses greater than seven years old, the no exposure category including those horses younger than eight years of age. The odds ratio and 95% confidence intervals were calculated ($4.10 < OR\ 36.0 < 813.51$), using a Fisher exact test to calculate the corresponding 2-tailed p - value ($p < 0.001$). Horses greater than seven years of age were 36 times more likely to develop acute tendinitis than horses less than eight years old.

4.4.4.2 Gender Distributions

The proportion of males and females in each SDF tendinitis category was calculated (Figure 24). Fifty-two of the 55 horses with no evidence of tendinitis were male. The male to female ratio in the acute tendinitis group was 3:1, considerably lower than in the group with no SDF tendinitis, where the ratio was 18:1. All horses with chronic tendinitis, with or without an acute recurrence were males. The effect of gender on the occurrence of SDF tendinitis, of any type, was determined by calculating odds ratios and 95% confidence intervals ($0.75 < OR\ 3.57 < 18.91$). Exposure to the risk factor was defined as being female, the no exposure group including all male horses. There was a non-statistically significant trend for females to suffer from SDF tendinitis, either acute, chronic or chronic recurrent, more frequently than males ($p = 0.09$).

4.4.4.3 Age and Gender Effect on the Occurrence of SDF Tendinitis

In order to investigate further the effect of age and gender on the occurrence of acute and chronic/chronic recurrent SDF tendinitis, multivariable logistic regression analysis was undertaken (Table 23). For acute and chronic/chronic-recurrent SDF tendinitis, the degree of fit was calculated and plotted against age for each gender (Figures 25 - 26).

Table 23. Multivariable logistic regression analysis of the effect of age and gender on the occurrence of acute and chronic/chronic-recurrent superficial digital flexor tendinitis among a group of Thoroughbred racehorses in training.

ACUTE SDF TENDINITIS		P-value	O.R. (95% C.I.)
Age – univariable		**0.0008**	1.28 < 1.82 < 2.59
Gender – univariable		**0.01**	1.58 < 6.74 < 28.28
Age/Gender – multivariable	Age	**0.001**	1.25 < 1.77 < 2.51
	Gender	**0.023**	1.3 < 6.25 < 30.13

CHRONIC/CHRONIC-RECURRENT SDF TENDINITIS		P-value	O.R. (95% C.I.)
Age – univariable		**0.0001**	1.8 < 3.28 < 5.99
Gender – univariable		0.68	
Age/Gender – multivariable	Age	**0.0001**	1.84 < 3.44 < 6.42
	Gender	0.64	

Key: SDF = superficial digital flexor O.R. = odds ratio

4.4.4.3.1 Acute SDF Tendinitis

For acute SDF tendinitis the effects of age and gender individually and in the combined model were both highly statistically significant. When the values for fit were plotted against age, with gender included in the model, the likelihood of a horse developing acute tendinitis increased with increasing age in both gender categories. At all ages the likelihood of developing acute tendinitis was greater among females compared to males.

4.4.4.3.2 Chronic and Chronic-Recurrent SDF Tendinitis

The effect of age on the occurrence of chronic and chronic-recurrent SDF tendinitis was highly significant alone and when combined with the effect of gender. Gender did not have a significant effect on the occurrence of chronic or chronic-recurrent tendinitis, either alone or in combination with age. The likelihood of a horse developing chronic or chronic-recurrent tendinitis increased with increasing age.

4.4.4.4 Distribution of SDFT Injuries between Limbs

The distribution of each category of SDF tendinitis between limbs is shown in Figure 27. Approximately two thirds of the acute injuries involved either the left or right limb only, with the remaining third having bilateral involvement. Ten of the twelve horses with chronic tendinitis sustained prior to the start of the study were affected bilaterally, the remaining two have unilateral injuries. Of the four horses suffering an acute recurrence of a previous injury, two developed injuries in both limbs, the remaining two involving single limbs.

4.4.4.5 Proportions of SDFT Injuries

The relative proportions of the population within each SDFT injury category were determined (Figure 28). Of the 96 horses involved in the study, 55 (57%) did not show any clinical or ultrasonographic evidence of SDF tendinitis during the period of investigation. Twenty-five of the 96 horses (26%) were found to have ultrasonographic evidence of acute tendinitis in one or both forelimbs during the period of study. Twelve horses (13%) had ultrasonographic evidence of chronic SDF tendinitis in one or both forelimbs, while a further four (4%) showed evidence of having chronic-recurrent tendinitis during the course of the investigation. Of the cases with an initial episode of acute tendinitis, six had ultrasonographic, but no clinical evidence of injury.

4.4.4.6 Acute SDF Tendinitis

The mean SDFT CSA profile was determined at each level for both forelimbs (Figure 29). The SDFT mean CSA values fluctuated between approximately 1.0cm^2 - 1.2cm^2, depending on the level of the tendon and the time of the ultrasonographic examination. The least variation in CSA between different levels of the tendon occurred at the second examination with the greatest recorded at the third examination. The mean CSA profiles for left and right forelimbs over the four examinations were also determined. A Mann-Whitney statistic value of 0.01 suggested a significant difference between limbs, with the right limb having higher values than the left throughout the length of the tendons.

Retrospective analysis of the ultrasonographic images and reports for all cases of acute tendinitis was undertaken. Six of the 25 cases of acute tendinitis were found to have ultrasonographically detectable changes which were considered, at the time of each examination, to be abnormal. The period between the detection of ultrasonographic abnormalities and the development of acute tendinitis varied between four months (the minimum period between examinations) and one year (maximum period of study). The changes included a difference between the left and right forelimb CSA at one or more levels in the tendon and the identification of one or more areas of decreased echogenicity.

4.4.4.7 Chronic SDF Tendinitis

The SDFT mean CSA values for the 16 horses with chronic tendinitis were averaged and the profiles determined at each of the four ultrasonographic examinations (Figure 30). The CSA values fluctuated between approximately 1.1cm^2 - 1.6cm^2. For both left and right limbs the CSA increased from level one to four, decreasing slightly to level five. The p - value of 0.46 calculated using a Mann-Whitney test was consistent with there being no significant difference between the left and right limb CSA values. The least and greatest variation in CSA between levels of the tendon occurred at the second and third ultrasonographic examinations respectively.

4.4.5 Comparison of SDFT CSA Between Uninjured Horses and Those Suffering Acute Tendinitis

Of the 25 horses with acute tendinitis, the 12 identified at the first examination had no prior measurements to use for comparison, thereby excluding them from the analysis. Of the remaining 13, only 4 underwent ultrasonographic examination at the session immediately before the examination at which the injury was first identified. These injuries were all detected at the second ultrasonographic examination. The mean SDFT CSA values obtained for each level of each tendon in these 4 horses were compared to equivalent examination results of the uninjured horses. Twenty-four of the 55 horses in this latter group received an ultrasonographic examination at the first session of imaging. As one of the categories contained less than five values, comparison of group means was undertaken using a Mann-Whitney test. (Table 24). At all levels there was no statistical significance detected between the pre-injury CSA values, compared to the equivalent level and limb of the uninjured horses.

Table 24. Mann-Whitney (MW) analysis of superficial digital flexor tendon mean cross-sectional area values from Thoroughbred racehorses prior to the development of ultrasonographically detectable changes compared to similar measurements from horses within the cohort remaining free of tendinitis during the study period.

Limb	Level	MW P-value	Limb	Level	MW P-value
Left	**1**	0.09	**Right**	**1**	0.31
	2	0.08		**2**	0.58
	3	0.17		**3**	0.49
	4	0.75		**4**	0.88
	5	0.53		**5**	1.00

4.5 DISCUSSION

4.5.1 General

The initial remit of the investigation reported here was to undertake a clinical and ultrasonographic examination of all horses at one NH racing yard on four occasions during a twelve-month period. One of the problems encountered involved the movement of horses to and from the yard during this period resulting in a variable number of horses being included at each examination. Over the course of the investigation only 17 of the 96 horses were examined on four occasions, exemplifying the frequency of movement of NH racehorses within the industry. Unfortunately this problem is inherent in the design of a cohort study where movement into and out of the study group can occur at any time for a variety of reasons.

Despite this movement of horses during the study period the age distribution within the cohort remained similar at each of the four examinations, although the male to female gender ratio increased slightly in the latter half of the study period.

4.5.2 Incidence of SDF Tendinitis

The frequency of occurrence of superficial digital flexor tendinitis has been the subject of investigations worldwide. All previously reported figures compare favourably with the frequency reported in this study of 43% of all horses examined over a one-year period. The much higher values calculated in this study relative to previous reports are the result of several inherent differences. Both Jeffcott and others (1982) and Rossdale and others (1985) investigated the situation among the TB flat racehorse population, where the occurrence of SDF tendinitis is generally perceived to be lower, compared to the NH population under investigation in this report. The definition of a "tendon" in these latter reports was not stated, making it possible that the values included extensor tendon and hindlimb flexor tendon injuries, increasing the difference between the reported values and those obtained here.

This anecdotal difference between flat and NH racehorses was confirmed in the racetrack fatality study reported by McKee (1995), where twice as many hurdlers suffered tendon rupture or severance compared to those racing on the flat. Wilson and others (1993) reported 28% of forelimb injuries were due to tendinitis. The percentage of all injuries would consequently have been lower and closer to those obtained in the UK studies.

4.5.3 Cross-Sectional Area Measurements

The measurement of cross-sectional area is the most objective means of assessing gross changes in the physical appearance of tendons. The assessment of fibre echogenicity and alignment are also used to assess injured tendons, but both are quantified using a much more subjective scale of measurement. The measurement of tendon and lesion cross-sectional area are both fundamental in the assessment of an injured tendon, including comparison with equivalent measurements in the contra-lateral limb. Because of the nature of the subject matter, namely horses in training, the limbs were not clipped, with the resultant ultrasonographic images being of insufficient quality to reliably measure mean echogenicity of the tendons. The images were however, of adequate quality to identify core lesions and the borders of these lesions and the affected tendons.

4.5.3.1 Horses With No SDF Tendinitis

Few reports exist regarding absolute values for cross-sectional area measurements of the normal and abnormal forelimb SDFT. Smith and others (1994) reported a significant difference between horses and ponies but not between TBs and heavy horses in terms of mean cross-sectional area values in normal animals. The mean values obtained in this investigation for the 55 horses with no evidence of tendinitis varied between $0.9cm^2$ and $1.1cm^2$, lower than the values reported by Smith and others (1994) for 15 TBs at all levels in the SDF, although the pattern of change in SDF CSA along the tendon was similar to that reported in this investigation, with a minimum mean CSA around the mid-metacarpal region in both cases. Similar patterns were reported by Gillis and others (1995a) and Gillis and others (1995b) for a group of untrained and trained TB horses, respectively. The similarity between these two groups and the results obtained here suggest that there may be little difference in the CSA pattern along the length of the tendon in trained and untrained horses, although this could be influenced by factors such as intensity of exercise. Comparison of the values obtained between left and right limbs in this investigation failed to identify any significant difference among the unaffected horses, a finding consistent with that reported by Smith and others (1994).

The effect of exercise on the CSA and echogenicity were investigated by Gillis and others (1993) among a group of TBs in training. Although no statistically significant effects were reported, a trend towards a decrease in echogenicity and increase in CSA was identified. Among the group of 11 horses receiving all four examinations in the study reported here, a difference was detected between the values reported at each of the four examinations for levels three to five inclusive. The most consistent findings were the greater values obtained at the first examination relative to the other examinations and the smaller values reported at the final examination relative to earlier examinations. Examinations one and four were undertaken at the same stage of consecutive seasons making it difficult to attribute differences between the values to exercise. It is possible that this difference could in part be due to a change in the SDF CSA with age. Also, in view of the fact that the majority of significantly different values obtained were at levels four and five of the tendon, it is possible that they were due to errors occurring at the time of examination in terms of selection of site on the tendon for image acquisition, rather than due to a change in the actual tendon CSA with exercise. A more frequent examination schedule would have been a more suitable method of determining change in CSA with time, as used by Gillis and others (1993).

4.5.3.2 Horses With Acute SDF Tendinitis

The SDF CSA profile for the 25 horses with acute tendinitis differed from the unaffected horses. The mean values at all five levels were greater and the shape of the profile was much flatter with a less clearly defined pattern. Despite an even number of acute injuries affecting the left and right limbs, the values obtained for the right limb were significantly greater than those for the left limb, although the majority of acute injuries were unilateral. This could be due to the right limb sustaining more severe injuries, with a greater increase in CSA, compared with the left limb. Investigations undertaken in the USA have consistently reported a higher incidence of SDF tendinitis in the left forelimb, relating this to the anti-clockwise direction of racing on dirt tracks (Rooney and Genovese 1981; Wilson and others, 1993; Wilson and others, 1996). No such consistent feature exists on the NH tracks in the UK.

Although the majority of absolute CSA values obtained from all 96 horses, including those with acute and chronic injuries, were between 0.81cm^2 and 1.3cm^2, the values obtained from some of the cases with acute injuries exceeded this. Calculation of the mean CSA for all 25 horses tended to mask the range of values obtained from the acute injuries. However, the values obtained at the first examination were higher than at subsequent examinations as the greatest number of acute injuries were detected at that examination.

4.5.3.3 Horses With Chronic SDF Tendinitis

The SDF CSA profile for the cases with chronic tendinitis differed from both the cases with acute tendinitis and those with no evidence of tendinitis. Instead of the mid-metacarpal region representing the site with the smallest CSA, levels three and four contained the largest mean CSA values representing chronic fibrosis and thickening within the area of injured tendon, in most cases greater than levels one, two and five. The mid-metacarpal region is well recognised as the site most frequently affected by tendinitis, although the proximal and distal extent of lesions shows considerable variation.

4.5.4 Age and Gender Distribution

The majority of NH racehorses in the UK are castrated males, making it more likely, in terms of absolute numbers, that any individual with evidence of tendinitis would be a male. In order to account for this skewed gender distribution, multivariable logistic regression was used to determine the effect of both age and gender on the likelihood of injury. The results demonstrated that both increasing age and being female increased the likelihood of developing an acute injury. Comparison with gender ratios reported in case series is of limited benefit as the ratio among the population from which the cases were drawn is very infrequently reported. However, Rooney and Genovese (1981) found no significant gender effect compared to the population. The difference in risk of sustaining an acute injury between males and females could be related to a difference in management between the genders. The potential breeding career of a mare makes it less of a concern if an acute tendinitis develops, compared to a gelding, which has limited options, if a racing career-ending tendinitis develops. This fundamental difference could result in geldings being "nurtured" more than mares to prolong the racing career of geldings in general. Of the 73 horses with tendon injuries reported by Marr and others (1993a), 75% of mares and only 47% of geldings were retired as a result of the injury, findings which support the hypothesis. Marr and others (1993a) also calculated that 60% of mares and only 29% of geldings that returned to competition suffered a recurrence of tendinitis, although the numbers involved were small.

Acute tendinitis is reported among horses of all ages. The horses in the study reported here with acute tendinitis varied between three and 12 years of age with a mean of 6.7 years. Similarly, Ordidge and others (1998) reported a range of between three and eleven years with a mean of 5.9 years. The increased risk of acute injury with increasing age reported here was implied by the results reported by Dow and others (1996), where only four of 80 acute injuries occurred in horses less than five years of age. Various investigations have focussed on the effect of age on the gross and histologic changes within tendons associated with increasing age. Gillis and others (1995c) found no correlation between age and SDF CSA or echogenicity, although the relationship between these variables and acute tendinitis was not determined in the results reported here. Changes within the structure of tendons with increasing age or the effect of cumulative sub-clinical fibre damage could be contributing factors in the increased incidence of acute tendinitis with increasing age among the horses involved in this study.

Chronic tendinitis is the result of one or more episodes of acute tendinitis over an extended period of time. The increased incidence of chronic tendinitis with increasing age is probably a reflection of this accumulation of injuries throughout the life of the individuals.

4.5.5 Injury Type and Distribution

A marked difference existed between the distribution of acute and chronic injuries between limbs in the results reported here, the acute injuries having an even distribution between left and right limbs, with approximately one third of the injuries having bilateral involvement. Of 73 acute injuries sustained by NH and point-to-point racehorses, defined by Marr and others (1993a) as injuries of less than 12 weeks duration, approximately equal numbers of horses had unilateral and bilateral injuries. In contrast, 75% of the chronic injuries reported in this investigation had bilateral involvement. A proportion of those individuals with bilateral chronic injuries, could have sustained unilateral acute injuries at separate times in each limb prior to the period of study. The individuals would then have presented as chronic bilateral injuries during the study period, rather than actually sustaining a bilateral injury initially *per se.*

Although containing a potentially biased population, the case series reported by Ordidge and others, (1998) included an approximately equal number of acute and chronic injuries. Similarly, Rooney and Genovese (1981) calculated 7% and 6% of horses at one track developed acute and chronic tendon injuries during one season respectively. The study reported here calculated 25% and 16% of horses in training at the yard during a twelve-month period showed evidence of acute and chronic tendinitis respectively.

4.5.6 The Early Detection of Acute SDF Tendinitis

Part of this investigation involved an attempt to identify any changes in SDF CSA prior to the development of acute tendinitis. Due to the movement of horses to and from the yard during the study period, only four of the cases with acute tendinitis had undergone ultrasonographic examination prior to the development of tendinitis and 24 with no evidence of tendinitis were examined on the same occasion. Although the results failed to identify a significant difference between the affected and unaffected animals it is possible that weaknesses in the study design masked any real differences. Clipping of the limbs would have allowed accurate assessment of CSA and echogenicity, which may be a more accurate means of identifying pre-injury changes within the tendons. Also, more frequent examinations might have revealed changes in the tendon prior to breakdown. Gillis and others (1993) used a two-week interval between ultrasonographic examinations, including assessment of both measurement parameters. The subtlety of pre-injury changes may have precluded their identification using relatively long periods between examinations and examining un-clipped limbs.

Despite the lack of statistically significant differences between normal and pre-injury SDFT CSA, a number of cases which, during the period of study developed acute tendinitis, showed ultrasonographic, but not clinical, evidence of changes within the tendon. Although determined subjectively, the examiners interpreted the changes within the tendons to be abnormal at the time of examination, without knowing that those cases would subsequently developed acute tendinitis. No reports of the use of diagnostic ultrasonography in the early detection of tendinitis could be found. Changes within the tendons of TB racehorses in training were detected by Gillis and others (1993) although none of the subjects developed evidence of acute tendinitis during the study period. Abnormal microwave thermographic patterns have also been reported among horses with and without the subsequent development of tendinitis (Marr and others, 1992). It is possible that faults inherent in individual study designs prevent the detection of differences in diagnostic imaging modality results between horses with and without tendinitis. This could account for the subjective findings of pre-injury abnormalities contradicting the objective findings of statistical non-significance.

4.5.7 Limitations of Investigation

The inability to clip the limbs prior to ultrasonographic examination resulted in some difficulty in the examination of the distal sites of measurement. This varied throughout the year but was generally a less significant problem during the summer months. The period of investigation extended from the middle of one racing season to the middle of another (December to December). In order to determine seasonal variations in SDFT CSA it would have been more appropriate to carry out the ultrasonographic examinations from before the start to after the end of a complete season. The use of more frequent examinations would have been useful in identifying cases of acute SDF tendinitis more promptly after their occurrence. The failure to identify any pre-acute injury changes in the SDFT CSA may have been due to the small number of cases that were included in this analysis. This was due in part to the extended period between examinations during which time a number of horses left the yard. More frequent examinations may also have allowed the identification of more subtle changes prior to the occurrence of acute SDF tendinitis.

4.6 CONCLUSIONS

The incidence of forelimb superficial digital flexor tendinitis among TB NH hurdlers and steeplechasers is higher than reported for TB racehorses competing on the flat in countries worldwide. Approximately one quarter of all horses included in this project developed acute tendinitis during the study period, with a further 17% showing evidence of chronic tendinitis, suggesting that once sustained, the injury can be a recurrent or persistent problem throughout the horses' athletic career. The implications of such high numbers of horses affected by this condition, in terms of limiting performance, extended periods of rehabilitation, premature termination of racing careers, limited usage in alternative, less demanding activities and the financial losses incurred, highlight the importance of tendinitis among NH racehorses. Although considerable advances have been made in understanding the complex, multi-factorial aetio-pathogenesis of SDF tendinitis, elucidating the micro-structure of normal and diseased tendons, there has been very little progress in the successful treatment of affected animals, the recurrence rate remaining well in excess of 50% irrespective of the treatment utilised.

The reported finding of an increase in the incidence of acute and chronic tendinitis with increasing age concurs with the theory relating to cumulative degenerative lesions developing over a period of time. However, the increasing incidence among females compared to males was an unexpected finding and warrants further investigation. However, the possibility of either hormonal or managemental differences between genders influencing the occurrence of tendinitis remains unclear.

In view of the high incidence of tendinitis and the paucity of effective and reliable treatment options, the early detection of horses at risk or with sub-clinical degeneration or damage within the superficial digital flexor tendon appears attractive. Although pre-race clinical examinations have been shown to accurately predict subsequent tendon breakdown, the study reported here was unable to correlate ultrasonographic changes with subsequent tendinitis. However, the limited number of cases included in this part of the study and the extended period between each examination could account for these findings. It may be more beneficial if an ultrasonographic examination of the tendons was undertaken in those horses with abnormal clinical parameters immediately prior to racing. The identification of a variety of abnormalities, including large core lesions, in a number of horses in this study with no clinical abnormalities, further complicates the issue of defining significant ultrasonographic changes and correlating them with the occurrence of clinical disease.

The use of biochemical markers of inflammation, measurable in a venous blood sample, has been investigated for a variety of orthopaedic conditions, including articular and tendon disease. In theory, detection of an increase in serum levels of chemical markers released in response to injury of the specific tissue would be a convenient and attractive means of diagnosing injury, detecting early degenerative changes and possibly quantifying the severity of injury. However, in practice, the identification of a suitable marker is complicated and expensive, although such assays may become available in the future.

In conclusion, forelimb SDF tendinitis remains a significant problem among racehorses competing over obstacles, resulting in injuries of varying severity. Although recent research has led to an increased understanding of the condition, treatment still frequently fails. Along with developing more effective treatment methods, resources should also be used to identify methods of detecting sub-clinical injury, thereby providing an opportunity to intervene prior to the occurrence of clinical signs of acute injury.

Key 1 - Ausonics Impact, Dynamic Imaging, Livingston, Scotland, UK.

2 - Microsoft Excel, Microsoft Corporation, Redmond, WA, USA.

3 - Epi Info 6.04a, Brixton Books, New Orleans, LA, U.S.A.

4 - Statistix 4.0, Analytical Software, P.O. Box 12185, Tallahassee, FL, USA

4.7 FIGURES

Figure 12. Ultrasonographic thermal image of an example of a case of acute superficial digital flexor tendinitis, identified during the investigation of the occurrence of tendinitis among a cohort of National Hunt Thoroughbred racehorses in training.

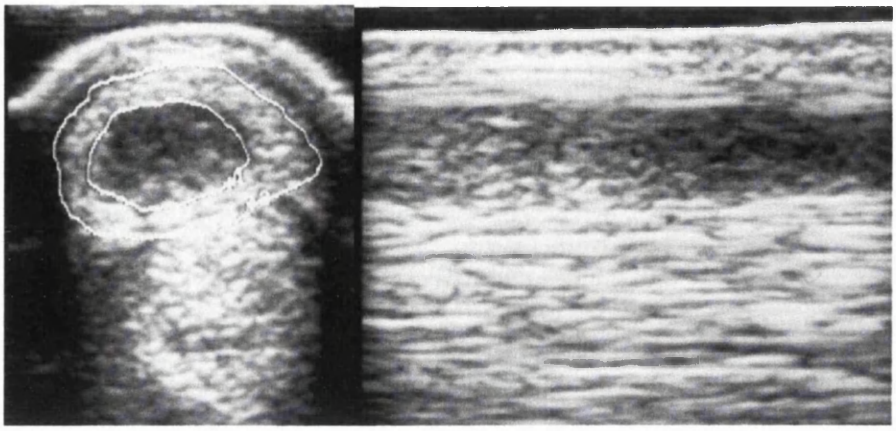


Figure 13. Ultrasonographic thermal image of an example of a case of chronic superficial digital flexor tendinitis, identified during the investigation of the occurrence of tendinitis among a cohort of National Hunt Thoroughbred racehorses in training.

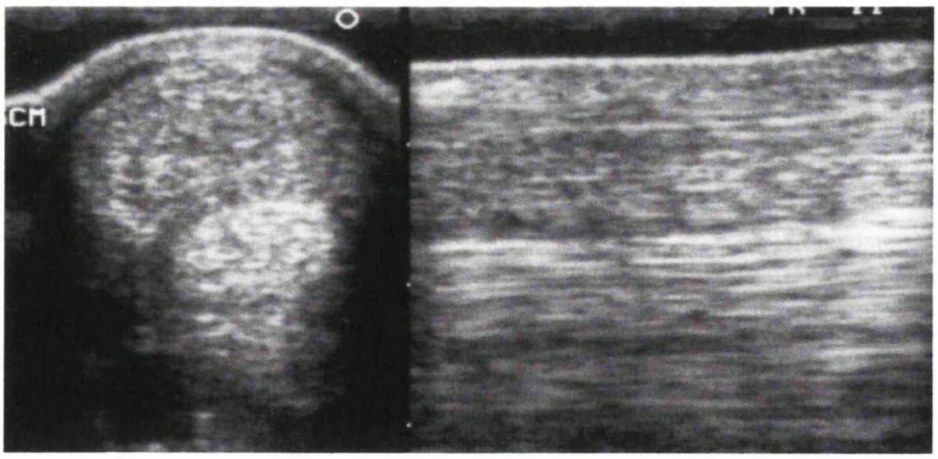


Figure 14. Age distribution of a cohort of Thoroughbred racehorses at each of four ultrasonographic examinations of both forelimb superficial digital flexor tendons.

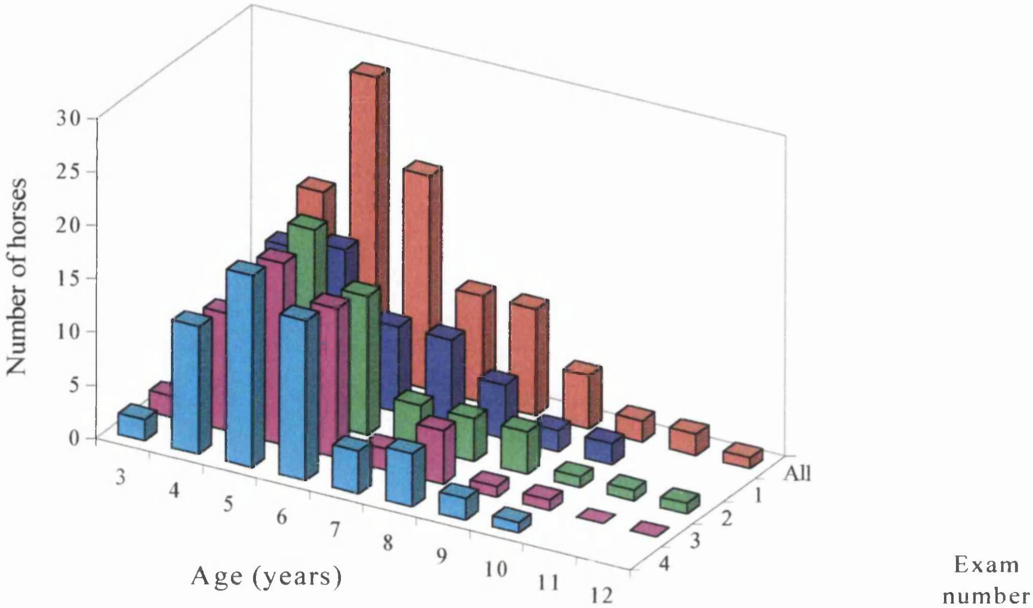


Figure 15. Gender distribution of a cohort of Thoroughbred racehorses at each of four ultrasonographic examinations of the forelimb superficial digital flexor tendons.

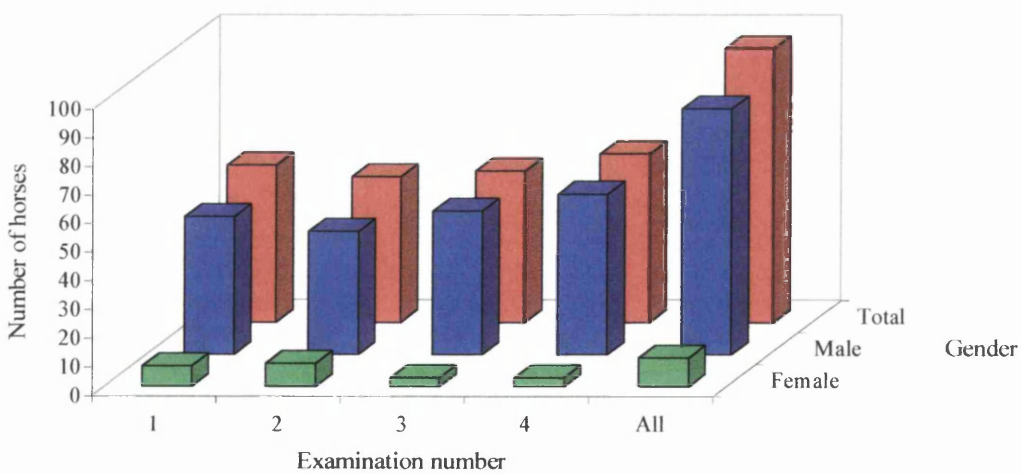


Figure 16. Age and gender distribution of cohort of 96 Thoroughbred racehorses undergoing between one and four ultrasonographic examinations of both forelimb superficial digital flexor tendons.

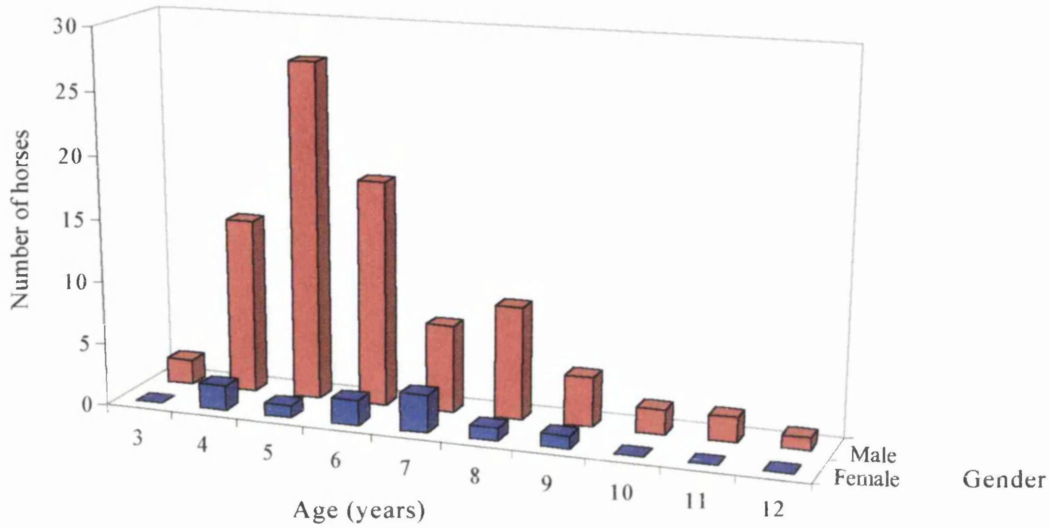


Figure 17. Mean forelimb superficial digital flexor tendon cross-sectional area profile for left and right limbs combined at each of four ultrasonographic examinations of 96 Thoroughbred racehorses.

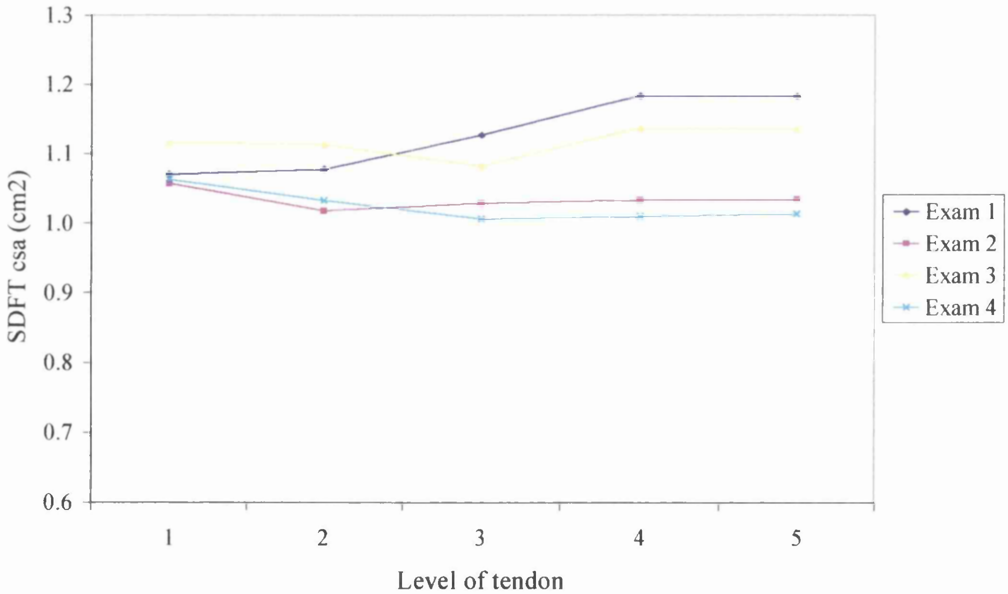


Figure 18. Distribution of mean forelimb superficial digital flexor tendon cross-sectional area values determined during four ultrasonographic examinations of 96 Thoroughbred racehorses.

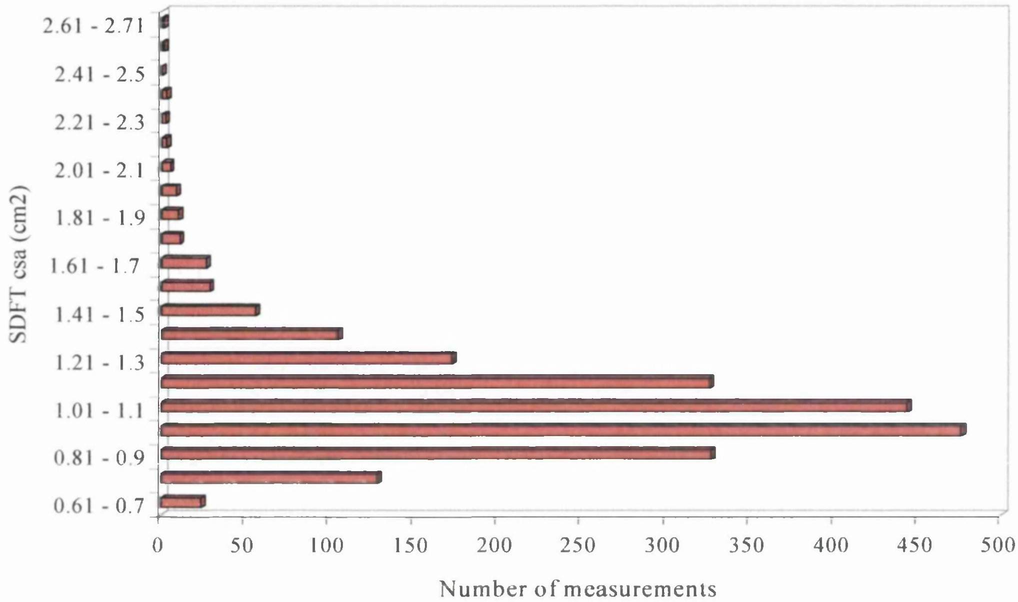


Figure 19. Mean superficial digital flexor tendon cross-sectional area values for both forelimbs of 17 Thoroughbred racehorses, examined ultrasonographically on four occasions.

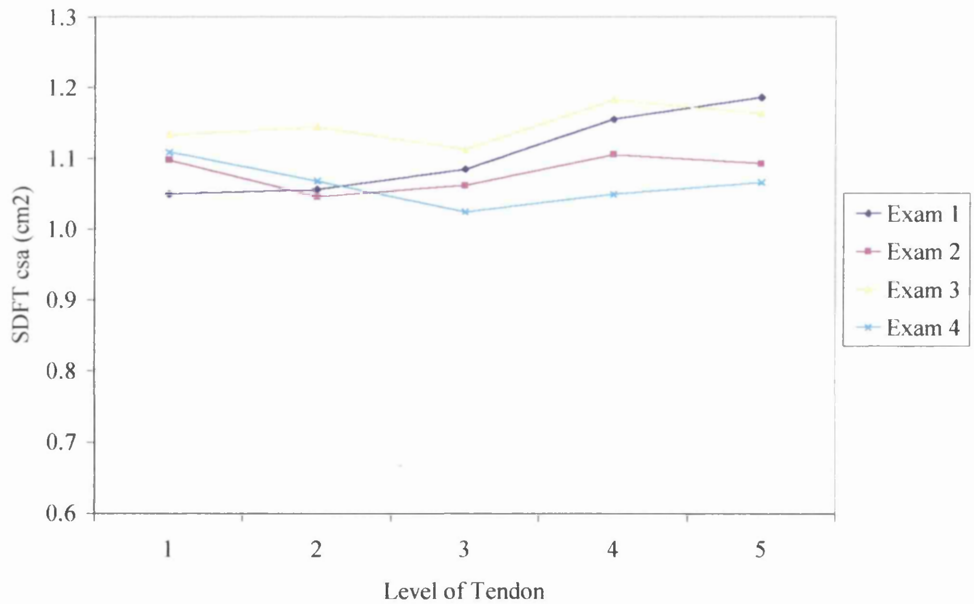


Figure 20. Age distribution of Thoroughbred racehorses with no evidence of forelimb superficial digital flexor tendinitis during a 12-month study period compared with the total cohort of horses and the three injury groups combined.

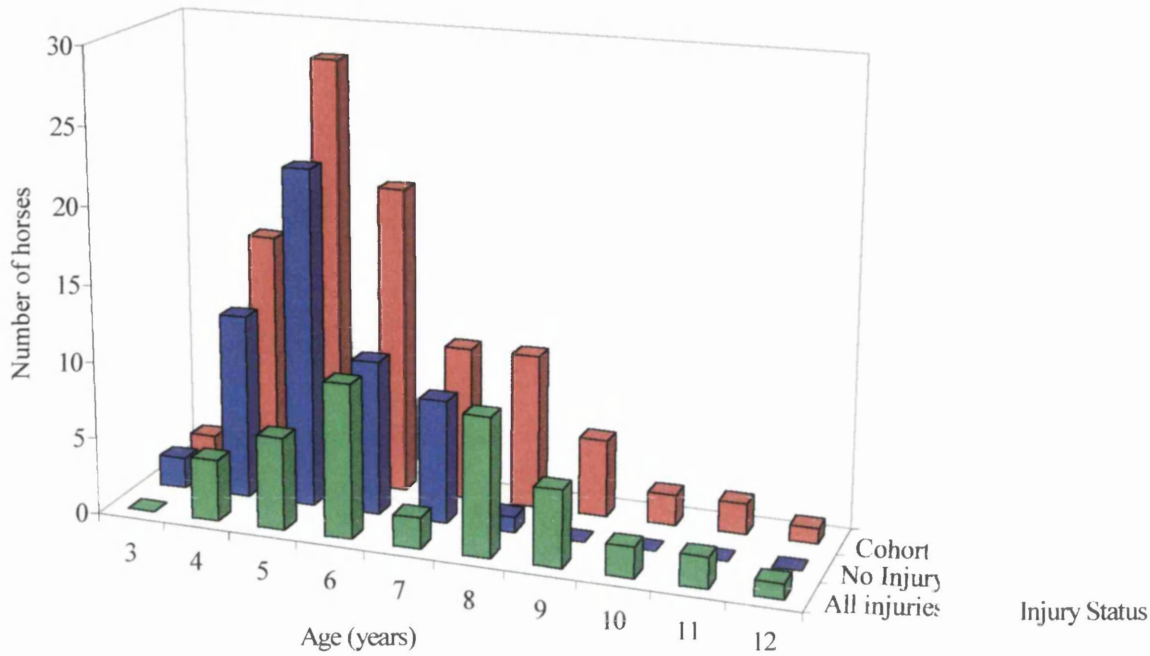


Figure 21. Mean forelimb superficial digital flexor tendon cross-sectional area values of 55 Thoroughbred racehorses with no ultrasonographic evidence of tendinitis examined on upto four occasions.

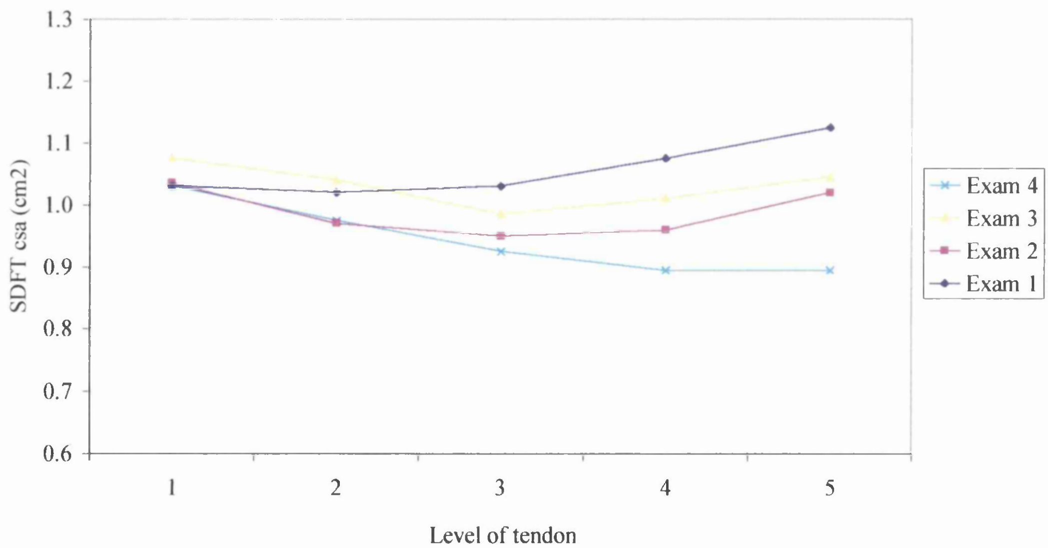


Figure 22. Mean forelimb superficial digital flexor tendon cross-sectional area at each level of 11 Thoroughbred racehorses with no evidence of tendinitis undergoing 4 ultrasonographic examinations.

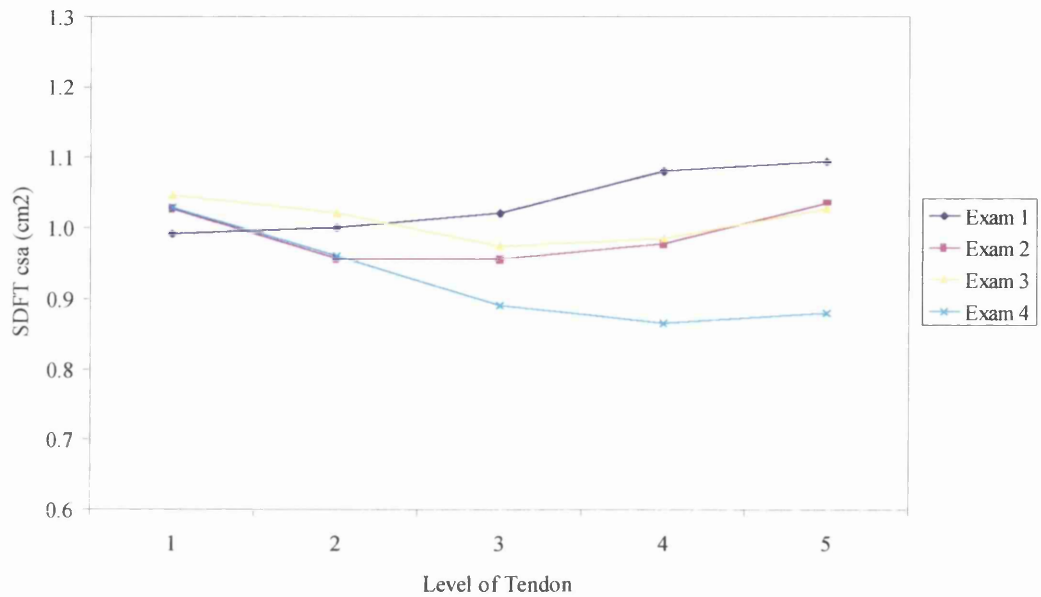


Figure 23. Age distribution of Thoroughbred racehorses with evidence of either acute or chronic uni- or bilateral forelimb superficial digital flexor tendinitis compared to the uninjured horses and the total cohort of 96 horses.

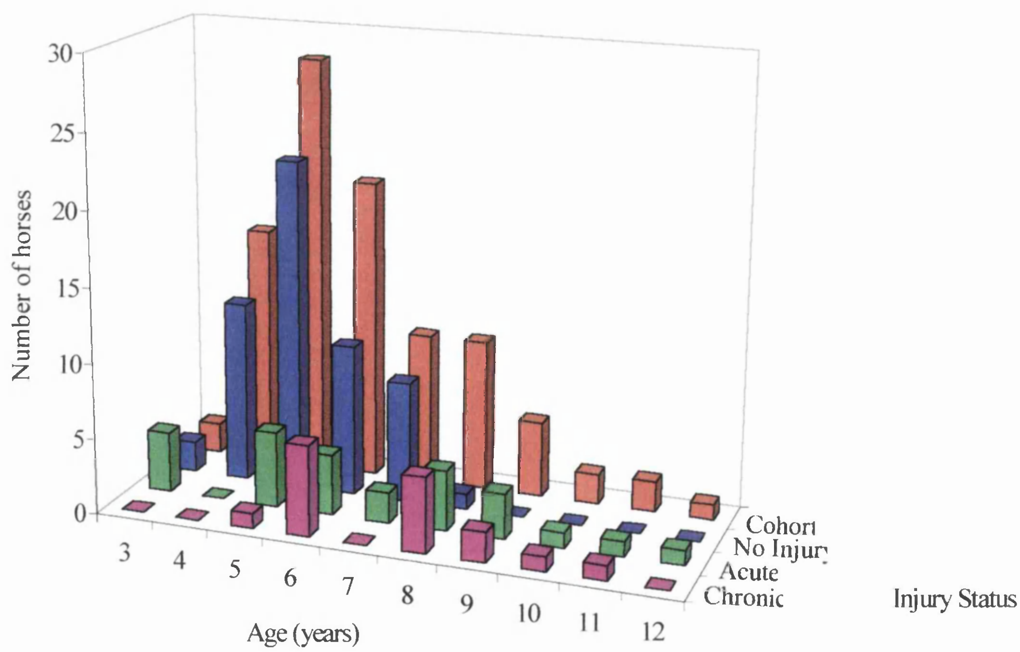


Figure 24. Gender distribution of Thoroughbred racehorses with either uni- or bilateral acute, chronic or chronic recurrent superficial digital flexor tendinitis.

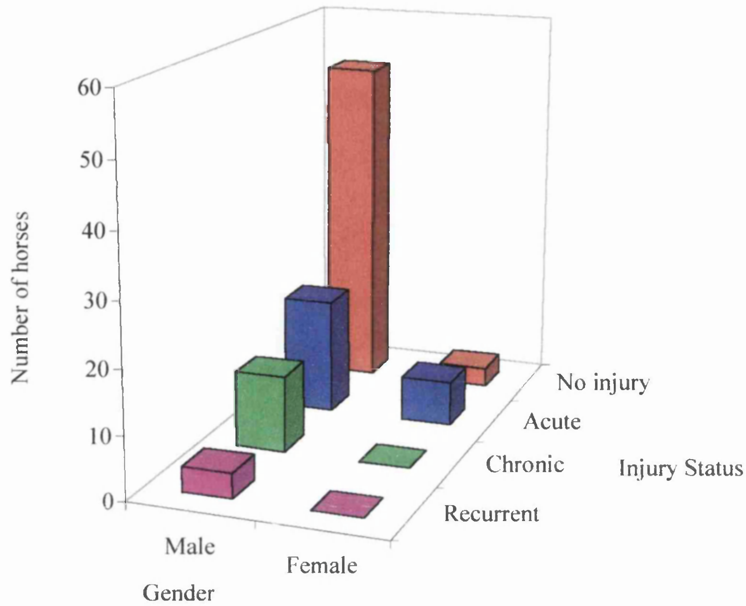


Figure 25. Results from multivariable logistic regression analysis of the effect of age and gender on the occurrence of acute forelimb superficial digital flexor tendinitis, among a group of Thoroughbred racehorses in training.

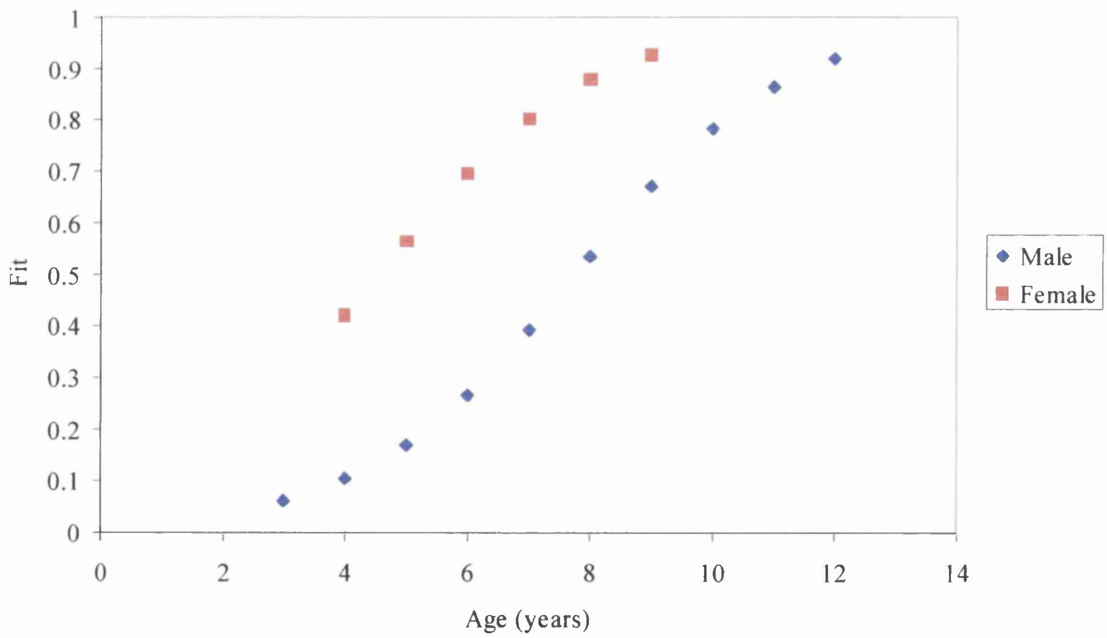


Figure 26. Results of multivariable logistic regression analysis of the effect of age and gender on the occurrence of chronic and chronic, recurrent superficial digital flexor tendinitis among a group of Thoroughbred racehorses in training.

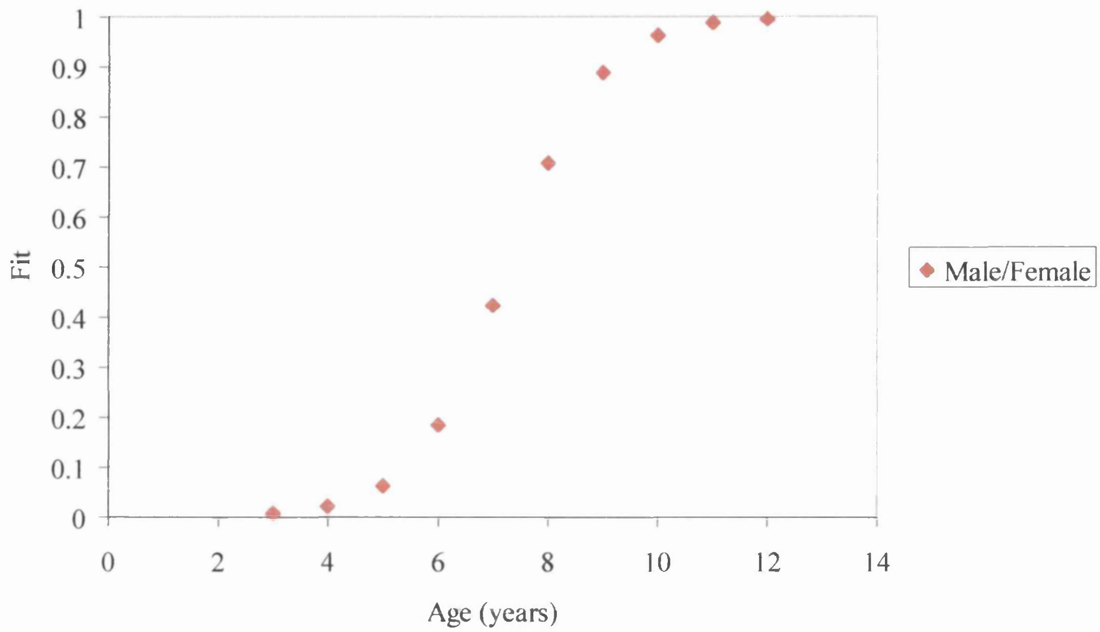


Figure 27. Distribution of forelimb acute, chronic and chronic recurrent superficial digital flexor tendinitis, detected clinically and ultrasonographically in a group of Thoroughbred racehorses in training.

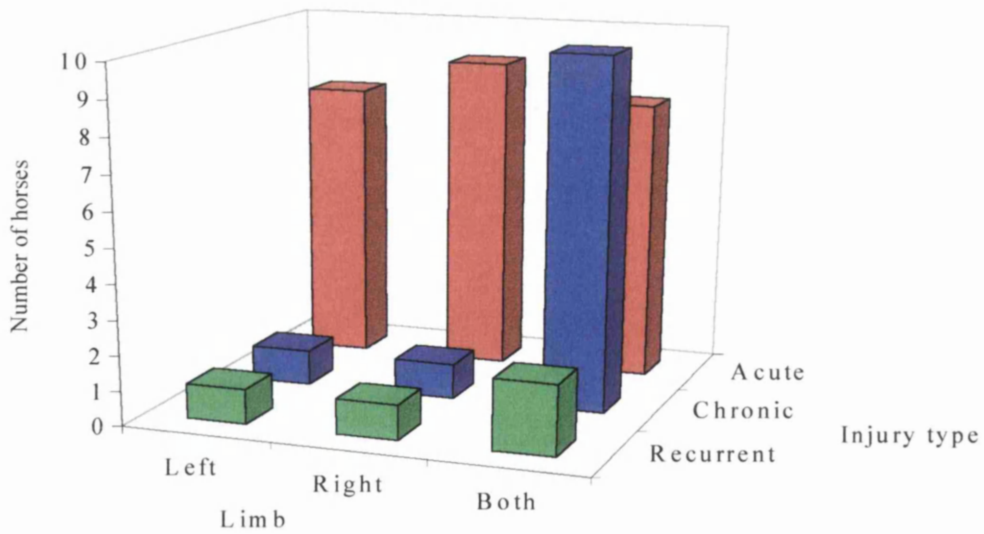


Figure 28. Proportion and percentage of total cohort of Thoroughbred racehorses suffering from either acute, chronic or chronic recurrent forelimb superficial digital flexor tendinitis, compared to those horses free of detectable tendinitis during the 12-month study period.

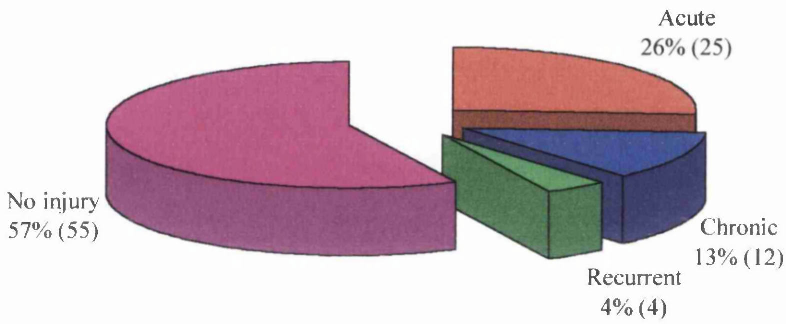


Figure 29. Mean superficial digital flexor tendon cross-sectional area values determined ultrasonographically at each of five levels in both forelimbs of 25 Thoroughbred racehorses with clinical and/or ultrasonographic evidence of acute tendinitis.

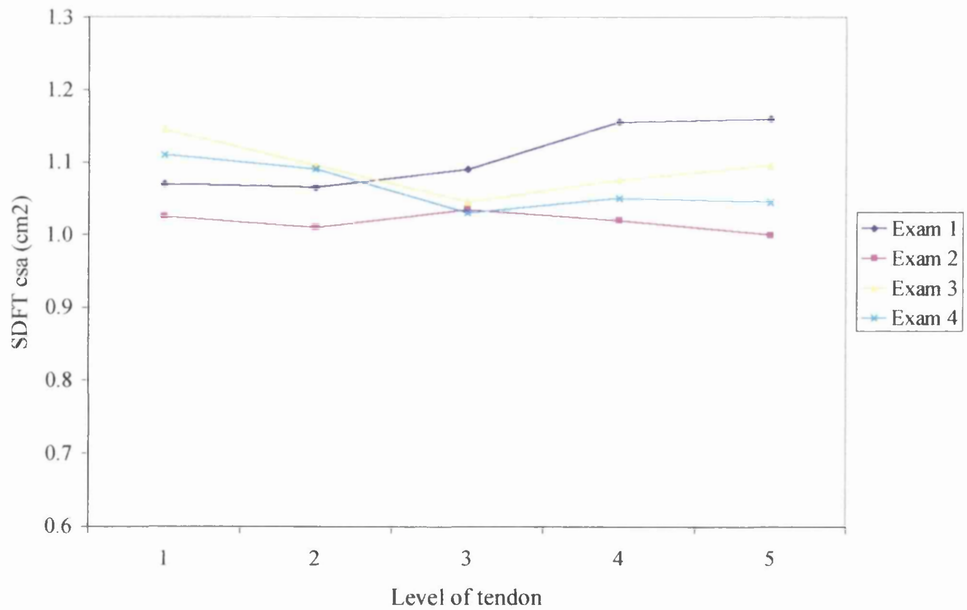
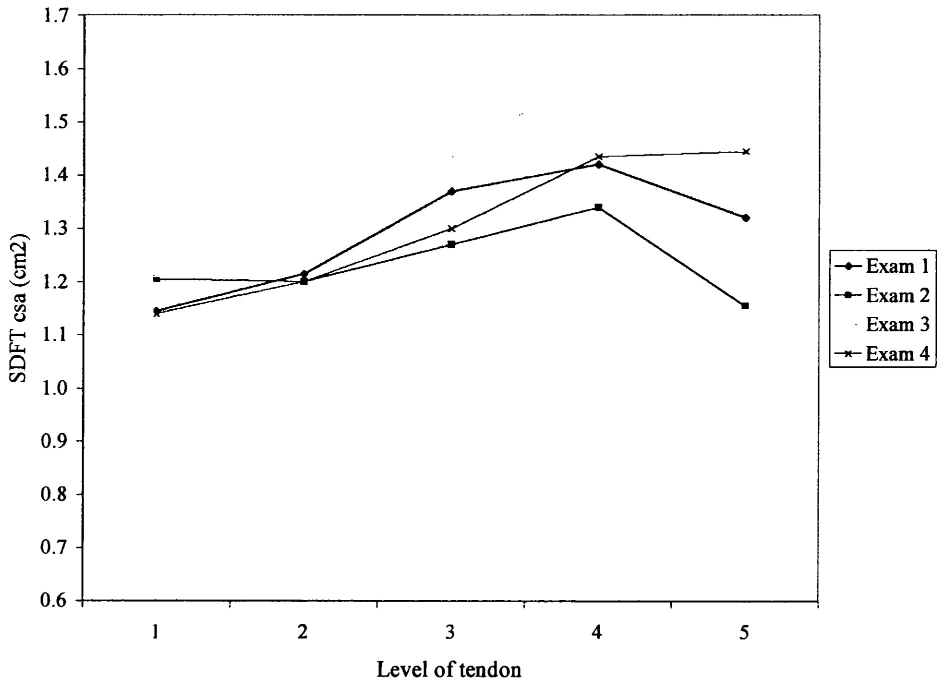


Figure 30. Combined left and right forelimb mean superficial digital flexor tendon cross-sectional area values of 16 Thoroughbred racehorses with clinical and/or ultrasonographic evidence of chronic tendinitis.



CHAPTER V

DESCRIPTIVE EPIDEMIOLOGY OF EQUINE DEVELOPMENTAL ORTHOPAEDIC DISEASE IN THE HUNTER VALLEY

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5.1 INTRODUCTION

As the injuries of racing TBs are multifactorial and may in some cases be related to conformational defects, study of the young animal and its conformation offers an exciting avenue for investigation. In collaboration with the University of Sydney, just such an opportunity arose. The Hunter Valley, situated in the Australian state of New South Wales, is a major equine breeding centre where a large number of world-renowned studs are based. Approximately 3000 TB foals are produced annually, destined for the national and internationals markets (Aldred, 1998). As a consequence of the establishment of a five year research plan developed by the Australian Rural Industries Research and Development Corporation (RIRDC) (RIRDC, 1996), the issue of the impact of DOD on the population and continued production within the Hunter Valley was identified as a cause of considerable concern (RIRDC, 1997). The resulting Industry workshop held in Scone, New South Wales, in March 1997 made several recommendations, the most fundamental of which was that the size of the problem in the Hunter Valley should be quantified as a matter of priority. In order to achieve this goal a number of points of action were identified, including:

1. the collation of available retrospective data from a representative sample of studs' records within the region, in order to estimate the prevalence of DOD over recent years;
2. the implementation of a prospective monitoring system.

The aims of this project were therefore:

1. to define a minimum dataset to be collected from participating studs;
2. to identify;
    a) the studs;
    b) the time period covered by their existing records;
3. to describe the nature of the existing records;
4. to create a database suitable for field entry of records acquired during visits to the studs;
5. to undertake the acquisition of retrospective data from a number of sources including stud and veterinary hospital records;
6. to collate, perform summary analysis and compare annual incidence figures;
7. to consider confidentiality/blinding issues.

5.2 MATERIALS AND METHODS

5.2.1 Case Definition

For the purpose of this investigation the definition of DOD included all cases of angular limb deformity (ALD) that were reported and treated by one of the described methods and all cases of OCD, confirmed using radiography and/or arthroscopy. Cases of ALD that were very mild and therefore either did not get reported or were treated conservatively were unidentifiable and so were excluded.

An ALD was defined as a medio-lateral deviation of either a fore or a hindlimb that did not resolve spontaneously, requiring either surgical intervention and/or remedial farriery, including the use of Dalric extension shoes or those constructed using Equilox polymer. Surgical procedures involved periosteal transection and elevation (PTE) and/or transphyseal bridging (TPB). A diagnosis of OCD was made on the basis of the results of both clinical and radiographic assessment of the affected articulation.

5.2.2 Retrospective Data Collection

5.2.2.1 Stud Records

A total of seven studs located within the vicinity of the Hunter Valley were approached, with the aim of determining both the quality and quantity of retrospective information maintained for each crop of foals, either born on site or arriving at some stage during the first year of life. The larger studs within the region were involved in the study, in the hope of simplifying the collection of retrospective data within a limited time frame. Management personnel at each stud were informed of the purpose of the project and information sought pertaining to methods of record keeping, specific points of information consistently recorded for each foal and accessibility of information.

5.2.2.2 Equine Hospital Records

The case records for all horses and foals undergoing general anaesthesia at the major equine referral hospital were obtained and summarised for the period 1988 to 1996. The information was retrieved from the anaesthetic record book that was completed for every general anaesthetic carried out at the hospital. The annual total number of anaesthetics performed, irrespective of procedure, was calculated for the period. The number of animals undergoing PTE, TPB and arthrotomy or arthroscopy was also determined. All arthroscopic procedures and arthrotomies, except those undertaken for the purpose of joint irrigation, assessment of articular fractures or as an adjunct to assessment of a joint following a traumatic incident, were included in the calculation. Foals undergoing more than one procedure for the treatment of an ALD, either simultaneously or on separate occasions, were counted for each procedure, unless it was a repetition of the same procedure.

5.2.3 Prospective Data Collection

The feasibility of initiating a standardised reporting and recording system, allowing an accurate calculation of the incidence of developmental orthopaedic conditions, was investigated. Standard forms were designed (Appendices I - IV) following discussion between veterinary surgeons and stud managers and distributed to each stud prior to the official start of the stud season (1st August 1997). For each diagnosed case of DOD a separate form was to be completed, including those animals suffering from either an ALD or appendicular skeletal system OCD. The studs were coded to maintain anonymity.

5.2.4 Statistical Methods

Data were summarised using methods appropriate for the information available and the hypotheses being tested. Case frequencies in 1995 and 1996 on respective studs were compared using a Pearson Chi-square or Fishers Exact Test, as appropriate. Linear trends of DOD occurrence over time at Stud 1 and procedures undertaken at the hospital were analysed by linear regression techniques. Fishers Exact Test and linear regression were applied to prospective data, as appropriate. In all cases, significance was set at the 5 per cent level.

5.3 RESULTS

5.3.1 Retrospective Data

5.3.1.1 Stud Records

Data for the 1995 and 1996 season were accessible at four of the seven studs, and for the 1996 season only at one stud. Of the remaining two studs, one maintained a basic recording system on cards, which did not allow rapid or straightforward collation of information. The information relating specifically to cases of DOD was also limited. The other stud had completed one season at the present site, again using a paper filing system with limited recording of disease occurrence. The size of the foal crop and numbers of cases are displayed in Table 25.

Table 25. Size of foal crop and numbers of foals diagnosed with either osteochondrosis diseccans (OCD) or angular limb deformity (ALD) and the treatment regimen employed for the years 1995 - 1996 at five stud farms in the Hunter Valley, Australia.

Stud	Foal crop		OCD		ALD classified by treatment						Total ALD	
					PTE		Dalric shoe		Equilox			
	95	96	95	96	95	96	95	96	95	96	95	96
1	341	313	18	12	25	27	43	30	87	1*	155	58*
2	180	110	2	0	6	2	0	0	0	2	6	3
3	284	253	8	7	23	22	53	58	0	0	76	80
4	160	160	9	9	28	28	6	6	6	6	40	40
5	25	25	--	0	--	0	--	3	--	3	--	6

Key: PTE - Periosteal Transection and Elevation
*Figure significantly different from previous year

The occurrence of each DOD was expressed as a percentage of the foal crop for each stud for the years 1995 and 1996 (Table 26). The relative frequency of different treatments employed in the management of ALD was also calculated. Evidence from the five studs for the 1995 and 1996 seasons indicated that the incidence of OCD was lower than that of ALDs with the incidence of OCD in 1995 and 1996, 3.8% and 3.3%, respectively and that of ALDs, 28.7% and 21.7%, respectively. The overall incidence of DODs at the 5 studs in 1995 and 1996 was 32.5% and 25.0%, respectively. Considering the studs individually, there were no significant differences in diagnosis and/or treatment rates between the two years with one exception, where a policy change greatly reduced the use of Equilox in the treatment of ALDs.

Table 26. Percentage of foal crop diagnosed with either osteochondrosis diseccans (OCD) or angular limb deformity (ALD) and the treatment regimen employed for the years 1995-1996 at five stud farms in the Hunter Valley, Australia.

Stud	OCD		ALD classified by treatment						Total ALD	
			PTE		Dalric shoe		Equilox			
	95	96	95	96	95	96	95	96	95	96
1	5.3	3.8	7.3	8.6	12.6	9.9	25.5	0*	45.4	18.5*
2	1.1	0	3.3	1.8	0	0	0	0.9	3.3	2.7
3	3	3	8.1	8.7	18.7	22.9	0	0	26.8	31.6
4	6	6	17.5	17.5	3.75	3.75	3.75	3.75	25	25
5	--	0	--	0	--	12	--	12	--	24
Total	3.8	3.3	8.5	9.2	10.6	11.3	9.6	1.4	28.7	21.7

Key: PTE - Periosteal Transection and Elevation
*Figure significantly different from previous year

The incidence of OCD in 1995 varied between 1.1% and 6.0% of the foal crop with a similar range of between 0% and 6% the following year.

The incidence of ALD showed a larger variation between studs, varying from 3.3% to 45.4% in 1995 and 2.7% to 31.6% in 1996. The different treatment methods varied between studs, based mainly on the personal preferences of those involved at each facility. This resulted in some procedures being performed more frequently at some studs and not at all at others.

Stud 1 also provided information pertaining to the incidence of OCD and CVM for the period 1990 to 1996, inclusive. The total number of cases of each condition in relation to the size of each foal crop was calculated (Figures 31 and 32). These values were also expressed as a percentage of the annual foal crop (Figure 33).

The incidence of both conditions affected a relatively small proportion of the foal crop during the seven-year period. However, unlike the frequency of CVM, which remained relatively constant, the incidence of OCD appeared to show a steady increase during the period of study. Regression analysis suggested that the trend in OCD was significant ($p = 0.02$) and the trend in CVM was not significant ($p = 0.73$).

5.3.1.2 Hospital Records

The total number of general anaesthetics performed annually at the hospital over a nine year period, along with the number of foals/weanlings anaesthetised to allow PTE, TPB or arthroscopy/tomy were recorded (Figure 34). The total number of anaesthetics was lowest in 1988 and, after a rise of over 50% of the 1988 figure in 1989, the number fluctuated between 227 and 272 over the following five years. Subsequent to this, the figure rose to 356 during 1996.

The number of foals undergoing at least one surgery for PTE was 70 in 1988, increasing slightly over the following five years, before dropping in 1994 and increasing again over the following two years to a frequency slightly greater than pre-1994. The number of cases per annum undergoing surgery for TPB fluctuated around a mean of 12, but remained at a low level. The number undergoing arthroscopy/tomy was also consistently lower than those undergoing PTE, showing a gradual increase over the period of study.

The percentage of each of the procedures, expressed as a percentage of the total number of anaesthetics performed during the period of study was also calculated (Figure 35). The sum of the three procedures was also determined and termed "Total DOD Sx". The procedures used to treat ALDs (PTE + TPB) were termed "Total ALD Sx".

The overall percentage of anaesthetics performed for foals undergoing PTE dropped slightly over the nine-year period, although peaks in 1993 and again in 1995 matched 1988 levels. This trend was not significant ($p = 0.37$). As the majority of anaesthetics were performed for this reason, the combined percentage for the three procedures (Total DOD Sx) mirrored these results. Between 33% and 47% (mean 39.4, ± s.d. 4.5) of general anaesthetics performed at the hospital during the period of study, were to allow the surgical treatment of either an ALD or OCD lesion.

During the first two years the percentage of cases undergoing TPB averaged 7.7% of the total anaesthetics. Over the remainder of the study period this figure remained below 3.5% and the trend was not significant ($p = 0.1$). Furthermore, the trend in the percentage of procedures undertaken for ALD surgery (Total ALD Sx), that is the sum of TPB and PTE but excluding arthroscopy/otomies, was also not significant ($p = 0.16$).

A gradual but significant increase ($p = 0.01$) in the percentage of anaesthetics undertaken for the purpose of treating and/or diagnosing OCD lesions was recorded, as reflected by the arthroscopy/otomy figures, surpassing the proportion attributable to TPB procedures in the latter half of the period.

5.3.2 Prospective Data

By 1st June 1998, 18 completed forms were returned for cases of ALD and three for OCD lesions. The source of each completed form was unknown. Descriptive statistics were determined for the ALD cases only, as the very low number of completed OCD forms returned made meaningful interpretation of results difficult. Although only a relatively small number of completed ALD forms were returned (18), the findings were presented in tabular (Table 27) and graphical formats (Figures 36 and 37). The descriptive statistics are discussed later, but the possibilities for statistical testing were limited given the lack of denominator data and the small numbers. Although there was a trend for foals born early to have a DOD diagnosed at birth when compared to those born late, this was not statistically significant (Fishers Exact Test, $p = 0.34$). However, there was a significant association between date of birth relative to expected date and the age of the dam, with older mares less likely to have early foals ($p = 0.03$).

Table 27. Summary data and statistics for 18 cases of angular limb deformities among Thoroughbred foals born in the Hunter Valley, Australia during 1997-1998.

Animal characteristics				
Dam age (years)	Mean 9.4	± s.d. 4.1	Median 9	Range 4-17
Dam Status	Wet 14	Dry 2	Maiden 2	
Gender	Colt 9	Filly 9		
DOB (days)	Range –12 to +14 (see figures 36 and 37)			
Disease characteristics				
ALD at birth (foals)	12/18			
Birth - ALD (days)	Mean 7	± s.d. 11	Median 0	
Birth - treatment (days)	Mean 17	± s.d. 11	Median 18	
Diagnosis - treatment (days)	Mean 10	± s.d. 12	Median 5	
Treatment - straight (days)	Mean 42	± s.d. 23	Median 44	Range 1-74
Anatomical details				
No. of joints (jt) involved	Total	26	8 - two jt	10 - one jt
Distribution (jt)	L carpus	11	Valgus 11	Varus 0
	R carpus	11	Valgus 10	Varus 1
	LF fetlock	1	Valgus 1	Varus 0
	RF fetlock	2	Valgus 2	Varus 0
	LH fetlock	1	Valgus 0	Varus 1
	RH fetlock	1	Valgus 0	Varus 1
Treatment (Tx) details				
Tx (foals)	Trimmed	9	Alone 0	Other Tx 9
	Equilox	2	Alone 0	Other Tx 2
	Dalric shoe	3	Alone 0	Other Tx 3
	PTE	16	Alone 5	Other Tx 11
	TPB	0	Alone 0	Other Tx 0
	Limb cast	1	Alone 1	Other Tx 0
Stall rest (days)	Mean 15		± s.d. 18	Median 5

Key: DOB = Actual date of birth (relative to predicted date)

ALD = Angular limb deformity L/R = Left/Right

LF = left fore RF = right fore

LH = left hind RH = right hind

PTE = periosteal transection and elevation TPB = transphyseal bridging

* dam status: wet = foaled previous year dry = no foal previous year

5.4 DISCUSSION

5.4.1 Retrospective Data

5.4.1.1 Stud Records

Of the seven studs approached, four were able to provide figures considered reliable for the diagnosis and/or treatment of DOD for the previous two seasons, and one could only provide this information for 1996. Due to the short time frame available for collation of retrospective data, the remaining two studs were unable to provide any figures.

It must be regarded as a reason for concern that the incidence in 1995 and 1996 of 32.5% and 25.0%, respectively, for the DODs investigated and, in particular the 28.7% and 21.7% attributed to the ALDs, was so high. From the information obtained, the incidence of ALDs appeared to be higher than for OCD, although the overall incidence and the individual incidence at each stud were similar in 1995 and 1996. The exception to this was at Stud 1 where the total ALDs treated in 1996 were significantly less than total ALDs treated in 1995. Although a policy change reduced the use of Equilox in the treatment of ALDs, there was no equivalent increase in the frequency of use of other treatment modalities between 1995 and 1996. It is possible that a change in management practice at the stud reduced the number of mildly affected foals treated with Equilox, the deformities correcting without intervention. This could create quite a marked reduction in the frequency of reported ALDs, as seen between consecutive years.

The percentage of foals diagnosed with OCD of all types involved a relatively small number of foals, making inter-stud comparisons difficult and of questionable value. The reasons for the relatively low incidence of OCD could be a reflection of the varied clinical presentation of the condition in its various forms (Jeffcott and others, 1993). Different management systems result in differences between the time spent by foals on the studs, with some residing for up to 18 months, whereas some foals may reside at the stud for a short period, or they may not actually arrive until some time after birth. As the stud records were the only source of information for the diagnosis of DODs, those studs where foals remain for longer periods are more likely to have a higher number of foals diagnosed. Stud 1 had a unique management system in the region due to close links with a race-training centre, which resulted in many foals remaining at the stud for longer than normal. From a commercial perspective, if a stud has a financial interest in the foal beyond its departure, then it is conceivable that conditions affecting the growing foal might be investigated at an earlier stage, e.g. the presence of a tibio-tarsal joint effusion in the absence of lameness, a typical presentation of OCD involving that joint (Laws and others, 1993). This could result in an increase in the frequency of diagnosis if more animals are investigated.

The time of surgical intervention for ALD is also a contentious issue (Fretz and others, 1978; Auer, 1989) and differences in percentage of foals treated is not necessarily a reflection of the true incidence. Some foals are treated immediately upon recognition of a limb deviation, whereas others may be treated conservatively for a period of time. Of this latter group, a proportion might be expected to respond without the need for further treatment. Alternatively, a proportion of those treated surgically at an earlier stage may have responded to conservative treatment. Also, the location of the deformity and the age of the animal at time of recognition will influence the decision of how and when to treat (Fretz and Donecker, 1983).

The extended records obtained from Stud 1 for the period 1990-1996 showed a trend in the recorded incidence of OCD. Although the total number of cases of OCD diagnosed increased over time, the size of the foal crop also increased. OCD expressed as a percentage of the foal crop, indicated an increase in the incidence of OCD. This apparent increase in number of diagnosed cases may be a reflection of a genuine increase, but it could also be a result of confounding influences. Within the Industry there has been an increase in the awareness of DODs over recent years (American Quarter Horse Association, 1986). This heightened awareness could have resulted in an increase in the attention paid to foals with respect to the signs associated with sub-clinical OCD. With more foals undergoing radiographic or arthroscopic evaluation, a rise in the frequency of diagnosis is quite likely. However, this finding was also reflected in hospital records obtained from the main equine referral centre, which also show a significant increase in the proportion of animals undergoing arthroscopy or arthrotomy for assessment or treatment of OCD.

The incidence of CVM, considered by some to be a manifestation of OC involving the axial skeleton (Jeffcott and others, 1993), did not show any significant increase over the seven-year period, remaining at low levels, with small fluctuations from year to year, making it difficult to draw any meaningful conclusions.

5.4.1.2 Hospital Records

The hospital anaesthetic record was a useful source of information for the estimation of frequency of surgical intervention for DODs. The hospital serviced the majority of the larger studs in the region and had a high surgical caseload. However, the figures reported are not necessarily the absolute frequencies of DODs for a number of reasons. Not all PTE were undertaken at the hospital; some would be undertaken at the stud by resident veterinary surgeons or by others unconnected with the hospital. Although most ALDs occur in animals less than one year old (Auer, 1990; Wagner and Watrous, 1990), some are diagnosed in older animals. Conversely, many cases of OCD are not recognised clinically during the first year of life. Given these facts, it is likely that a number of animals will leave the area prior to the development of any clinical signs and would consequently not be recorded on the hospital records.

The results do allow a comparison of the annual frequencies of each procedure over the nine-year period. Even so, changes in frequency of procedure over time should be interpreted with caution, as changes in the "vogue" methods of treatment of ALDs could result in an apparent increase or decrease in popularity of one procedure in favour of another (Auer, 1989). By calculating the combined percentage of the two surgical procedures, the effect of this confounding influence should be reduced, as irrespective of changes in the relative frequency each procedure is undertaken, as one increases the other will decrease proportionately. However, in the case of Stud 1, a decrease in the frequency of application of one procedure was not matched by an increase in the use of another, possibly resulting from fewer mildly affected foals receiving treatment.

Despite a slight overall increase in the surgical caseload, the percentage of general anaesthetics performed for the treatment of ALDs showed a slight decrease. This may be a reflection of a genuine decrease in the incidence of ALDs, or it could be a result of an increase in delay in opting for surgical intervention, or an increase in the frequency of undertaking PTEs at the stud, rather than referring them to the hospital.

In the case of OCD, the reported finding of an increase in arthroscopic procedures or arthrotomies concurs with the apparent increase in incidence determined from the retrospective stud data. Again, this increase could be a reflection of changes in the trends of treating OCD, with earlier surgical intervention resulting in an artificial rise in the apparent incidence of the condition.

5.4.2 Prospective Data

Although the forms were distributed at the start of the foaling season the return rate for completed forms was much lower than expected. As the source of each returned form was unknown, the diligence of each stud with regard to completion of forms remains unknown. However, the data collected for the cases of ALDs highlighted several points of interest.

Firstly, ALDs were reported in mares over a wide age range, which is probably a reflection of the age distribution of the study population, suggesting that the incidence of ALD occurrence is not influenced by the age of the dam. Secondly, the gender of affected foals showed an even distribution, as in previously reported studies (Fretz and Donecker, 1983). However, without denominator data from the mare population and foal crop in general it is not possible to comment on the significance of these findings.

Two thirds of the foals with ALDs were diagnosed at birth. Two thirds of the affected foals were born prematurely, 75% of which had a deformity at birth. However this was not a statistically significant finding. Auer (1990) proposed that foals born prematurely were more likely to suffer ALDs due to incomplete maturation of the long bones and joints. In the group of foals born later than expected there was an even distribution between foals born with deformities and those developing them at a later date.

Only five of the 18 foals were treated by one or more of the previously described methods, within the first week of life. This finding concurs with the generally accepted belief that many foals that are born with some degree of deformity warrant the use of conservative methods of treatment prior to more radical interventions (Auer, 1990). This is reflected in the mean time of ten days between diagnosis of the ALD and the initiation of treatment.

Multiple deformities affecting the same animal are not uncommon. Fretz and others (1978) reported 51% of foals suffering from ALDs had involvement of more than one articulation. In the study reported here, eight of the 18 cases reported had two joints affected. Carpal valgus deformities were by far the most frequently reported, with left and right limbs affected in approximately equal numbers. The average time between diagnosis and initiation of treatment did not vary with the location of the deformity; both carpal and fetlock deformities had a mean interval of 10 days. This is surprising in relation to the recognised differential in length of period of maximum growth between the epiphyseal regions associated with the respective articulations (Fretz and others, 1978).

All forms of foot care, whether involving trimming or the application of a prosthesis, were undertaken in combination with another form of therapy. PTE was the most frequently undertaken procedure, usually in combination with foot care. TPB was not reported as a method used to treat any of the foals in the 1997/1998 season. The high number of foals receiving surgical intervention may be a genuine trend in the preferred forms of treatment of ALD, but it could be a reflection of a reporting bias, where the studs are more likely to complete a report form for a foal with a more severe deformity requiring intervention rather than one that corrected with exercise restriction alone.

5.4.3 Limitations of Investigation

Collection of retrospective data is always dependent on the quality of previous data recording and method of storage, with gaps in data sets frequently complicating data analysis, often with no means of completing the blanks. Although one stud provided access to a large retrospective database, some of the data was stored in paper format, while more recent files were stored on a computer database. The remainder of the studs stored the vast majority of retrospective data in paper format. This along with inevitable differences in the quality and nature of the information recorded, resulted in practical time limitations for data retrieval from the vast paper files.

The dependency on lay staff to accurately and consistently record the diagnosis and treatment of DODs among the foal crop and complete the forms provided again lead to an incomplete data set, particularly for the OCD cases. For such a prospective investigation to be more successful and allow the reliable collection of data, with consistency between different studs would require a member of the research project to make regular visits to each stud to ensure all cases are recorded.

Although, a DOD was defined in this project, the identification of cases, particularly among the retrospective data would be subject to criteria used by individual studs. This could result in mild cases being un-reported unless they receive corrective farriery and/or surgical treatment, thereby under-diagnosing the conditions. The financial implications to a stud that is found to have a high incidence of DODs, in terms of the effect on its reputation, is also an area of concern when agreeing to be involved in such a project.

5.5 CONCLUSIONS

Despite the project being undertaken within a limited time frame the acquisition of retrospective data from a number of sources was possible, leading to a number of interesting findings. A pilot study to determine the feasibility of a larger scale prospective study of DOD was also initiated. This project aimed to quantify the annual incidence of DODs and also identify and monitor any trends in the incidence of individual DODs.

In general, the studs surveyed utilised good quality computer recording systems to maintain records of individual animals during their stay at the facility. Some of the studs had only recently upgraded the system from paper to electronic format, prior records available for assessment but requiring considerable time to examine. The studs still using paper-based files were aware of the benefits of computerised systems and will probably upgrade in the near future. Other than ease of access of data, the nature of the filing system had little bearing on the information recorded.

The computer system most frequently used was a commercially available program, designed specifically for accounting and record keeping on stud farms[1]. The program is a Windows 95 based system with considerable scope and flexibility in terms of the type and nature of information stored. In a larger scale project this system could be used as the primary information storage facility, although for data analysis the information would be required to be transferred to other compatible programs[2,3]. Utilisation of these systems would benefit stud management and researchers alike as the information would be readily available to both, without the necessity to repeat data transfer between paper and electronic formats.

Retrospective data are notoriously difficult to collect in terms of accuracy, reliability and completeness of information. Although variable between studs, intra-stud variability would conceivably be less. Given sufficient time and resources, the collation and analysis of this information would be worthwhile.

The incidence of ALDs showed considerable variation between studs and between the two years investigated in some cases. This variability could be a result of differences in the management strategies for diagnosis and treatment of ALDs, not necessarily a genuine reflection of the differences in incidence. Future projects monitoring the incidence of ALDs and any other DOD should consider inter-stud differences in case definition and management philosophies, to avoid the collection of biased or inaccurate data.

The number of foals diagnosed with some form of OC appears to be increasing on some of the studs. This finding warrants further investigation to identify the cause of this apparent increase, even if it is as a result of increased awareness and investigations, as the Industry currently perceives the incidence to be rising.

The studs within the Hunter Valley are serviced by a number of veterinary centres. The records analysed in this project were only from one surgical facility. Although the analysis of information obtained from this source was a worthwhile exercise, the previous statement in combination with the finding that an unknown number of foals undergo surgical treatment for ALDs on farm, limit its usefulness for future studies. A pre-requisite for quantification of data from this source would be involvement of all major veterinary service providers, with a standard recording system. Acquisition of surgical procedure records carried out on-farm would also be beneficial.

The pilot study proved to be more successful in the collection of ALD cases rather than those diagnosed with OC. Despite a standardised reporting system with a simplified form, taking very little time to complete, the return rates for both were extremely low. Larger scale projects of this nature would require a co-ordinator resident in the Hunter Valley, who would make regular visits to each stud involved. This would serve several functions; firstly it would maintain interest in the project over the period of data collection as regular feedback would be possible; and secondly much of the data could be collected by the individual and incomplete data could be identified and retrieved at each visit.

The area of the Hunter Valley contains a large population of breeding horses at a relatively small number of centres. In general, management systems are similar, although individual variations between studs clearly occur. Given this situation, the region provides an ideal environment for the large-scale study of the conditions affecting breeding horses and their offspring. Management compliance in the sensitive field of data collection was extremely good and data storage systems are becoming increasingly standardised. These features make the future study of this population of horses a realistic and exciting prospect.

There is no doubt that the situation in the Hunter Valley warrants further investigation. However, until a standardised case definition is established and records are maintained in a consistent fashion both between studs and over time, it is unlikely that definitive conclusions will be reached. The sensitivities of an Industry that relies to some extent on a reputation of excellence must also be addressed. The differences between studs and the potential damage to stud reputation, blood line or individual mare, stallion or foal from such a study cannot be underestimated. Confidentiality, blinding and anonymity are essential ingredients of such an investigation but there is a necessity for the Industry to be willing to accept study findings and recommendations. The Australian Industry, RIRDC and in particular the stud owners and managers of the Hunter Valley are to be congratulated on their courage and commitment in addressing the issues of DOD in the TB. It is to be hoped that this report will assist the relevant bodies in the formulation of future strategies that will be for the ultimate benefit of the racing TB in Australia and throughout the world.

Key 1 - Studmaster, Microsoft Corporation, Redmond, WA, USA.

2 - Microsoft Excel, Microsoft Corporation, Redmond, WA, USA.

3 - Microsoft Access, Microsoft Corporation, Redmond, WA, USA.

5.6 FIGURES

Figure 31. Total number of Thoroughbred foals diagnosed with developmental orthopaedic disease born annually on one stud farm in the Hunter Valley, Australia over a seven-year period, compared to the total annual foal crop at the same stud farm.

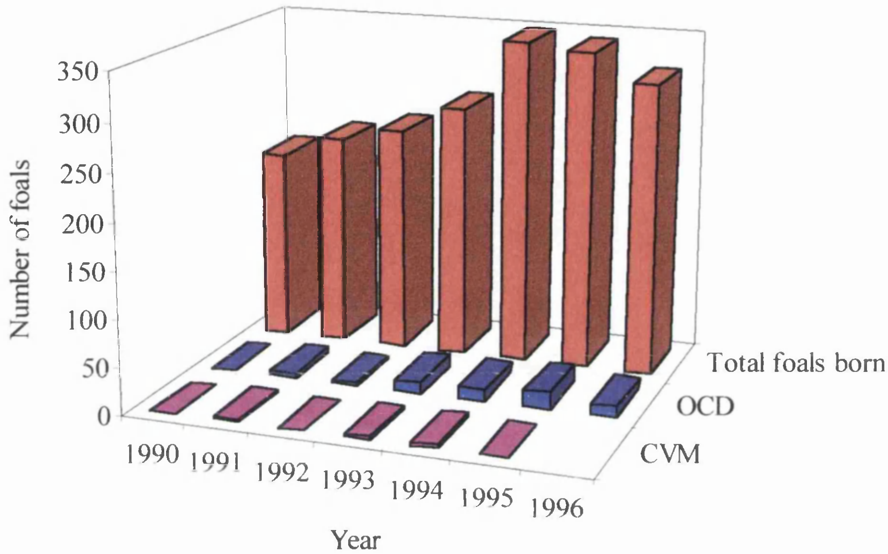


Figure 32. Total number of Thoroughbred foals diagnosed with developmental orthopaedic disease born annually on one stud farm in the Hunter Valley, Australia over a seven-year period.

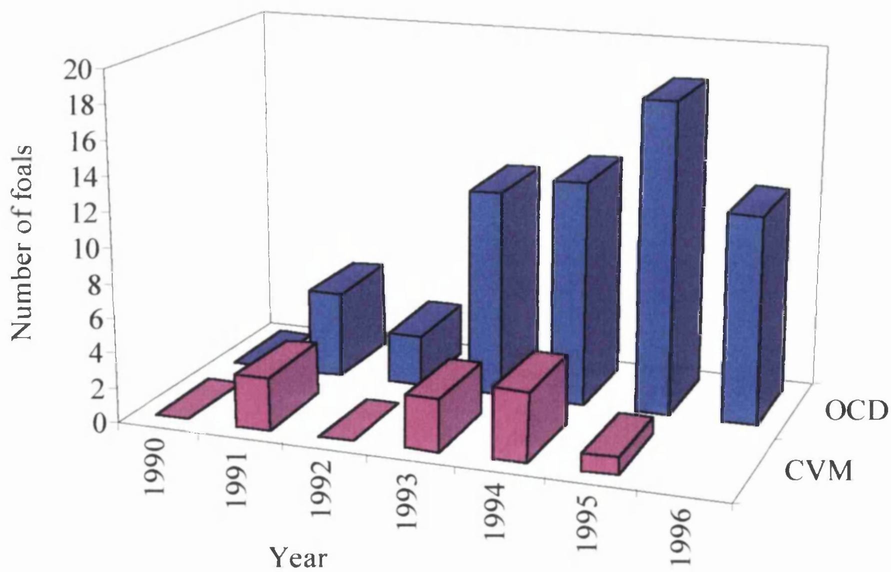


Figure 33. Percentage of annual foal crop diagnosed with developmental orthopaedic disease born on a Thoroughbred stud farm in the Hunter Valley, Australia over a seven-year period.

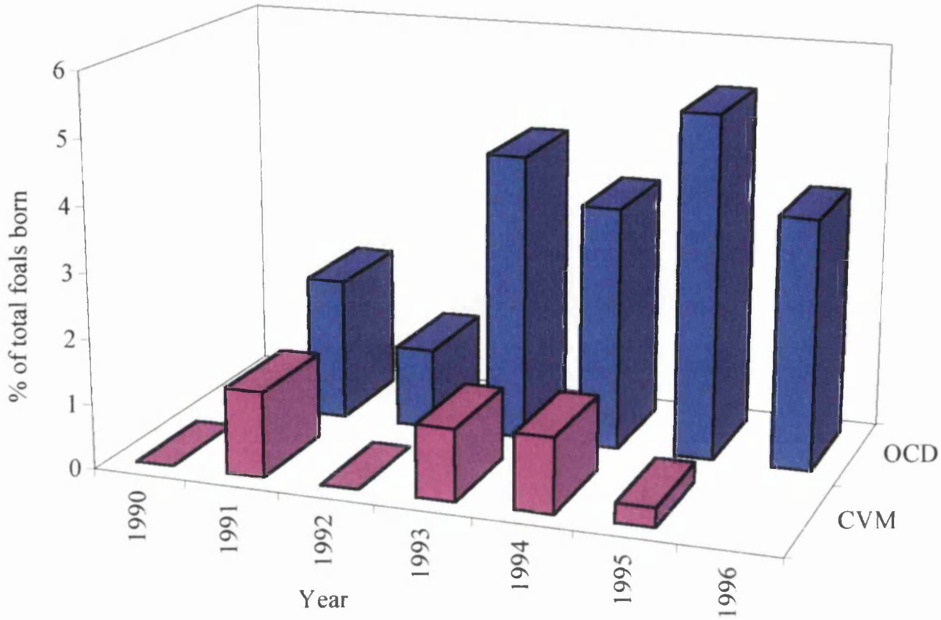


Figure 34. Total number of general anaesthetics (GA) performed annually on Thoroughbred horses and foals for all procedures and in the diagnosis and/or treatment of angular limb deformities and osteochondrosis at an equine hospital in the Hunter Valley, Australia over a nine-year period.

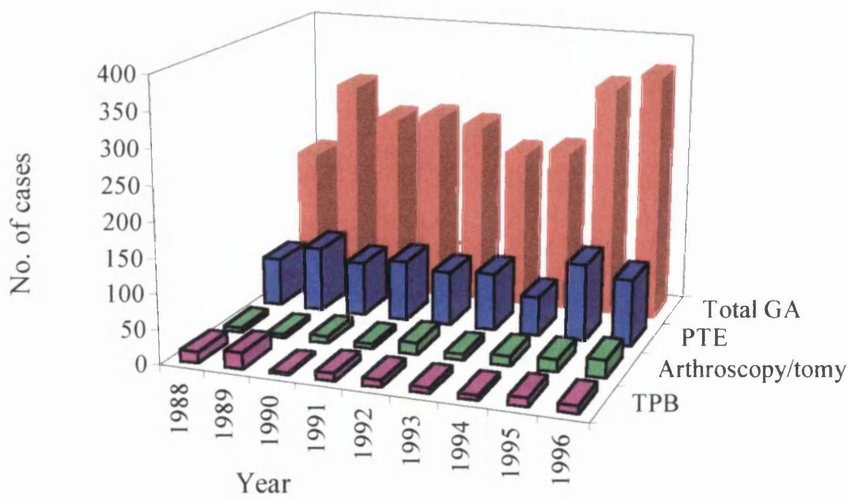


Figure 35. Percentage of all general anaesthetics (GA) associated with surgical procedures used in the diagnosis and/or treatment of developmental orthopaedic disease undertaken on Thoroughbred horses and foals at an equine hospital in the Hunter Valley, Australia over a nine-year period.

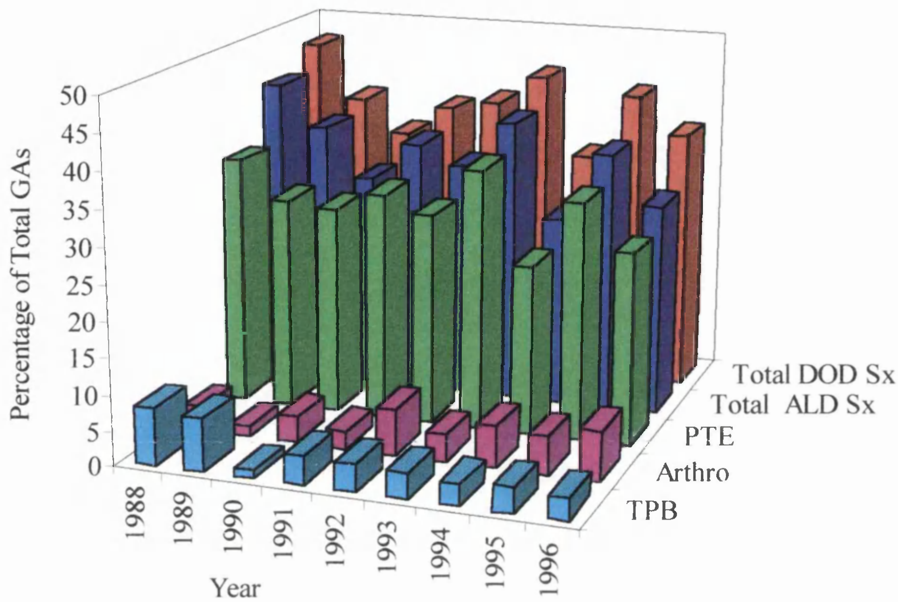


Figure 36. Actual date of birth of Thoroughbred foals born in the Hunter Valley, Australia and diagnosed with either congenital or acquired angular limb deformity, relative to their calculated due date of birth during the 1997 foaling season.

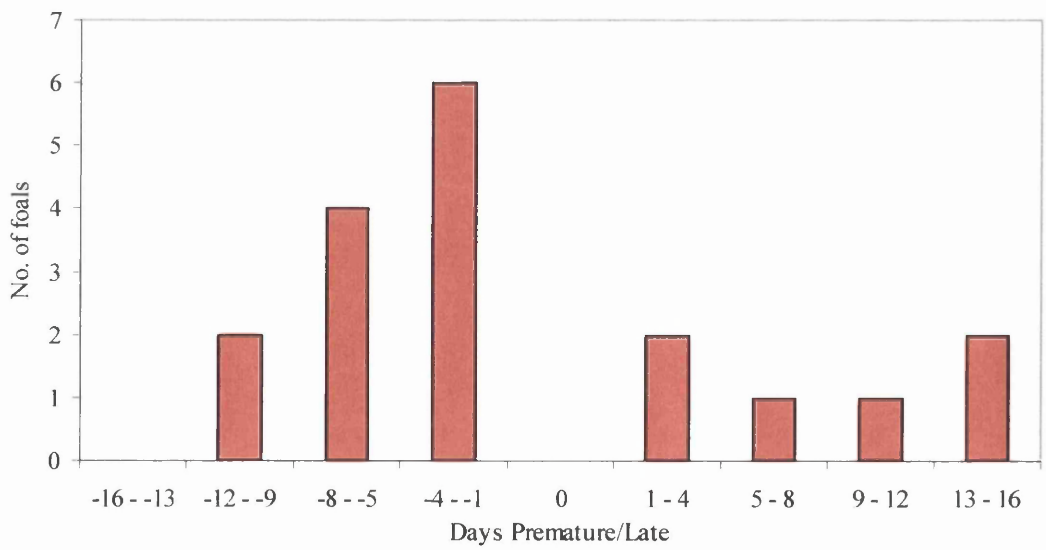
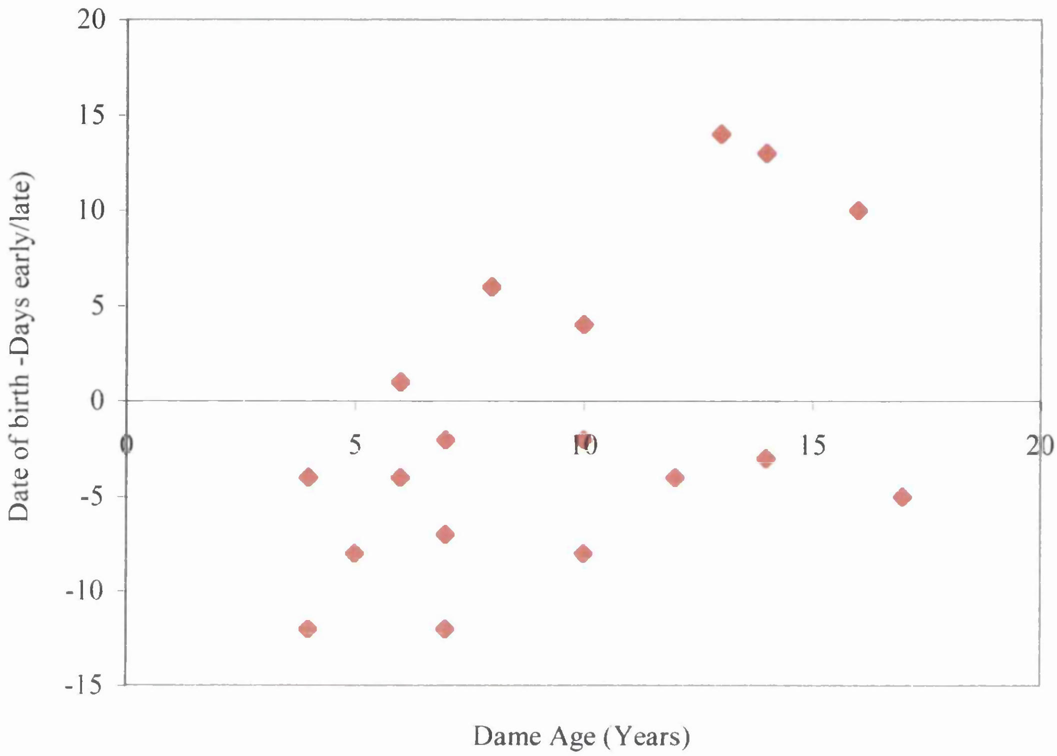


Figure 37. Relationship between age of dam and actual date of birth, relative to calculated date of birth, among Thoroughbred horses at stud farms in the Hunter Valley, Australia during the 1997 foaling season.



GENERAL DISCUSSION

GENERAL DISCUSSION

Orthopaedic disease is one of the most significant causes of wastage from the TB racehorse population (Jeffcott and others, 1982; Rossdale and others, 1985; Bourke, 1990; Bourke, 1995a). Conditions such as OC and ALDs affect young foals and immature adults, in some cases preventing the use of individuals from following a career in racing. There is genuine concern among the research and TB breeding communities that the incidence of certain developmental orthopaedic conditions could be increasing over recent years. Although there is a paucity of quantitative data to substantiate this theory, the investigation reported in Chapter five found a significant increase in the number of confirmed cases of OC between 1990 and 1996.

The very nature of TB racing results in horses frequently being exposed to innumerable risk factors, whether racing or training, that could contribute to the sudden or eventual occurrence of MSIs. The use of epidemiological investigative and analytical principles and techniques is being increasingly reported in the study of racetrack MSIs. Multivariable analysis of potential risk factors has been used to study a large number of general variables such as signalment, racing conditions etc (Mohammed and others, 1991; Peloso and others, 1994a; Bailey and others, 1998), but has also been employed in the more focussed analysis of the factors defining a single variable such as the racing shoe (Kane and others, 1996). Both methods effectively simultaneously analyse multiple variables.

The use of epidemiological techniques in the investigation in Chapter two revealed a number of findings of significance to the racing industry. The absence of any relationship between age and the occurrence of fracture injuries supports the views of the protagonists of racing young TB horses, when the musculoskeletal system is not fully mature. Also, the implications of certain training surfaces having a possible benefit, in terms of a reduced injury rate warrant further investigation. Previously reported investigations of the effects of exercise surfaces have focused on the racing surface (Hill and others, 1986; Clanton and others, 1991), frequently reporting conflicting results. In view of the fact that racehorses spend the majority of their time exercising on training surfaces, it is quite plausible that the condition of these surfaces would be likely to have a significant effect on the occurrence of injury, particularly where stress related remodelling of bone or degeneration of tendon/ligament fibres has occurred over a period of time. Although a relatively small number of different surface materials are utilised in the construction of training surfaces, mainly turf, fibresand and various combinations of synthetic materials in the UK, there are likely to be many more subtle differences in the surfaces and in the way they are used. Admittedly, financial limitations may favour the racetrack based investigations. Further studies on the effect of different exercise surfaces should involve the analysis of the training environment, as it is likely that many fractures occurring at the racetrack resulted from the sub-clinical cumulative damage sustained when training.

Understanding the temporal relationship between the accumulation of microdamage to and degeneration of a particular structure and the appearance of a clinically recognizable MSI is one of great importance in developing future strategies to reduce the incidence of injuries. In Chapter two, the findings of this investigation suggest that both training and racing related factors are probably important in influencing the occurrence of MSIs. The total number of fractures sustained while training was considerably greater than those occurring when racing, as might be expected given that the total time spent exercising was considerably greater than that spent racing. Despite the total number of racing fractures being smaller than training fractures, the racing fracture incidence was ten times greater than the training fracture incidence. These findings suggest that suitable conditions exist during training for fractures to occur, but, on a time spent basis, the likelihood of a fracture occurring was greater when racing compared with training. The previously reported occurrence of fractures when both racing and training (Robinson and Gordon 1988; Bathe 1994; Johnson and others 1994a; Wilson and others 1996) is consistent with exposure to risk factors during both these activities. However, it is likely that different combinations of variables are involved with each activity.

Cumulative, stress related injury to osseous tissues has become the popular focus of many investigations with the increased availability of such diagnostic techniques as nuclear scintigraphy. The technological advancements involved in the development of diagnostic ultrasonography have allowed considerable advances in understanding of the equivalent situation involving tendinous tissues. Early investigations of the incidence of SDF tendinitis relied solely upon physical examination in the diagnosis of an injury (Rooney and Genovese 1981). This precluded the identification of many subtle sub-clinical changes in the gross tendon structure as reported in Chapter four. If pre-injury changes occur in bone, then similar cumulative insults might also affect tendinous tissues, resulting in an area of weakened tendon. Although the investigation reported in Chapter four was unable to identify pre-tendinitis changes in CSA ultrasonographically, this may have been due to limitations in study design. The sub-clinical ultrasonographic changes in echogenicity reported among some of the horses that subsequently developed acute tendinitis suggests that the occurrence of tendinitis may well be preceded by degenerative changes in the tendon macro and micro-structure.

The identification of an age related association with tendinitis could be explained by the accumulation of microdamage over a period of time, resulting in a weakened tendon. Furthermore, the female gender relationship with tendinitis incidence raises the issue of whether or not to breed from mares that are retired to stud after developing tendinitis. Investigation of the incidence of SDF tendinitis among the offspring of brood mares with tendinitis compared with unaffected mares should perhaps be the subject of further study.

Measurement of variables by its very nature results in a certain amount of variation, which may or may not be sufficient to alter the true values of the variable under investigation. Statistical calculations allow the measurement of margins of error and variation when large numbers of values are analysed. A certain amount of variation is inevitable when humans undertake the repeated measurement of a subject. Diagnostic ultrasonography frequently includes both the objective and subjective assessment of soft tissues. Due, in part to the complexities of the ultrasonographic imaging of soft tissues, the creation and interpretation of images is subject to numerous possible sources of variation. Unfortunately, standardisation of the technique is possible to only a limited degree. In Chapter three it was possible to show from the reported results that diagnostic ultrasonography could be undertaken consistently by an examiner and even between examiners during the acquisition of images, although image analysis showed a consistent, significant variation between examiners. The subsequent ultrasonographic investigation of SDF tendinitis incidence was therefore undertaken in a manner that avoided any variation occurring between examiners during image analysis.

In order to fully understand the aetio-pathogenesis of disease and monitor the effect on any interventions directed at reducing its incidence, it is essential to have a knowledge of the pre-existing disease incidence in the population under investigation. This frequently involves the use of retrospective and/or prospective data collection. The investigations reported in Chapters two, four and five used both sources of information to obtain information relating to the incidence of three types of orthopaedic disease affecting TB racehorses. Prospective data collection primarily involved the use of a cohort study design, involving three populations of horses being monitored over specified time periods, to determine the incidence rate of each particular condition among the horses in each cohort. The inherent dis-advantage of a cohort study design is the large number of subjects required to provide sufficient case numbers if the disease incidence is low. However, such a design is very useful when monitoring a population over an extended period of time, allowing the comparison of epidemiological risk factors for disease, between diseased and healthy subjects within the population, allowing inference on the basis of injury given exposure rather than exposure given disease, the fundamental difference between cohort and case control studies.

Data analysis involved the use of descriptive statistics to establish basic population parameters. This was followed by the use of various epidemiological analytical techniques used in the simultaneous analysis of multiple variables, to determine the effect of each individual variable on the disease incidence, while controlling for certain confounding variables. Techniques such as multivariable logistic regression allow the simultaneous analysis of a large number of potential risk factors for a particular disease and have been used in human health epidemiology, prior to their more recent introduction into the study of animal health and disease. As computers become more advanced, the speed of data analysis and capacity for data storage and manipulation will continue to increase, again furthering the ability of the researcher to undertake more detailed and extensive data collection and analytical investigations.

In conclusion, the occurrence of disease is a highly complex subject, the investigation and acquisition of knowledge and the resultant increased understanding occurring at several different levels. Firstly, the exposed, at risk population must be identified and clearly defined, including the specific definitions for case, control and cohort subjects. Once the population has been identified, baseline incidence data can be determined, either at a specific point in time or, as in the investigations reported here, over a fixed time period, either retrospectively or prospectively. These data can then be used to provide information on the relative importance of the particular condition to the population. Secondly, by identifying variables to which the population may be exposed, the relationship, if any, between the occurrence of disease and the presence or absence or a particular variable can be determined. Only when both aspects of disease quantification are addressed and the relevant information obtained can the complexities of disease occurrence be unravelled, the goal of the investigation being to introduce appropriate interventions that will ultimately reduce the disease incidence.

APPENDIX I

EXPLANATORY NOTES FOR ANGULAR LIMB DEFORMITY REPORT FORM

Sire/Dam + Foal ID sire and dam name plus foal id number/brand

Dam type Maiden Dry Wet circle choice **Dam age** in years

Date due expected foaling date **Date of birth** actual foaling date

Gender Colt Filly Geld circle choice when problem first noted

1)First seen date problem first noticed **First treated** date problem first treated

Joint affected 1NC = near fore knee 2OC = off fore knee

3NFF = near fore fetlock 4OFF = off fore fetlock 5NH = near hock

6OH = off hock 7NHF = near hind fetlock 8OHF = off hind fetlock

Direction enter number (from "joint affected" above) below valgus or varus

valgus = leg deviates out below affected joint (carpus,hock or fetlock)

varus = leg deviates in below affected joint (carpus,hock or fetlock)

Treatment enter number (from "joint affected" above) on line

trim to balance e.g. 1,7 equilox_____ dalric shoe e.g. 7

strip _____ bridge______ euthanasia ______

other(brief)_______________________________________

Period boxed total period spent in box after diagnosis

Approx. date leg straight approximate date when limb/joint considered as normal as likely to become

2)Date treated date of second treatment for the above (use new form for new problem)

Joint as above **Direction** as above

Treatment as above **Period boxed** as above

Approx. date leg straight as above

Comments any comments relating to severity of condition or success/failure of treatment(brief)

APPENDIX II

SAMPLE ANGULAR LIMB DEFORMITIES SUMMARY REPORT FORM

Please complete for all cases of acquired angular limb deformity. For repeat treatment of the same joint use the same form. For more than two treatments of the same joint/limb use a new form.

Sire/Dam + Foal ID ______________________________

Dam type Maiden Dry Wet **Dam age**________

Date due _____/_____/_____ **Date of birth** _____/_____/_____

Gender Colt Filly Geld

1)First seen _____/______/_____ **First treated**_____/_____/____

Joint affected 1NC 2OC 3NFF 4OFF 5NH 6OH 7NHF 8OHF

Direction valgus varus valgus varus valgus varus valgus varus

____ ____ ____ ____ _____ _____ _____ _____

Treatment trim to balance_____ equilox_____ dalric shoe ______

strip _____ bridge______ euthanasia ______

other(brief)______________________________________

Period boxed _____/_____/_____ to _____/_____/_____

Approx. date leg straight _____/_____/_____

2)Date treated _____/_____/_____

Joint 1NC 2OC 3NFF 4OFF 5NH 6OH 7NHF 8OHF

Direction valgus varus valgus varus valgus varus valgus varus

____ ___ ____ ____ _____ _____ _____ _____

Treatment trim to balance____ equilox____ dalric shoe____

strip____ bridge_____ euthanasia _____

other(brief)________________________

Period boxed _____/_____/_____ to _____/_____/_____

Approx. date leg straight _____/_____/_____

Comments ______________________________________

APPENDIX III

EXPLANATORY NOTES FOR OCD REPORT FORM

A new form should be used for each affected animal, including all joints affected.

Dam/Sire + FoalID dam and sire name plus foal id number/brand

Dam type Maiden Dry Wet circle choice **Dam age** in years

Date due expected foaling date **Date of birth** actual foaling date

Gender Colt Filly Geld circle choice when problem first noted

OCD in offspring of Sire Y N ? Dam Y N ? circle choice, "?" = unsure/don't know

Date seen date problem first noticed **Date diagnosed** date diagnosis confirmed (if different from date first noticed)

Initial clinical finding Effusion Lame Other circle/complete choice

Diagnosis Clinical Radiography Arthroscopy Other circle/complete choice

Joint affected 1NH = near hock 2OH = off hock 3NS = near stifle

4OS = off stifle 5NHF = near hind fetlock 6OHF = off hind fetlock

7NFF = near fore fetlock 8OFF = off fore fetlock 9NSH = near shoulder

10OSH = off shoulder Other (name) circle/complete choice

Lesion type Fragment(s) Rough bone Cart. erosion

Bone cyst Other(brief)

use number from "joint affected" above e.g. " Fragment(s) 1,2" if both hocks affected with a fragment

Treatment Arthroscopy Arthrotomy Euthanasia
Rest Analgesics
Other(brief) use numbers as above

Vet case number if applicable - include vet case number for follow-up at clinic

Comments any comments relating to severity of condition or success/failure of treatment(brief)

APPENDIX IV

SAMPLE OSTEOCHONDROSIS SUMMARY REPORT FORM

Please complete for each case of suspected or confirmed OCD.

Dam/Sire + FoalID__________________________________

Dam type Maiden Dry Wet **Dam age**________

Date due _____/_____/_____ **Date of birth** _____/_____/_____

Gender Colt Filly Geld

OCD in offspring of Sire Y N ? Dam Y N ?

Date seen _____/____/____ **Date diagnosed** _____/_____/_____

Initial clinical finding Effusion Lame

Other______________________________

Diagnosis Clinical Radiography Arthroscopy

Other______________________________

Region(s) affected 1NF 2OF 3NH 4OH 5Spine

Joint affected 1NH 2OH 3NS 4OS 5NHF 6OHF

7NFF 8OFF 9NSH 10OSH

Other (name)____________________________

Lesion type Fragment(s) Rough bone Cart. erosion

Bone cyst Other(brief) _______________

Treatment Arthroscopy Arthrotomy Euthanasia

Rest Analgesics

Other(brief)_____________________________

Vet case number ____________________________________

Comments ____________________________________

____

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