FLEXURAL LIMB DEFORMITIES IN THOROUGHBRED FOALS IN NEW ZEALAND

A thesis presented in partial fulfilment of the requirements for the degree

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Abstract

The aims of this thesis were to describe the descriptive epidemiology of congenital flexural limb deformities (FLD) in foals on commercial Thoroughbred stud farms, and to describe the management and treatment of these foals. Data were collected on five commercial Thoroughbred stud farms in the Auckland and Waikato regions. Data were collected primarily by stud farm personnel, and assisted by study personnel when on farm. Data were collected on a selective population of 203 foals during the 2013/2014 season.

Pre-selection by stud farm personnel towards foals with FLD prevented the calculation of prevalence and resulted in 67% (135/203) of the foals with records having one or more FLD recorded. Laxity was observed to affect 87/135 foals, contracture of at least one joint region 57/135 foals and 6/135 foals were back at the knee; nine foals suffered from multiple forms of deformity. The median score for laxity was 2 (IQR 2-3) on a four point scale. The median score for contracture affecting hoof-ground contact was 2 (IQR 2-3) on a three point scale, while the median score for contracture affecting the fetlock and carpal regions was 2 (IQR 2-2). Multiple scorings over time were provided for 69/135 foals, 64 of these foals showed improvement in the severity of deformities by the final scoring.

Inter-observer agreement (between study personnel) was strong when scoring flexural laxity (κ=0.95), contracture affecting hoof-ground contact (κ=1.00) and contracture in the joint regions (κ=0.85). In contrast, inter-observer agreement between study personnel and stud farm personnel was lower when scoring flexural laxity (κ=0.69) and when scoring contracture in the fetlock and carpal regions (κ=0.14).

Treatment data were provided for 40/135 foals. Confinement was the most common form of treatment provided for mild and moderate cases of flexural contracture and flexural laxity; severe cases of flexural contracture required more invasive forms of treatment in combination with confinement. Improvement in the severity of deformities was observed following treatment in 28/42 (67%) cases of contracture observed to effect hoof-ground contact, 33/43 (77%) cases of contracture affecting the fetlock and carpal regions and 36/56 (64%) cases of laxity.

This thesis provides insight into the effect of FLD on Thoroughbred foals in New Zealand. The results indicate that foals tend to be mildly or moderately affected by FLD at birth and that treatment by stud farms is pragmatic.

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List of Abbreviations

ALD	Angular limb deformity (deformities)
DIP	Distal interphalangeal joint
DOD	Developmental orthopaedic disease
FLD	Flexural limb deformity (deformities)
HRNZ	Harness Racing New Zealand
IQR	Interquartile range
LF	Left fore
LH	Left hind
MCP	Metacarpo-phalangeal joint
MTP	Metatarso-phalangeal joint
NZ	New Zealand
NZB	New Zealand Bloodstock
NZTBA	New Zealand Thoroughbred Breeders Association
RF	Right fore
RH	Right hind
SB	Standardbred
TB	Thoroughbred

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Introduction

Of the $1,635 million contributed to New Zealand's Gross Domestic Product by the racing industry, the Thoroughbred sector is responsible for more than 70% of it (IER, 2010). Despite the high numbers of participants involved and more than 30,000 horses in training (IER, 2010), the number of horses being produced yearly is declining (Bolwell et al., 2014; Rogers et al., 2009). Foal numbers appear to be on a decline worldwide (Anonymous, 2013; Fennessy, 2010) and the New Zealand Thoroughbred Breeders Association predicted that the 2012/2013 foal crop will be reduced further to 3,800 foals from a high of 5,882 (NZTBA, 2014; Rogers et al., 2014). In addition, the number of horses exported yearly has also declined, with 1,511 exported in 2012/2013 to a value of $130 million (NZTBA, 2014). Management of these horses has a strong commercial focus; from birth foals are managed to produce promising sales and racing prospects (Waldron et al., 2011).

Racing from the age of two, the median career length of most Thoroughbreds is between two and three years (Tanner et al., 2013; Rogers et al., 2012). As a result breaking and training begins early – from about 15 months of age – to provide education and increase skill levels (Bolwell et al., 2010b; Perkins, 2005). Worked six times a week, training progresses with the aim of reaching and completing milestones such as first gallop, first trial or first race; these milestones are widely used as indicators for future performance (Bolwell et al., 2013; Bolwell et al., 2010a).

Wastage (the loss of horses and training days) is a large problem in the racing industry and has been widely studied. Wastage occurs throughout three main stages of production – reproduction, training and racing. Reproductive losses may be the result of fertility problems; early embryonic death; abortion; prematurity; dysmaturity (Lester, 2011; Bailey, 1998). Following weaning, a number of horses are also lost as a result of export; 30% of the New Zealand foal crop is exported each year (Fennessy, 2010; McCarthy, 2009). Furthermore, an additional third of the foal crop fail to reach training or are never registered with a trainer (Tanner et al., 2012; McCarthy, 2009). Developmental diseases, voluntary retirement and involuntary retirement from racing also have a part to play. The end result is a much diminished racing population placing pressure upon the population to perform.

Foal growth occurs rapidly and as a result, daily activity and exercise play a large part in continual healthy development (Rogers et al., 2012; Barneveld & van Weeren, 1999). Developmental orthopaedic diseases are a risk that must be accounted for in growing foals as they can cause temporary or permanent damage. These diseases include osteochondrosis;

physitis; subchondral cystic lesions, cuboidal bone malformation; angular limb deformities; flexural limb deformities.

Flexural limb deformities result in persistent hyperflexion of the joints in the limb and are commonly observed as a flexed joint or a joint which cannot be completely extended (Kidd, 2012; Auer, 2006; Munroe & Chan, 1996). In contrast, flexural laxity of the limbs results from the flaccidity of the flexor muscles (Auer, 2006; Munroe & Chan, 1996). Both flexural limb deformities and flexural laxity are commonly observed in new foals (Auer, 2006; Munroe & Chan, 1996) and are widely classified as being mild, moderate or severe in nature (Adams & Lescun, 2011; Lescun & Adams, 2011) – however an objective method of scoring has yet to be produced. In addition, treatment options also vary and ultimately it will likely be the clinician who decides what is required for foal improvement and as a result it is difficult to know what may be observed in the New Zealand population.

Limited information is available regarding the prevalence of flexural limb deformities and flexural laxity at birth (particularly in New Zealand), with variation in the definitions of deformities and the way data were collected and analysed. The focus by previous authors has tended to be upon flexural limb deformities, with few accounting for flexural laxity. Platt (1979) reporting the incidence in Thoroughbred foals (0-2 months) of 'knuckling fetlocks' as 11.3 per 1000 foals, and the incidence of contracted legs as 6.2 per 1000 births. In contrast, O'Donohue et al (1992) reported that 18/193 (8.4%) Irish Thoroughbreds (0-18 months) treated for developmental orthopaedic disease had contracted tendons. Also using Irish Thoroughbreds, Galvin and Corley (2010) identified 53 cases of contracture or laxity in 343 horses between 0-12 months of age. A recent study completed in New Zealand reported a 19% prevalence of angular and flexural deformities in Standardbred foals (Stowers et al., 2010). The variation demonstrated here makes it difficult to assess the possible effects on Thoroughbred foals here in New Zealand; anecdotally most foals are said to be affected however no data is available to back this up. Limited data has suggested that limb abnormalities observed in the foal early on in life may negatively affect their future athletic career (Platt, 1979) and Stowers et al (2010) reported a delay by Standardbred foals affected by limb deformities to qualify for racing than those without. With this awareness it is important to determine the true effect of limb deformities in Thoroughbred foals so that further study may be undertaken if necessary to determine the effect on career.

The purpose of this thesis is to review the existing literature, to produce a semi-quantitative method of scoring flexural limb deformities and subsequently determine the prevalence of these deformities in New Zealand Thoroughbred foals, while also identifying the commonly utilised treatment methods and their success. Being able to compare foal deformities and treatment methods across farm should provide a greater insight into flexural limb deformities and how New Zealand farms approach them. In addition, knowing the extent to which deformities are observed may encourage further work into the causes and effects on the growing Thoroughbred.

Chapter 1 Literature Review

1.1 Commercial Horse Production

1.1.1 Industry

The New Zealand racing industry contributes more than $1,635 million to New Zealand's Gross Domestic Product. The Thoroughbred racing sector is responsible for 70% of this contribution while the Standardbred racing sector is responsible for 25% (IER, 2010). The New Zealand Racing Board (NZRB) oversees the racing industry and is responsible for the administration of racing and wagering across each of the sectors (NZRB, 2012). New Zealand Thoroughbred Racing (NZTR) and Harness Racing New Zealand (HRNZ) act under the NZRB, and were established to provide a greater level of management and support to those involved in each sector, while also directly administering the rules of racing (NZRB, 2012).

More than 47,000 people actively participate in the production and training of more than 30,000 racehorses in New Zealand (IER, 2010). During the last 20 years the number of mares bred each year and the subsequent number of foals produced in both sectors has declined (Rogers et al., 2009) (Figures 1-1 & 1-2). The result of this is a reduced pool of horses available for training and racing. During the 2010/2011 Thoroughbred season 164 stallions covered 6,103 mares to produce 4,039 foals (NZTBA, 2014). In comparison, during the same season (2010/2011) within the Standardbred industry 90 stallions covered 3,365 mares to produce 2,365 foals (HRNZ Inc, 2012b, 2012a). The New Zealand Thoroughbred Breeders Association estimated foal numbers to further reduce in the 2012/2013 season to ~3,800 (NZTBA, 2014).

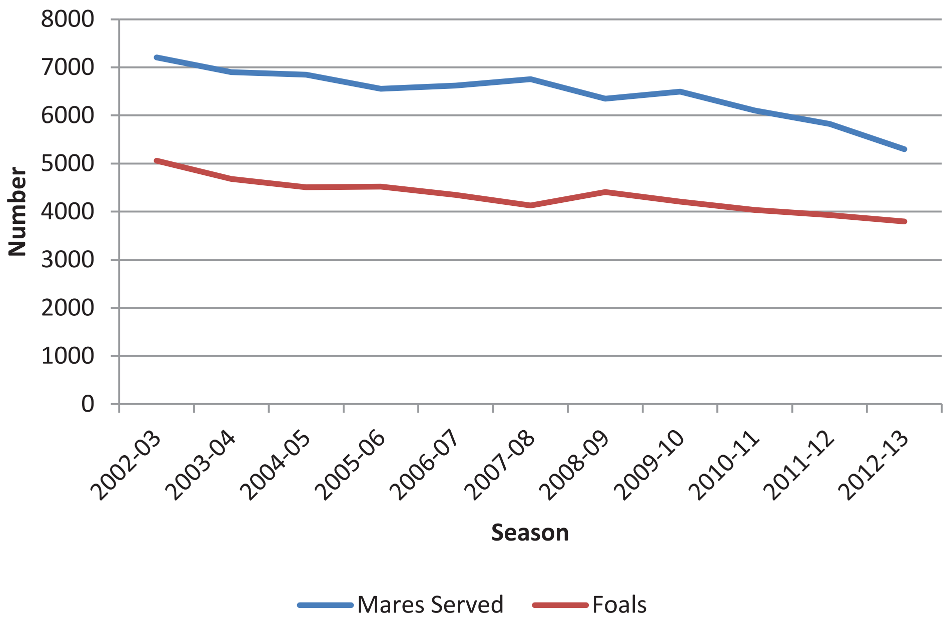

Figure 1-1 The number of Thoroughbred mares served annually and the annual Thoroughbred foal crop (NZTBA, 2014).

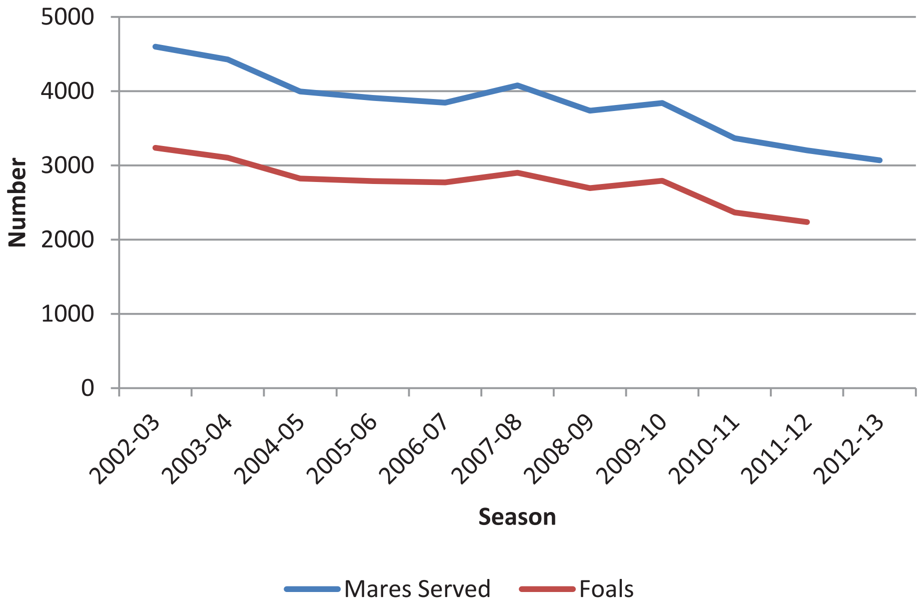

Figure 1-2: The number of Standardbred mares served annually and the annual Standardbred foal crop (HRNZ Inc, 2013).

During the last decade New Zealand has been consistently ranked eighth in the world based on annual Thoroughbred foal crop numbers (Anonymous, 2013; Fennessy, 2010). The maintenance of this ranking despite a reduction in the annual foal crop is in part due to the international decline in the number of Thoroughbred foals born, with six of the seven countries ranked above New Zealand also experiencing a decline in population (Table 1-1) (Anonymous, 2013; Fennessy, 2010).

Table 1-1: International Thoroughbred foal crops for the 2007 and 2012 breeding season (Anonymous, 2013; Fennessy, 2010).

Country	2007	2012
Argentina	7,538	8,135
Australia	18,255	15,540
France	5,384	4,369
Great Britain	5,839	4,366
Ireland	12,633	7,546
Japan	7,516	6,819
New Zealand	4,338	4,183
United States of America	36,071	22,500

1.1.2 Sales & Export

New Zealand is known for producing high class Thoroughbreds with the ability to compete on the international circuit (Fennessy, 2010). The primary focus of commercial Thoroughbred breeders is to produce yearlings for the annual New Zealand Thoroughbred yearling sales in February (Bolwell et al., 2010b). Overseen by New Zealand Bloodstock (NZB), the yearling sales have approximately 1,500 yearlings pass through the sales ring annually (Waldron et al., 2011). The sale is divided into three categories (Premier, Select or Festival) and each yearling is allocated to one of these categories by NZB; selection criteria is based upon an individual's pedigree, conformation and type (Waldron et al., 2011; Bolwell et al., 2010b). Yearlings entered in the premier category are perceived to be of a superior quality to those selected for the select and festival categories and as a result receive greater interest and fetch higher prices (Waldron et al., 2011). To maximise sales price commercial breeders attempt to focus the production of yearlings for this premier category (Bolwell et al., 2010b).

It is estimated that commercial farms spend ~$NZ26,000 annually (excluding stallion fees) per yearling in preparation for sale (NZTBA, 2010). By preparing yearlings for the premier category, stud masters have the chance to increase their return on this expenditure; yearlings sold in the select and festival categories often struggle to cover the expense required to prepare a yearling for sale and sell at a loss. Figures reported by New Zealand Bloodstock (NZB) from the 2014 yearling sales showed a 78% clearance rate, with 959 horses selling for an aggregate of $69.6 million (NZB, 2014b). Median sales price across the sales were: premier

$NZ110,000 (NZB, 2014d), select $NZ35,000 (NZB, 2014c) and festival $NZ10,000 (NZB, 2014a). Hence many breeders would have made a net loss on their select and festival sale yearlings.

Latest figures reported by the New Zealand Thoroughbred Breeders Association (NZTBA) show that during the 2012/2013 season 1,511 horses were exported at a market value of ~$130 million (NZTBA, 2014). Australia is New Zealand's largest export market (61.4%), followed by Singapore (14.1%) and Hong Kong (10.5%) (Fennessy, 2010; IER, 2010). In recent years, export numbers have fluctuated and the trend has been for the export of fewer but higher value horses. The NZTBA reports that 2,000 horses were exported over the 2000/2001 season at a value of $115 million, in comparison 1,511 horses were exported in 2012/2013 at a value of $130 million (Figure 1-3) (NZTBA, 2014).

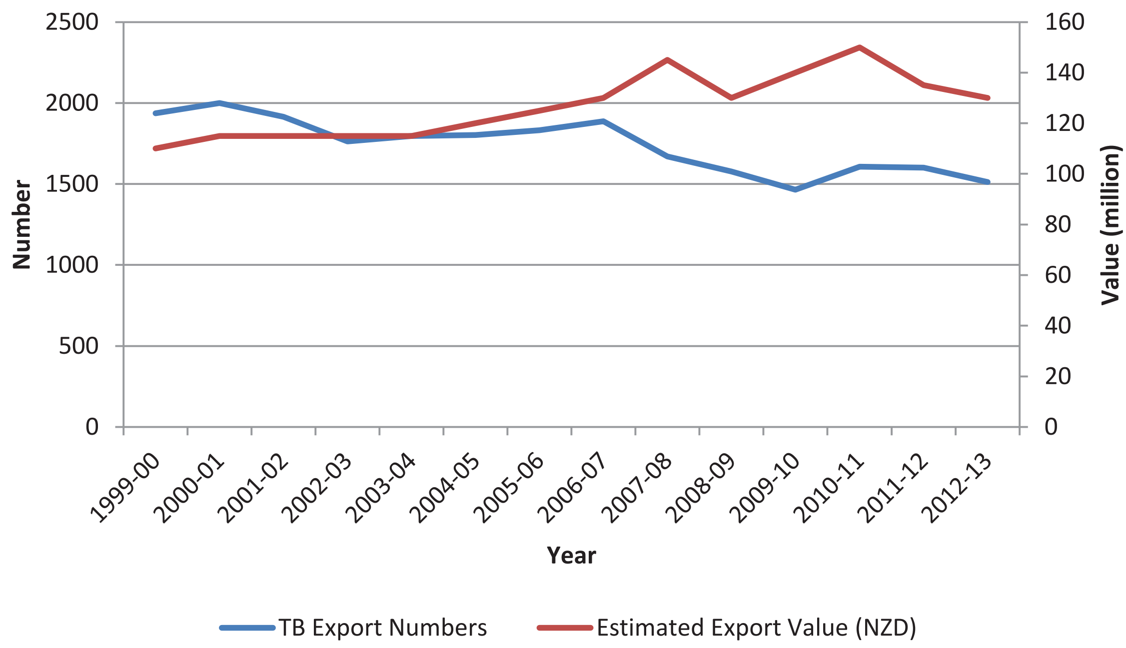

Figure 1-3: Data reporting the number and value of Thoroughbred exports for the period 1999/00 to 2012/13 (NZTBA, 2014).

1.1.3 Management

In 2007, a survey of the commercial Thoroughbred stud farms within New Zealand reported little variation in the management practices of the farms, and knowledge appeared to be freely exchanged between farms (Rogers et al., 2007). Follow-up studies completed in 2009 (Stowers et al., 2009) and 2010 (Bolwell et al., 2010b) examining the management and preparation of weanlings and yearlings, also reported little variation between farms in management.

The commercial constraints of the Thoroughbred industry, primarily linked to the production of a foal as close to the official birthdate of August 1 as possible, mean that breeding animals are restricted to a short breeding season (September to December). Mare gestation length has shown to vary widely amongst Thoroughbreds with many foals born between 320 and 360 days (Silver, 1990), however average gestation length is accepted as 335-342 days. As a result of this variable gestation length, mares must be managed accordingly to avoid a sizeable shift in foaling date away from 1 August (Dicken et al., 2012; van Rijssen et al., 2010). Two New Zealand studies reported a longer mean gestation length than the accepted average: 349 days for Standardbreds in Southland (Dicken et al., 2012), and 352 days for Thoroughbreds in the Manawatu region (van Rijssen et al., 2010).

The Thoroughbred breeding season officially begins September 1 and many farms try to start breeding as close to this date as possible. A number of management strategies are used to encourage the mare to start cycling earlier in the season including the use of light therapy, hormone use, a rising plane of nutrition, and rugs (Rogers et al., 2007). Farms aim to breed dry (non-pregnant) and maiden mares as early as possible in the breeding season, removing added pressure towards the end of the season as wet mares (lactating mares with a foal a foot) are ready to breed. Owners with mares having difficulty conceiving towards the end of the season or late foaling mares will often choose to leave the mare empty and rebreed early next season (Rogers & Gee, 2011).

Weaning occurs between 4 -7 months of age (Stowers et al., 2009; Rogers et al., 2007); the majority of foals are box weaned, however some farms may utilize gradual pasture weaning. At this stage, weanlings are also introduced to concentrates and receive early handling including trimming and drenching, if this has not already occurred previously (Stowers et al., 2009). The entire weaning and education process takes between one and two weeks on average (Rogers et al., 2007), following which weanlings are returned to pasture and kept in groups of between two and eight. All weanlings are brought in for additional education during yearling preparation (Stowers et al., 2009).

Yearling preparation generally begins in late October/early November on most farms and ensures yearlings are ready for the sales in February. Preparation lasts between 12 and 16 weeks, during this time farms provide yearlings with a combination of boxing and pasture access (Bolwell et al., 2010b). Controlled exercise is provided by the majority of farms and usually takes the form of hand walking; many farms also utilize mechanical horse walkers or lunging. While exercise is known to be beneficial for musculoskeletal health and development, a recent study found that exercise was provided to most yearlings as a form of education rather than fitness (Bolwell et al., 2010b).

The temperate New Zealand climate means horses have the advantage of being raised at pasture year round, without the need for supplementation with large quantities of concentrate feed (Grace et al., 2002). However, studies have shown that is it is common practice on commercial farms to provide additional feed to young stock in the form of concentrates (Stowers et al., 2009; Rogers et al., 2007). Concentrate feed is provided to maximise size and maturity at the time of yearling sales due to a perceived uncertainty that pasture composition and quality will be adequate to provide young horses with all the energy and nutrients required for this desired growth (Stowers et al., 2009). It is not uncommon for concentrates to provide weanlings with between 50% and 80% of their daily digestible energy requirements (Stowers et al., 2009; Rogers et al., 2007).

1.2 Career

The Thoroughbred racehorse starts its career early and can be racing from the age of two years. Career length varies for each horse and the reported median career length of most Thoroughbreds is between two and three years (Tanner et al., 2013; Rogers et al., 2012). Thoroughbreds are trained to compete in one of two types of racing: flat racing and jumps racing. Flat-racing horses may race from two years of age, horses intended for jumps racing (hurdling or steeple chasing) must be three and four years old, respectively, before they start racing (NZTR Inc, 2011).

Breaking and early training of the racehorse begins at around 15 months of age (Perkins, 2005); following this, horses enter race training or are spelled for a time before entering race training (Bolwell et al., 2010a). Trainers tend to start two year olds in early race training to provide early education and increase their skill level (Bolwell et al., 2010a). Following entry into training, horses are worked six times a week; cantered daily, and faster work is incorporated a couple of times a week as fitness levels increase. As training progresses, the time spent on the track remains similar (no longer than 10 minutes), however as a result of increased fitness and preparation for racing, the speed and distance covered is greater (Ely et al., 2010; Kingston et al., 2006; Harkins & Kamerling, 1990). Within New Zealand a trial start is often used as a training milestone and an indication of progress towards race fitness (Bolwell et al., 2013; Bolwell et al., 2010a).

Opposition against two year old racing is not uncommon due to the belief by many that the horse is not mature enough physically (or mentally) to sustain the stress and load. However, this reservation appears ill-founded. Recent literature suggests otherwise that two years olds appear to benefit from racing at a young age, many racing longer than those that started racing when older (Rogers et al., 2012; Velie et al., 2012; Knight & Thomson, 2011; Rogers et al., 2008).

1.3 Wastage

Wastage describes the proportion of horses lost throughout production and contributes to a reduction in the number of horses entering racing and participating to their full potential (McCarthy, 2009). Approximately one third of Thoroughbreds in New Zealand are lost between birth and training each year (Tanner et al., 2012); to reduce these levels of wastage whilst maintaining the level of horses produced, production must become more efficient (Bailey, 1998). Wastage occurs throughout three main stages of the production process: reproduction, training and racing.

Reproductive loss includes fertility problems, early embryonic death, abortions and twinning (Bailey, 1998). Low live foaling percentages in Thoroughbreds have been associated with low conception rates and may relate to the mare or stallion (Bailey, 1998). Older breeding mares in particular have lower conception rates and/or have complications with pregnancies, as a result increasing the risk of foal loss (Hanlon et al., 2012b; Jeffcott et al., 1982). Early embryonic death is thought to be a major cause of reproductive inefficiency and results in the loss of the embryo during the early stages of pregnancy (Bailey, 1998). Abortion of the fetus at any stage during pregnancy is also reported as a cause of significant breeding loss and may result from bacterial infection, virus contraction, twinning or placental abnormalities. While the presence of twins has previously caused substantial loss during pregnancy, the introduction of ultrasound technology has reduced this effect (Bailey, 1998).

Following foaling, the risk of foal sickness or death is at its greatest during the first week of life (Bailey, 1998); particularly for premature or dysmature foals[1] (Lester, 2011). Failure to consume colostrum or failure of passive transfer of antibodies from mare colostrum possibly provides one of the greatest risks to foal health. Colostrum provides all the energy, nutrients, immunoglobulin's and other protective factors needed for the foal's immunity, while also assisting with growth, metabolism and disease prevention (Becvarova & Buechner-Maxwell, 2012). Foal loss also occurs as a result of difficulties during foaling (e.g. premature separation of placenta) or deformities present at birth (e.g. contracted foal syndrome) (Frazer, 2011).

[1] Dysmature foals show signs of immediate postnatal maladjustment and weakness. These foals are premature-like, but are delivered in the full term period (>320 days gestation) (Foote et al., 2012; Wohlfender et al., 2009; Rossdale & Ousey, 2002)

The loss of premature and dysmature foals following birth, may occur rapidly if signs are not recognised and treatment is delayed (Lester, 2011). Any foal identified (or suspected) to be premature or dysmature should avoid long periods of lateral recumbency in an effort to minimise lung collapse (Lester, 2011). In addition, foals must be kept warm as they are at greater risk of contracting hypothermia (Lester, 2011; Koterba, 1993). Many of these foals may suffer from delayed ossification of the carpal and tarsal bones and flexural deformities; exercise should be restricted, while radiographs of the joints taken to assess the degree of ossification delay (Lester, 2011; Wong et al., 2003).

Limited data are available regarding the number of premature foals lost in the first few weeks of life. Early research by Platt (1973) investigated perinatal mortality in the Thoroughbred and reported that 13/183 (7.1%) foals submitted for autopsy were premature and died at birth or shortly after. In contrast, Morley and Townsend (1997) undertook a large survey evaluating mare reproductive performance and foal morbidity, mortality and athletic potential. Of the 990 pregnant mares, 11 (1.1%) produced premature foals and in the first 14 days of life these foals had a 2.4 times greater chance of morbidity and a 7.2 times greater chance of mortality than foals born at 320 days (Morley & Townsend, 1997). More recently, a retrospective study looking at parturition, dystocia and foal survival at an equine facility in the United States of America collected data from predominantly Thoroughbreds and Quarter Horses. Of foals for which gestation length was known, 12/1041 (1.2%) were premature, one of these was reported to die in the first 5 days of birth (McCue & Ferris, 2012).

A considerable loss of horses in the production process occurs following weaning; McCarthy (2009) and Fennessy (2010) report that 30% of the New Zealand Thoroughbred foal crop is exported each year, corresponding closely to the 28% of Thoroughbred foals exported in the UK (Wilsher et al., 2006). In addition to this, a further one third of all New Zealand horses also fail to reach training or register with a trainer (Tanner et al., 2012; McCarthy, 2009). These figures also correspond to early wastage figures produced in UK, where 38% of horses never entered training (Jeffcott et al., 1982); in contrast Wilsher et al (2006) observed 48% of their Thoroughbred foal crop failed to enter training.

Developmental diseases have also been suggested as responsible for preventing a number of foals from entering training (Bailey, 1998). There may also be an effect of gender; a reported 61% of the New Zealand Thoroughbred population that fail to enter training are fillies (McCarthy, 2009) and this is believed to reflect the positive bias of breeders and trainers towards colts (NZTR Inc, 2008).

Of those horses that enter training, it is not uncommon to lose horses as a result of voluntarily retirement as many show little ability for the sport and are regarded too slow (Wilsher et al., 2006; Jeffcott et al., 1982). Research completed on New Zealand Thoroughbreds in training by Perkins et al (2004) identified that 360/555 (64.9%) horses in the study were voluntarily retired, commonly due to lack of ability. Involuntarily losses from racing also occur and are commonly the result of musculoskeletal injury or respiratory illness. Of the New Zealand Thoroughbreds involuntarily lost from the racing population, 78.8% were the result of musculoskeletal injury, while 15.6% were the result of respiratory illness (Perkins et al., 2004).

This loss during training flows on into racing with an observed decline in the number of horses starting and in the number of races per horses (NZTR Inc, 2008). This decline subsequently places pressure upon those entering or already racing to maintain racing numbers. Levels of wastage in the UK have remained relatively unchanged and innovative changes are required to improve mare and stallion selection and the subsequent development and training of foals (Wilsher et al., 2006).

To maintain and increase the number of horses starting despite the sizeable population drop, the average number of lifetime starts per horse needs to increase. With a thriving export market, it has been suggested that New Zealand must consider increasing the number of horses imported to counteract this loss (NZTR Inc, 2008). The industry also needs to establish why such a high proportion of horses remain unregistered; these horses account for a large proportion of wastage. Lastly, the industry needs to address the cause and effects of injury, taking steps to reduce its effect on involuntary retirement (NZTR Inc, 2008).

1.4 Foals

1.4.1 Bone & Cartilage Development

Fetal growth occurs as a result of cell division and enlargement (Frape, 2010). At or soon after birth, cell numbers reach maximal capacity and any further growth results from enlargement of the cells (Frape, 2010). The length of time required for completion of growth varies amongst tissues, organs and other structures within the body and often continues well into adult life (Frape, 2010).

The skeletal system of the fetus starts off as a cartilage template; throughout gestation this template undergoes ossification and becomes bone (Wong et al., 2003). Primary sites of ossification (in the shaft of the long bone) begin showing on radiographs between 60 and 155 days of gestation (Firth, 2011). Secondary ossification sites (at the ends of the long bone) are evident radiographically at around 300 ± 35 days of gestation (Firth, 2011). The bones of the carpus and tarsus begin to ossify from as early as 120 days of gestation; the cuboidal bones are the last to appear and begin ossification between 275 and 335 days of gestation (Firth, 2011; Wong et al., 2003; Soana et al., 1998). At birth, ossification of these structures remains incomplete and each cuboidal bone has a final layer of cartilage around the outside that must ossify. By approximately 30 days of age this ossification is complete; up until this point, the cuboidal bones are at risk of permanent deformation (e.g. angular limb deformities)(Wong et al., 2003).

The horse is born with a highly developed musculoskeletal system and is capable of standing and ambulating within hours of birth. As a result of this, tissue development must be adequate to ensure the foal is able resist the forces resulting from this movement (Firth, 2011). Further growth and maturation occurs following birth ensuring the foal adapts effectively to exercise and workload requirements. Foal growth occurs rapidly until weaning where an observed decrease occurs, following this weaning growth rates increase again, slowing as they reach adulthood (Morel et al., 2007).

It is during this period of initial rapid growth that the foal adapts to its environment physically and mentally. It is thought that foals are born with 'blank' joints that adapt under the influence of loading (Rogers et al., 2012; Barneveld & van Weeren, 1999). Daily activity and exercise therefore plays a large part in the healthy development of the foal – particularly bone and cartilage. When foals are not provided with the opportunity to exercise and load the musculoskeletal system, optimal musculoskeletal development is hindered (Rogers et al., 2012; Barneveld & van Weeren, 1999).

As the horse reaches adulthood, bone growth begins to slow and eventually ceases. At this point the cartilaginous growth plate ossifies and it is now impossible to alter growth (Baxter, 2011b). Timing of closure varies on the bone and the joints involved, with some areas closing before the foal becomes a yearling. The more distal in the limb a physis/growth plate is located, the sooner it closes (Baxter, 2011b). The distal physis of the third metacarpal bone (MCIII) closes after 3-4 months (Auer, 2012; Witte & Hunt, 2009), the distal physis of the radius do not close radiographically until 20—24 months (Smith, 2010).

1.4.2 Prematurity & Dysmaturity

Premature foals are defined as foals born prior to 320 days of gestation. Typically, premature foals present as smaller, lighter and may have a joint laxity, a domed head and droopy ears; many are weak and unable to stand (Lester, 2005; Rossdale et al., 1984). Thoroughbred foals have been reported to weigh between 49.6 and 55.2 kg on average at birth (Galvin & Corley, 2010; Elliott et al., 2009; Rossdale, 1976). Little is recorded on the average weight of premature foals at birth, however 14 premature foals identified by Rossdale (1976) weighed on average 33.8 ± 2.5 kg.

The term dysmature is commonly used to describe foals that show signs of immediate postnatal maladjustment and weakness. These foals are premature-like, but are delivered in the full term period (>320 days gestation) (Foote et al., 2012; Wohlfender et al., 2009; Rossdale & Ousey, 2002). These foals experience intrauterine growth retardation and may show poor muscle development, fetlock contracture and have a long coat and tail at birth (Lester, 2005). Most of these foals will remain smaller than their counterparts during the first 12-18 months of life and are less likely to be successful athletes than their siblings (Lester, 2011).

Premature and dysmature foals are also often reported to have poor cartilage development and/or ossification in the epiphyses and cuboidal bones; when radiographed, wide radiolucent carpal and tarsal spaces are observed (Firth, 2011). Poorly ossified, this thicker cartilage has a tendency to deform and fail under loading (Firth, 2011). Permanent deformation leads to development of angular limb deformities and/or degenerative joint disease, and could pose a threat to future athletic soundness (Wong et al., 2003).

Causes of premature birth vary and may occur as a result of induced labour, twinning or problems with the placenta (infection, oedema or separation) (Lester, 2005; Koterba, 1993). Causes of dysmaturity also vary; delayed parturition may be linked to a disturbance of fetal hormones and a delayed maturation of the hypothalamic-pituitary-adrenal (HPA) axis (Lester, 2005). Consumption of tall fescue pasture infected with the endophyte *Neotyphodium coenophialum* has been associated with prolonged gestation and dysmaturity (Foote et al., 2012; Lester, 2011). While endophyte-infected tall fescue has been found along New Zealand roadsides, only endophyte-free varieties of tall fescue are sown removing this risk (Young et al., 2013; Dicken et al., 2012; Hoskin & Gee, 2004; Easton et al., 1994).

1.4.3 Developmental Orthopaedic Disease (DOD)

Developmental orthopaedic disease (DOD) is the term used to describe all orthopaedic abnormalities that are observed in the growing foal disturbing normal development (McIlwraith, 1993). Developmental orthopaedic disease may be inherited or acquired (Jeffcott, 1996) and may affect all limb joints (Lepeule et al., 2011). Abnormalities traditionally included in the DOD syndrome include: osteochondrosis, acquired angular limb deformities, physitis, subchondral cystic lesions, flexural limb deformities and cuboidal bone malformation

(McIlwraith, 1993). These conditions originate at sites of endochondral ossification and are the result of abnormalities in the articular-epiphyseal cartilage complex and the growth plates (physis) (Jeffcott, 1996). While these conditions are all grouped together as developmental complications observed in the growing foal, each is unique and usually requires differing treatment; each condition should be addressed on an individual basis.

Osteochondrosis (OC) is best described as a bone disease of the young horse that results from the failure of endochondral ossification and may affect the articular epiphyseal cartilage complex or the metaphyseal growth plate (McIlwraith, 1993). Multiple factors are identified to contribute to the development of OC including over-nutrition, genetic predisposition, hormones, and exercise; these factors may also exacerbate the condition if not monitored closely (McIlwraith, 2004; Jeffcott, 1997). Treatment varies with the site and severity of OC (Jeffcott, 1997) and as yet no single treatment has been identified to provide complete recovery in all cases.

Physitis (also known as epiphysitis, metaphysitis and physeal dysplasia (Bramlage, 2011; Frape, 2010)) is the term used to describe inflammation of the physis, or growth complex, at the ends of immature long bone in the horse (Bramlage, 2011). Like OC, multiple factors are believed to result in physitis and may include: external trauma, abrupt changes in exercise, uneven weight bearing, infection, nutrition and even genetic predisposition (Bramlage, 2011; Gaughan & Hanna, 2011; Jeffcott, 2005; Ellis, 2003). Physitis is regarded as a self-limiting condition as it usually disappears following growth plate closure (Jeffcott, 2005), however treatment is provided to address the condition and to prevent secondary damage/permanent angular deformity (Bramlage, 2011).

Subchondral cystic lesions can be found in the stifle, fetlock, pastern, coffin, and elbow joints (Kawcak & Baxter, 2011) and are proposed to be manifestations of osteochondrosis or the result of intra-articular subchondral bone trauma (McIlwraith, 2011; Baxter, 1996). One universal treatment program for all subchondral cystic lesions is not possible as many factors must be taken into consideration including: location and size, amount of articular movement, secondary articular changes, duration of lameness, age and intended use of horse (Baxter, 1996). Treatments that are available include intra-articular medications, surgical debridement of the lesion and intra-lesional injection of corticosteroids (Kawcak & Baxter, 2011).

Cuboidal bone malformation results from a delay in endochondral ossification (McIlwraith, 1993). Commonly seen in premature or immature foals, foals present with angular limb deformity (carpus) or sickle hock conformation (tarsus) (Kawcak & Baxter, 2011; McIlwraith, 2011). Permanent deformity may result from forces placed upon the insufficiently ossified cartilage (McIlwraith, 1993). Treatment aims to prevent the collapse of the bone structures until they completely ossify; foals may be confined and bandages, splints or casts may be applied to provide some support (Kawcak & Baxter, 2011).

1.4.4 Angular Limb Deformity

Angular limb deformities (ALD) are the result of a lateral (valgus) or medial (varus) deviation of the limb, distal to the deformity (Auer, 2012; Smith, 2010). Valgus deformities (Figure 1-4) result in an outward rotation of the hoof, while varus deformities result in medial rotation of the hoof (Auer, 2012). Angular deformities are often seen in combination with axial rotation; with time the limb adapts to this imbalanced loading and results in the development of permanent rotational deformities (Auer, 2012).

Figure 1-4: Foal presenting with carpal valgus in the left and right forelimbs.

Carpal valgus is the most common form of ALD and is considered to be normal if angulation is between 2° and 5° (Trumble, 2005). Maintained in this range, a growth spurt at approximately 8-10 months of age broadens the chest and straightens the limb naturally (Trumble, 2005; Greet & Curtis, 2003). In addition to this, a mild degree of carpal valgus has shown to be desirable and may serve as a protective mechanism, decreasing the odds of carpal fracture and carpal effusion (McIlwraith, 2011; Anderson et al., 2004).

Angular deformities are divided into two main categories, congenital (perinatal) or acquired. Congenital ALD have normal physes and result from a disparity in growth of the physeal complex, while acquired ALD involves disruption to normal bone formation resulting in weakened structural areas that collapse (Bramlage & Auer, 2006). Congenital factors resulting in ALD include incomplete ossification, laxity of the periarticular structures and aberrant intrauterine ossification; acquired factors include unbalanced nutrition, excessive exercise and trauma (Auer, 2012; Witte & Hunt, 2009), infection, exercise and physeal dysplasia (Witte & Hunt, 2009).

Angular deformities may originate from various locations in the limb: along the diaphysis of the bone (not in physis or metaphysis); in the joint of a limb (carpal/tarsal); or in the physeal growth area (physis, epiphysis or metaphysis) (Bramlage & Auer, 2006). Diagnosis requires thorough examination and manipulation of the limb in combination with radiographs. Early diagnosis allows for early intervention and may prevent further/permanent damage (Auer, 2012). Where possible, foals should be observed from all angles, but particularly from the front and the back to determine the severity of the deformity and the level of treatment required. Radiographs are an important tool and are the only way of determining the exact location or level of severity (Auer, 2012; Smith, 2010; Witte & Hunt, 2009). Angular deformities often occur in association with rotational deformities (Smith, 2010; Greet & Curtis, 2003) or flexural limb deformities (Jeffcott, 2005).

Treatment methods are commonly divided into non-surgical and surgical; treatment choice varies with the appearance and severity of the ALD. Non-surgical techniques include: stall rest/controlled exercise (up to six weeks), splints or casts (up to four weeks), and hoof manipulation (trimming or extensions). Surgical techniques address ALD through growth acceleration or retardation (Auer, 2012; Witte & Hunt, 2009). Periosteal transection and elevation (periosteal stripping) is performed on the concave side of the limb and should be performed from about four weeks of age to ensure correction occurs before the rapid growth phase is completed (Auer, 2012; Smith, 2010; Witte & Hunt, 2009). Multiple techniques have been described to slow bone growth and induce straightening including: staples; screws and cerclage wires; the use of a single transphyseal screw (Auer, 2012; Witte & Hunt, 2009) or bone plates (Auer, 2012). Figure 1-5 shows a foal in which both periosteal stripping and staples were used to resolve ALD. Recently, the use of extracorporeal shockwave therapy has also been recommended for growth retardation (Smith, 2010). In severe cases of ALD, some clinicians may utilise wedge osteotomy (Auer, 2012).

Figure 1-5: Foal presenting with a minor carpal valgus deformity in the left forelimb and a marked carpal valgus deformity in the right forelimb. Both limbs were treated with periosteal stripping, after showing no improvement in the right forelimb, a staple was inserted.

Limited data are available on the number of foals that are affected by ALD at birth; the work completed tending to concentrate more on the causes and the relevant treatments. A survey carried out in Ireland on Thoroughbred horses up to the age of 18 months aimed to identify the incidence and prevalence of developmental skeletal problems (O'Donohue et al., 1992) and determined that 193 (11.3%) of the 1711 horses surveyed required treatment for developmental orthopaedic diseases. Of these 193 horses, 92 (43%) were observed to suffer from angular limb deformities (O'Donohue et al., 1992). In contrast, data recently published in New Zealand from Standardbred foals observed such a low number of angular deformities that they were combined with flexural deformities for analysis and reporting (Stowers et al., 2010).

1.4.5 Flexural Limb Deformities

1.4.5.1 The Problem

Flexural limb deformities are commonly termed contracted tendons and are the result of a deviation in the sagittal plane that results in persistent hyperflexion of the joints in the limb (Auer, 2006; Munroe & Chan, 1996). Observed as a flexed joint or a joint that cannot be completely extended, they are named after the affected joint(s); these may include the distal interphalangeal joint (DIP), the metacarpo-phalangeal joint (MCP), the metatarso-phalangeal joints (MTP), the carpus and the tarsus (Kidd, 2012; Auer, 2006; Munroe & Chan, 1996). It is not uncommon for multiple joints and multiple limbs to be affected in foals (Figure 1-6); foals may also suffer from multiple deformities at a time (hyperextension and hyperflexion) (Auer, 2006).

Figure 1-6: Foal presenting with bilateral contracture of the carpal regions.

Flexural deformities are considered to be a component of 'developmental orthopaedic disease', despite no association with problems of bone development (McIlwraith, 1993). Traditionally classified as being either congenital or acquired, a distinction is made between deformities present at birth and those that occur at a later phase of growth. Congenital deformities are present at birth or may develop within the first few hours of life (Adams & Lescun, 2011); these deformities may affect one or more limbs. Acquired deformities are traditionally observed from around 6 weeks of age (Adams & Lescun, 2011) and may be unilateral or bilateral (Baxter, 2011a).

1.4.5.2 Pathogenesis

Gerring (1989) stated that the "pathological process within tendon or muscle has not yet been demonstrated". It has since been suggested that contracture is resultant from rapid bone growth in comparison to tendons, however there is no evidence to support this (Greet, 2000). With little known about the pathogenesis of flexural deformities, multiple factors are identified as possibly playing a role in disease development. Suggested factors include: uterine malpositioning, toxin exposure during gestation (locoweed or hybrid Sudan grass), genetic mutations, goiter, influenza outbreaks (Kidd, 2012; Auer, 2006) and abnormal nervous/musculotendinous development in utero (Adams & Lescun, 2011). Uterine malpositioning is widely believed to be a common contributor to contraction, however it is suggested that while this may be the case when foals are large and intrauterine development is crowded, other factors are more likely (Kidd, 2012).

Observed in the first few hours of life, the severity of a congenital contracture is widely classed as being mild, moderate or severe. Little attempt has been made to distinguish between these three levels of severity, however some guidance is given by Adams and Lescun (2011). When suffering from a mild form of flexural contracture foals will be observed to stand, feed and move about without assistance. Foals suffering from a moderate case of flexural contracture are able to stand and feed with minimal assistance, but are observed to place additional stress on other limbs in compensation for the affected limb(s). Lastly, severe flexural deformities are classed as those that prevent the foal from standing unassisted.

Mild cases of flexural contracture are often not immediately distinguishable, however with increasing severity (moderate) the foal's heels are observed to lift off the ground when bearing weight. Foals suffering from a severe case of contracture will be observed to stand on 'tip toe', with the entire sole of the hoof off the ground. The foal may also be observed to 'knuckle over' on the affected joint and as a result is likely to have difficulty standing and ambulating without assistance (Auer, 2006).

It is believed that while some foals identified suffer from simple contractures, others may be suffering from a form of contracted foal syndrome (Greet, 2000). Contracted foal syndrome (CFS) results in malformation of the foal and is recognised by bilateral contraction of the joints in the forelimb and/or hindlimb. In addition, the foal may also suffer from scoliosis, torticollis and cranial deformities (Crowe & Swerczek, 1985). These additional symptoms may not always be immediately recognisable or may not have been previously linked to the disease.

1.4.5.3 Treatment

Treatment of flexural limb contracture is ultimately determined by the severity of the deformity. Mild cases of contracture, where the foal is capable of standing, walking and feeding unassisted, will often resolve spontaneously and require no treatment (Adams & Lescun, 2011). These cases can also respond well to controlled exercise programs implemented from birth. In more severe cases, exercise is still encouraged, particularly for those foals needing encouragement or assistance to help to stand and ambulate (Kidd, 2012).

Exercise encourages the relaxation and subsequent stretching of the palmar/plantar musculotendinous units and should be monitored daily (Adams & Santschi, 1999).

Physiotherapy in combination with exercise may also be beneficial for mild to moderate forms of flexural contracture (Hunt, 2011; Orsini & Kreuder, 1994). Gentle manipulation of the limb 4-6 times a day (for 5-10 minutes) to normal position is recommended (Rodgerson, 2008; Orsini & Kreuder, 1994); longer sessions (15 minutes) are also suggested, but at 4-6 hour intervals (Hunt, 2011). Physiotherapy aims to encourage normal limb extension through the gradual stretching of the flexor structures causing the contracture (Kaneps & Smith, 1998; Leitch, 1985).

The use of oxytetracycline given intravenously has become a common treatment for flexural contracture. Administered once daily for up to three days, oxytetracycline increases the ability of the foal to bear weight on the developing tendons and ligaments; complete correction of the deformity usually occurring in as little as 24-48 hours (Kidd, 2012). Its use must however be carefully monitored as muscle/tendon relaxation is not targeted and will affect all musculotendinous units (contracted or not); hyperextension of unaffected joints can occur (Adams & Lescun, 2011). In severe cases, the response to oxytetracycline may be minimal and as a result require other forms of treatment (Auer, 2006).

The mechanisms behind the successful use of oxytetracycline to promote correction are uncertain. It is hypothesized that because oxytetracycline is able to bind calcium, it may inhibit calcium mediated muscle contraction and in doing so, inhibits muscle contraction. In inhibiting muscle contraction, the joints relax and subsequently return to more normal angles (Arnoczky et al., 2004; Kasper et al., 1995; Madison et al., 1994). In contrast, a more recent study suggests that oxytetracycline inhibits the remodelling of collagen; in doing so the connective tissues of the ligaments and tendons are more susceptible to lengthening and the foal is able to bear weight on the limb normally (Trumble, 2005; Arnoczky et al., 2004).

The use of toe extensions has been shown to prevent excessive wear on the toe and help to provide a greater area of hoof-ground contact, increasing the tensile forces on deep digital flexor tendons (Kidd, 2012; Auer, 2006). Extensions also aid a delay in breakover when the deformity affects the distal interphalangeal joint (DIP) or the metacarpo/metatarso-phalangeal joints (MCP/MTP); successful correction can usually be observed within two weeks (Kidd, 2012). Mild flexural contracture responds particularly well to the application of toe extensions, particularly if the foal is observed to knuckle over on the joint (Kidd, 2012).

More severe cases of contractural deformities will require the use of splints or casts (Figure 1-7) to help force extension of the affected limb(s). Splinting of the affected limb increases the tension on the musculotendinous unit and in doing so encourages relaxation and corrects contracture (Baxter, 2011a; Auer, 2006). Foals observed to 'knuckle over' severely on their joints in particular will benefit from the use of splints and enable them to walk freely (Rodgerson, 2008). Provision of non-steroidal anti-inflammatory drugs (NSAIDS) is recommended to reduce the level of pain the foal is exposed to while the limbs are held in extension (Kidd, 2012; Auer, 2006).The advantages of splints (over casts) are that they are easily removed, readjusted and reapplied; they must however be well padded and checked regularly for rubbing. Splints used for mild cases of contracture will require limited use; 2-3 days maximum. Moderate and severe cases will require longer, with some foals requiring splints for a number of weeks (Adams & Lescun, 2011). Splinting, when used in combination with oxytetracycline, provides more effective treatment for severe deformities (Auer, 2006; Greet, 2000).

Figure 1-7: Foal presenting with contracture in the fetlock region of the left forelimb; a cast was provided as treatment.

Surgery is seldom necessary with congenital flexural contractures of the limb (Adams & Lescun, 2011; Auer, 2006), and is usually reserved for cases that have not responded to other therapies. Flexural deformities of the MCP/MTP joints that have not responded to other treatment may benefit from surgery, which requires the transection of the flexor tendons and/or suspensory ligaments (Kidd, 2012; Adams & Lescun, 2011; Baxter, 2011a). Figure 1-8 shows a foal in which bilateral transection of the flexor tendons was undertaken to correct bilateral contracture in the fetlock regions. Severe cases of contracture at the MCP joint requiring the severance of all supportive structures should be viewed as a salvage procedure only and in many cases will never truly provide full correction (Adams & Lescun, 2011). When deformity of the MCP/MTP joints occur secondarily to abnormal bone formation, arthrodesis of the joint is performed (Kidd, 2012; Adams & Lescun, 2011; Baxter, 2011a). Arthrodesis is again regarded as a salvage procedure and results in paddock sound horses (Kidd, 2012).

Figure 1-8: Foal presenting with bilateral contracture in the fetlock and hoof regions at birth. Following an unsuccessful treatment regime, the foal underwent surgery for bilateral check ligament desmotomy in both forelimbs.

Horses that are over at the knee (flexural contracture observed at the carpus) may also be treated with surgery, which requires transection of the flexor carpi ulnaris and the ulnaris lateralis tendons at the point of insertion on the accessory carpal bone (Kidd, 2012; Adams & Lescun, 2011). In mild or moderate cases, horses are reported to remain relatively unaffected by the procedure and do continue on to have an athletic career; severe cases are usually less successful (Adams & Lescun, 2011). In severe cases of carpal flexion, the flexor tendons and palmar capsule of the middle carpal and antebrachiocarpal joint may be transected (Kidd, 2012; Adams & Santschi, 1999); while this procedure allows limb straightening, the prognosis for success is guarded (Kidd, 2012).

In all cases of flexural deformity, treatment outcome is ultimately determined by the severity of the flexural contracture and the treatment methods used; each case will have a differing prognosis. In brief, where manual correction/extension of the limb is possible, treatment and prognosis is good (Auer, 2006). Severe cases, where the limb cannot be extended easily, have a more guarded prognosis and rely upon more severe treatment plans (Auer, 2006). From an athletic perspective, prognosis is regarded to be favourable if the deformity responds well to treatment within the first two weeks and the foal is active without assistance. For those with severe deformities at the carpus or tarsus prognosis of athletic potential is often poor (Hunt, 2011). Euthanasia is often necessary for foals that do not respond to treatment or where surgery is impractical.

1.4.5.4 Treatment Implications

The limited data available suggest that limb abnormalities early on in a foals life may adversely affect future athletic career (Platt, 1979). Stowers et al (2010) reported that Standardbred foals in New Zealand affected by limb deformities tended to qualify for racing at a later stage to those without limb deformities.

Hunt (2011) reported that the prognosis for future athletic performance is good for foals that respond favourably to treatment in the first two weeks of life. It tends only to be those with severe deformities in which limiting surgical procedures have been performed that are reported to have reduced athletic potential (Kidd, 2012). More research is required to provide further evidence for the implications of limb deformities on athletic career as reports are conflicting and do not provide a comprehensive answer.

1.4.5.5 Acquired Flexural Limb Deformities

Acquired flexural deformities are observed in the foal from between 6 weeks and 6 months of age, however, FLD may also appear at much later stages (e.g. yearlings and mature horses). They have been associated with rapid bone growth and the exposure to painful conditions (e.g. laminitis) resulting in contraction of the musculotendinous unit (Kidd & Barr, 2002). Treatment options are similar to those for congenital contractures and may include: physiotherapy, administration of NSAIDS, the use of toe extensions or shoeing, casts and surgery. In addition to this, adjustments must often be made to the horses' nutrition and feeding levels. Euthanasia may be required in severe cases where treatment has not proven successful or will not resolve the condition (Kidd, 2012).

1.4.6 Flexural Laxity

1.4.6.1 The Problem

Flexural laxity (or hyperextension) is commonly termed tendon laxity and results from flaccidity of the flexor muscles; it is often accompanied by periarticular ligament laxity and joint instability (Auer, 2006; Munroe & Chan, 1996). Observed in many newborn foals (Figure 1-9), the condition is affects either the fore or hind limbs and on occasion all four limbs; premature (<320 days) and dysmature foals are particularly prone to the condition (Lescun & Adams, 2011; Trumble, 2005; Munroe & Chan, 1996). Laxity is commonly observed in the MCP, MTP and DIP joints (Hardy & Latimer, 2003; Munroe & Chan, 1996).

Figure 1-9: Foal presenting with bilateral laxity in the hindlimbs.

1.4.6.2 Pathogenesis

Laxity results from a weakness in the musculotendinous unit (Rodgerson, 2008), however researchers are yet to describe which structures are specifically involved. Weakness may be the result of immaturity, systemic illness, lack of exercise or excessively long toes (Rodgerson, 2008). Breed may also have some effect, with Munroe and Chan (1996) stating that the heavier horse breeds and Thoroughbreds appear to have higher rates of incidence for the deformity. Laxity of the carpus (back at the knee) commonly affects the premature foal. Bone ossification in these foals is often incomplete and requires careful management to ensure no further damage is caused (Hardy & Latimer, 2003). Leitch (1985) suggests that laxity of the periarticular supporting structures and inadequate carpal flexor support may be the cause of carpal laxity.

Flexural laxity cases are classified as being mild, moderate or severe. Mild cases of laxity result in the slight dropping of the fetlock when weight bearing (Munroe & Chan, 1996) and foals are observed to ‘rock’ back and forward from the sole to the coronary band (Lescun & Adams, 2011). Without treatment the foal will continue to walk on the caudal area of the hoof, encouraging the lengthening of the toe and a rounding of the heel, deteriorating the problem further (Munroe & Chan, 1996). Moderate cases of laxity result in a complete loss of contact between the hoof sole and the ground. The foal consistently bears weight on the coronary band, while the fetlock sits very low to the ground (Lescun & Adams, 2011). When suffering from a case of severe laxity, foals are observed to walk on the caudal aspect of the pastern and fetlock (Lescun & Adams, 2011), and the hoof sole is entirely off the ground.

Carpal laxity has not been classified by severity and is simply described as having been observed (Hardy & Latimer, 2003). This may be because it tends only to be observed in premature foals and therefore does not occur often.

1.4.6.3 Treatment

Treatment of flexural laxity is quite straightforward and it is widely accepted that mild cases require little attention, often resolving spontaneously (Kidd, 2012; Auer, 2006; Munroe & Chan, 1996). Foals are closely monitored from birth and when required their ability to exercise freely is limited as excessive exercise results in further weakening of the muscle and soft tissue.(Auer, 2006; Hardy & Latimer, 2003).

The use of swimming has been advocated by some as a suitable form of physiotherapy for these foals; the musculotendinous units strengthen gradually without the additional stress of bearing weight on the limb (Lescun & Adams, 2011; Auer, 2006). Foals with moderate laxity may require light bandaging of the heels, pastern and fetlock, to minimize injury when in such close contact with ground surface (Figure 1-10). However, these bandages must not provide any level of support to the joint as this further relaxes the musculotendinous unit (Kidd, 2012; Auer, 2006; Munroe & Chan, 1996). Heel extensions or glue on shoes are widely used in cases of moderate and severe flexural laxity to help maintain normal hoof-ground contact and encourage weight bearing, while minimizing foal ambulation on the DIP and MCP/MTP joints (Kidd, 2012; Auer, 2006; Hardy & Latimer, 2003; Munroe & Chan, 1996).

Figure 1-10: Foal presenting with moderate to severe bilateral laxity in the hindlimbs and was bandaged to minimise injury.

The use of splints is advocated by some clinicians to support the fetlock and hold it in position as muscle tone develops (Lescun & Adams, 2011). Bandaging and splints also provide support to the carpus (and tarsus) and avoid the complications of bone damage (incomplete ossification). These should be removed for a time during the day to encourage loading of the limb, strengthening the tendons and ligaments (Lescun & Adams, 2011). Splints should never incorporate the hoof as this provides complete support of the limb and promotes further relaxation of the musculotendinous unit (Lescun & Adams, 2011; Auer, 2006; Hardy & Latimer, 2003).

In situations where these techniques have proved unhelpful or the condition has deteriorated, surgery may be used in an attempt to save the foal from euthanasia. While generally not recommended, some owners may wish to salvage the foal for future use as a breeding animal. As a result, surgical arthrodesis of the fetlock may be performed, fusing the joint together (Lescun & Adams, 2011). The use of tenoplasty in small or miniature foals has also been discussed, however is not currently recommended (Kidd, 2012). Where these methods prove unsuccessful or too costly, foals will often be euthanized.

Treatment for carpal laxity is limited; radiography is initially recommended to establish the degree of cuboidal bone ossification. Recommendations can be made in regards to exercise and possibly bandaging or splinting of the affected area (Hardy & Latimer, 2003).

1.4.6.4 Treatment implications

Given that treatment prognosis is good for all but the most severely affected foals with flexural laxity (Lescun & Adams, 2011), many resolving spontaneously (Lescun & Adams, 2011; Munroe & Chan, 1996), it is likely that their athletic potential is relatively unaffected. In comparison, foals in which fetlock arthrodesis is performed do not have any athletic potential as this procedure is regarded as a salvage procedure only (Lescun & Adams, 2011). Further research is however required to determine the true implications of treatment on the future athletic potential of foals.

1.4.7 Number of foals affected by flexural contracture and laxity

Some authors have suggested that the incidence of limb deformities is increasing (Auer, 2006; O'Donohue et al., 1992), however few data are available to support this. Of the work completed on limb deformities, much attention has focused upon flexural contracture; unfortunately, few data have been collected on flexural laxity involving the fetlock region, carpus or tarsus. It is likely that this has stemmed from the awareness that flexural laxity deformities are generally self-correcting and require little intervention in comparison to cases of flexural contracture.

Early studies reported the incidence of ‘knuckling fetlocks’ in Thoroughbred foals at 11.3 per 1000 births; the incidence of contracted legs was 6.2 per 1000 births (Platt, 1979). If flexural laxity was observed in this population, incidence rates are likely to be categorised under ‘other limb defects’; the incidence rate was 15.7 per 1000 births for this group (Platt, 1979). Additional data reported by Platt (1979) suggested that of 1095 foals for which conformation data were available, 10 foals had hyperextension of the fetlocks at birth. Crowe and Swerzek (1985), identified the presence of limb contracture in 20% of the foals they examined submitted for necropsy; no observation appeared to have been made of flexural laxity.

O’Donohue et al (1992) identified 18 (8.4%) horses with contracted tendons from a group of 193 Irish Thoroughbreds (0-18 months) treated for developmental orthopaedic disease. It is unclear as to how many of these cases were congenital and how many were acquired, and no mention was made as to how severe a case had to be to require treatment. A similar study was also completed on Irish Thoroughbreds and identified the causes of disease and death in foals up to the age of 12 months (Galvin & Corley, 2010). Cases of contracture or laxity were identified in 53 of 343 foals. In that study, the two conditions were combined and it is unclear which foals suffered from contracture or laxity. Researchers also identified the range of treatment length, which varied between 0 and 42 days (3.1 days on average) for contracture/laxity cases (Galvin & Corley, 2010).

Recent work in New Zealand on Standardbred foals aimed to identify the number of foals affected at birth by limb deformities (Stowers et al., 2010). The presence of both angular and flexural deformities were recorded, however, these were combined for analysis. The combined prevalence of limb deformities was 19%; it is unclear what proportion of this figure accounts for flexural deformities.

With considerable variation in the reports of flexural deformities in Thoroughbred and Standardbred horses it is difficult to determine what may be observed in the Thoroughbred population in New Zealand. Previous research has concentrated more on the effects of flexural contraction than flexural laxity and has neglected to define the severity of the deformities observed.

1.5 Aim and Objectives of Thesis

The aim of this thesis is to document the prevalence of flexural deformities (contracture and laxity) in New Zealand Thoroughbred foals. The objectives are to:

a) Develop scoring systems capable of identifying the presence and severity of flexural contracture and flexural laxity
b) Determine the level of agreement observed between personnel scoring the deformities
c) Identify the interventions used to treat these deformities.

Chapter 2 Descriptive epidemiology of flexural limb deformities in Thoroughbred foals in New Zealand.

2.1 Abstract

The aim of this study was to identify the prevalence and severity of flexural deformities in Thoroughbred foals in New Zealand and examine changes over time. The effects of farm, mare age, foal gender and date of birth on the prevalence of flexural deformities were examined. Data were collected on 203 foals from five Thoroughbred stud farms during the 2013/2014 season. Foals were scored by stud farm and study personnel using semi-quantitative three and four point scale scoring systems designed specifically for the trial at birth, two weeks and six weeks of age.

Pre-selection of foals with deformities by farm staff prevented the calculation of prevalence. Of the foals scored at birth 135/203 (67%) were observed with one or more flexural deformities; 87/135 had laxity, 57/135 had contracture in at least one joint region and 6/135 were back at the knee. The median score for contracture affecting hoof-ground contact was 2 (IQR 2-3) on a three point scale, while the median score for contracture observed in the fetlock or carpal regions was 2 (IQR 2-2). The median score for laxity was 2 (IQR 2-3) on four point scale. In total 69 foals were followed during the season, with 64 showing improvement in the severity of deformity by the final scoring; 5/5 cases of back at the knee had improved, 62/68 (91%) cases of contracture had improved and 91/97 (94%) cases of laxity had improved.

The pre-selection of foals resulted in a high percentage of flexural limb deformities within this sample; some of the foals had multiple deformities. The scores recorded for these foals tended to be low, reflecting a greater proportion of mild deformities than moderate or severe ones. Improvement was shown in the severity of scores for most foals followed.

2.2 Introduction

Irrespective of the racing jurisdiction approximately one third of the horses bred in New Zealand as racehorses fail to enter training each year (Tanner et al., 2012; McCarthy, 2009). In association with this, the majority of injuries to racehorses occur while in training and it is reported that only 48% of horses in training start in an official race (Bolwell et al., 2013). It has been proposed that the presence of limb abnormalities early in a foal's life may adversely affect its future athletic career (Stowers et al., 2010; Platt, 1979). Standardbred foals in New Zealand with limb deformities at birth were older when they qualified for racing compared to those without limb deformities at birth (Stowers et al., 2010). Long term surveillance by Platt

(1979) on a group of foals that had been observed with congenital limb deformities performed less successfully than their counterparts with normal conformation. Therefore, identifying and addressing limb deformities early in a foal's life may be important in reducing injury and wastage later in the foal's competitive life.

Within the literature it is difficult to obtain consensus on the true prevalence of limb deformities within equine populations due to differences in the definition and identification of the deformity, and the sampling frame used. In some cases the definition of the deformities has included a combination of both flexural and angular deformities (Stowers et al., 2010) or deformities have been grouped under the broad category of developmental orthopaedic disease (DOD) (O'Donohue et al., 1992). Platt (1979) reported an incidence rate of 11.3 per 1000 births for 'knuckling fetlocks'[2] and an incidence rate of 6.2 per 1000 births for contracted legs[3] in Thoroughbred foals up to two months of age in the UK.

Using the criteria of DOD, O'Donohue et al (1992) conducted a cross-sectional survey on the prevalence of DOD in a population of 1,711 Thoroughbreds that required treatment. The presence of DOD was identified by farm staff and/or veterinary surgeon in 193 horses aged between 0-18 months; only 18/193 (8.4%) were identified to suffer from contracted tendons (O'Donohue et al., 1992). Most authors state that congenital flexural deformities decrease in severity with time (and treatment). O'Donohue et al (1992) used a wide sampling frame spanning 0-18 months, and as such a proportion of these foals are likely to have suffered from the acquired form of flexural deformities, widely observed in the older foal between four weeks and four months of age (Kidd, 2012). While some attempt was made to determine the number of congenital deformities at birth, no attempt was made to determine which DOD were observed at this stage (birth) (O'Donohue et al., 1992).

In contrast, data from a population of Standardbred foals (evaluated by a clinician within 24 hours of birth) in New Zealand were used to investigate the combined prevalence of angular and flexural (contracture only) deformities; results identified that 19% of foals were affected. The potential for bias in this population was high, given that this study only took place on two farms in Canterbury, under the guidance of the same veterinary clinician and only recorded deformities if the clinician regarded them as so (Stowers et al., 2010).

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[2] Contracture of the flexor tendons which resulted in varying degrees of flexion of the fetlock joints (Platt, 1979).

[3] Contracture of the flexor tendons which resulted in varying degrees of flexion in the carpus, tarsus and other joints of the lower legs (Platt, 1979).

The aim of the current study was to capture data from Thoroughbred foals in New Zealand at birth (within 48 hours) to determine the prevalence of flexural deformities (laxity and contracture) and document the changes in severity in the first two weeks of life.

2.3 Materials and Methods

2.3.1 Recruitment of Studs/Foals

Farm selection was limited to commercial Thoroughbred stud farms in the Auckland and Waikato regions. Of these farms, a convenience sample was then enrolled in the trial; these farms were moderate to large in size (Rogers et al., 2007) and willing to participate in the trial.

Following enrolment each farm was visited two months before the breeding season (1 August) to discuss the score evaluation sheet and the study protocol. The evaluation sheet then underwent five iterations to refine the scoring protocols and the on farm recording systems. Two weeks prior to the start of the breeding season each farm was visited and provided with the scoring systems and advised of the standard operating procedure for completing the forms.

Of those initially contacted, five Thoroughbred stud farms (farms A-E) were enrolled in the trial; one in South Auckland and four in the Waikato region. Farms were asked to score all foals at birth and to provide additional scoring where possible during/after treatment, at two weeks and six weeks.

2.3.2 Scoring System

Stud personnel were required to score foals according to two three point (contractural deformities) and one four point (laxity deformity) scoring systems, ensuring that all farms identified flexural deformities to the same level of severity. These scoring systems were adapted from previous descriptions (Adams & Lescun, 2011; Lescun & Adams, 2011) and the master scoring sheet contained both a written description and visual images (diagrams and pictures) to provide clear delineation between scores. The system was designed in this way to permit scoring for 'back at the knee', flexural laxity and flexural contracture separately. Foals that were not observed to suffer from flexural limb deformities (FLD) at birth received scores of 1 and were deemed 'clean'.

2.3.2.1 Back at the knee

Stud personnel were asked to record the presence of 'back at the knee', rather than score it.

2.3.2.2 Flexural Laxity

When scoring flexural laxity, one score was required for each limb, as determined by the images (and descriptions) provided (Figure 2-1).

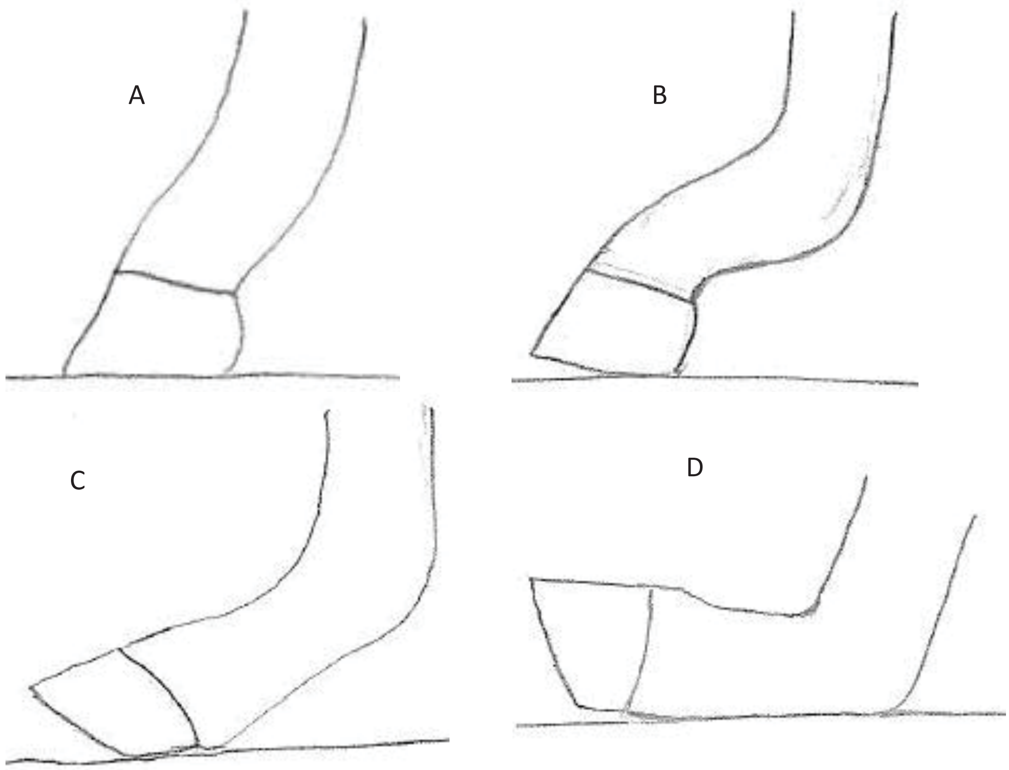


Figure 2-1: Diagrams of the four scores used to score the severity of flexural laxity in foals. Score 1 (A) - normal. Score 2 (B) - foal stands on caudal aspect of hoof and is observed to 'rock' back and forwards between toe and heel. Score 3 (C) - heel contact only, toe is off ground completely as is most of hoof sole. Score 4 (D) – hoof completely off ground, foal stands on caudal aspect of fetlock.

2.3.2.3 Flexural Contracture

For scoring flexural contracture two scoring systems (Figure 2-2, Table 2-1) were required to differentiate the effect contracture can have on the hoof (through pastern) and on the joint regions (e.g. fetlock, carpus). Stud personnel were asked to identify the affected joints on a diagram provided.

The first scoring system described the degree of hoof-ground contact observed and is shown in Figure 2-2.

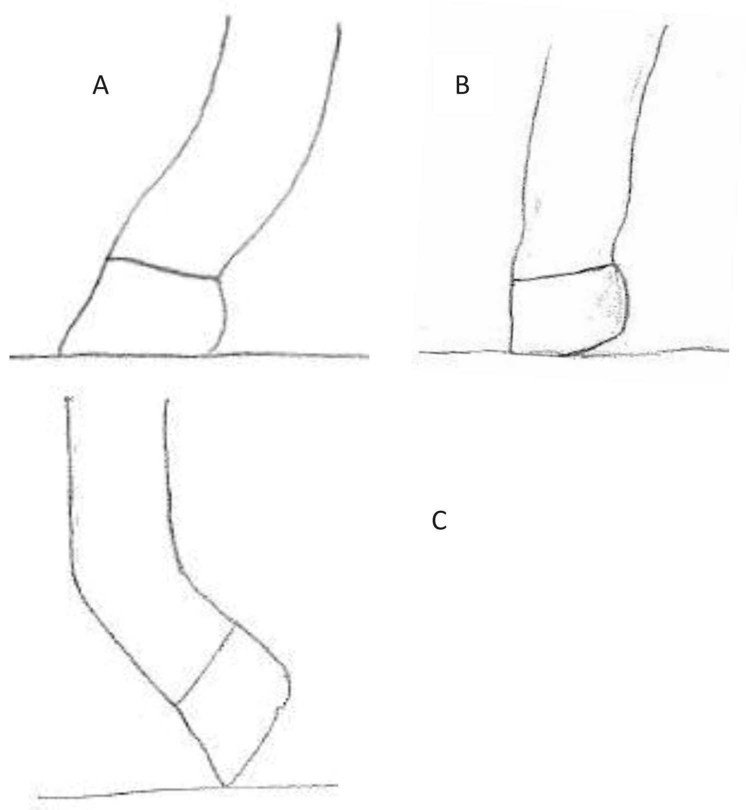


Figure 2-2: Diagrams of the three scores used to score the degree of hoof-ground contact observed in foals with flexural contracture. Score 1 (A) - hoof-ground contact is normal. Score 2 (B) – some sole contact with ground, heel is entirely off ground; foal is up on toes and may have some difficulty in standing unassisted (moderate contraction). Score 3 (C) - entire sole of hoof off ground, foal is essentially standing on tips of toes; unlikely to be able to stand unassisted (severe contraction).

If contracture was also observed to affect other areas of the fore limbs (fetlock and carpus) and/or hind limbs (fetlock), a second scoring system was used (Table 2-1). This allowed staff to semi-quantitatively categorize the severity of the contracture on the affected joint(s).

Table 2-1: Scoring system used to describe the severity of flexural contraction observed in the fetlock and carpal regions of the limb.

Score	Severity of contraction
1	Foal is able to stand normally. Normal or mild contracture.
2	Foal may require some assistance to stand without assistance. Moderate contraction.
3	Foal is unable to stand without assistance. Severe contraction.

2.3.3 Data Collection

Limb deformity data were collected on *pro forma* recording sheets. These datasheets required identification of the foal (dam, sire, sex, date of birth) followed by an assessment of limb conformation using the scoring methods described earlier (Section 2.3.2). If a deformity was present in the foal, the score and location (e.g. fetlock region) were indicated on the scoring *pro forma* recording sheet (Appendix A). Additional information about the foal and foaling (e.g. was assistance required at foaling, time taken for foal to stand or suckle etc) was gathered in the form of *pro forma* recording sheets that were filled out at the time of birth by stud farm personnel. These forms were customised for each stud farm to assist with compliance and reduce the opportunity for additional increases in workload for stud personnel.

The protocol for evaluation of FLD at birth required the foals to be evaluated either by the foaling staff at the time the foal first stood or at the morning assessment, usually by 8am when the foaling attendant and/or the stud master would routinely evaluate the foals and make management decisions. The limit for at birth assessment, due to the perceived plasticity of FLD, was 48 hours post-partum. Foals undergoing treatment for flexural deformity were subsequently monitored and data were recorded on a *pro forma* recording sheet. Where possible, foals were rescored daily during the treatment period by the stud staff. In addition, stud personnel recorded the time point at which the deformity showed signs of improvement and the point at which they believed treatment had been successful. Where possible, foals were also re-scored at two and six week intervals.

Study personnel visited farms on a fortnightly basis in order to address any issues that may have arisen. Study personnel were each assigned to three of the five stud farms enrolled in the study (one farm was visited by both study personnel). During these visits the foals were photographed and scored by study personnel to provide a comparison of scoring between each other and with the farms (Chapter Three).

Completed stud farm datasheets were collected by the study personnel and checked for consistency and errors before being entered into a customised Microsoft Access database (2010; Microsoft Corporation, Washington, USA). If data were missing, the records were checked with stud farm personnel; if these errors could not be rectified the data were subsequently entered as missing. During data entry, scoring time point was categorised by the number of days from date of birth (birth-2 days, 3-7 days, 8-14 days, 15-21 days and ≥ 22 days). Photographs taken of these foals at the time of scoring were catalogued into individual folders for each foal for referral at a later stage.

2.3.4 Statistical Analysis

To test for normality of data, continuous variables (gestation length, time to expel placenta, stand and feed) were screened using histograms and then tested using the Shapiro-Wilks test. Normally distributed data were reported as mean and standard deviation, while non-parametric data were reported as median and interquartile range (IQR). The Kruskal Wallis equality-of-populations rank test was used to compare the median time for the mare to expel her placenta and the median time to stand between the foals with FLDs and those without. The Wilcoxon rank-sum test was used to compare the median time to feed for foals, allowing for either the presence or absence of FLD and whether feeding was assisted by stud farm personnel or not.

Categorical variables gender, farm and birth month were summarised as numbers and percentages based upon the presence or absence of FLD. Mare age was categorised into a binary variable (<12 years and ≥12 years,) and was summarised as numbers and percentages based upon the presence or absence of FLD. All categorical variables were tested with a Chi square test. Data were analysed in Stata 12.0 (StataCorp LP, Texas, USA).

2.4 Results

2.4.1 Descriptive Data

Due to time and management constraints the sample population was pre-selected by the farm staff and prevented the calculation of true prevalence. Across the five farms, data were recorded for a selected population of 203 foals within the first 48 hours of birth; 13/203 (6%) were scored more than 24 hours after birth. Of these 203 foals, 135 (67%) were observed to have one or more flexural deformities present. The number of foals scored by month varied and is shown below (Figure 2-3).

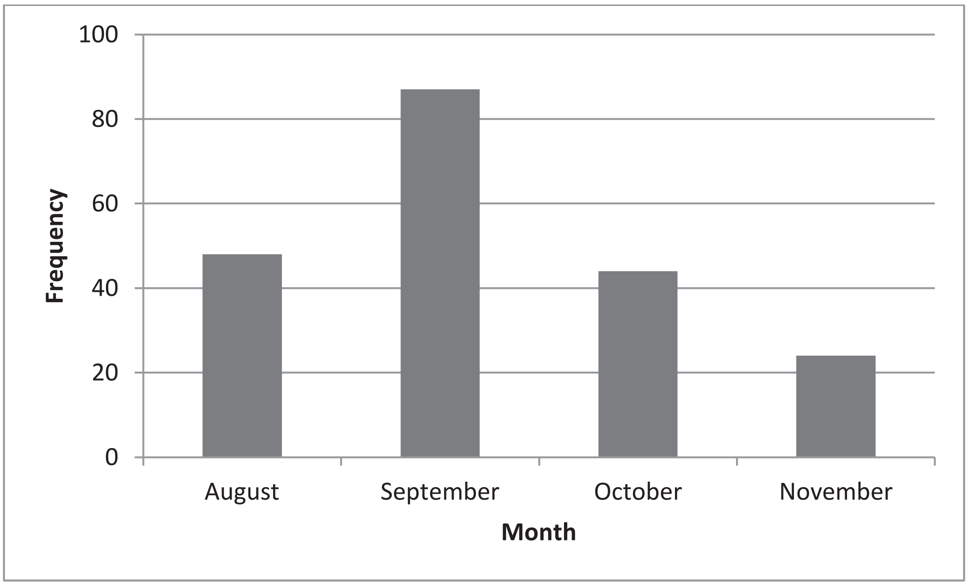


Figure 2-3: The total number of foals scored in this study was observed to vary by month.

2.4.1.1 Gestation length and common measures taken at foaling

The gestation length for the foals included in the study was 347 ± 9 days. There was no significant difference in the median time to expel placenta for mares with foals with limb deformities (30 minutes; IQR 20-59) and those with foals with no limb deformities (35 minutes; IQR 25-60) (P=0.28). Foals scored clean at birth took a median time of 35 minutes (IQR 27-50) to stand following birth similar to that of foals with a flexural limb deformity (40 minutes; IQR 30-50; P=0.65)

On 2/5 farms it was common for foals to be provided with a bottle containing some of the dams colostrum (or stored colostrum if Brix percentage considered too low) before their first suckle from the dam. There was no significant difference in the time to suckle between foals with limb deformity and clean foals when not provided feed assistance (P=0.379). Foals recorded with a deformity were offered a bottle sooner after foaling than clean foals (P=0.005) (Figure 2-4).

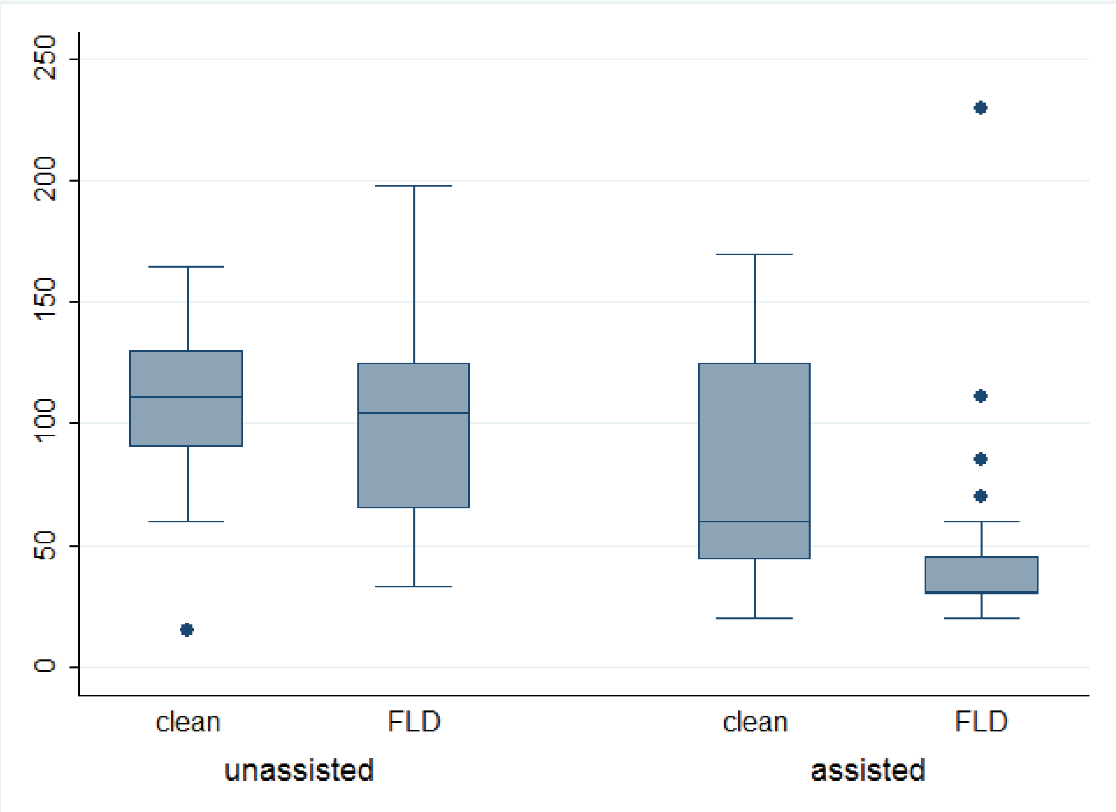


Figure 2-4: The effect of feeding assistance on the median (IQR) time (minutes) taken for foals to feed, when accounting for the presence of deformity. Data is presented as a box and whisker plot. Medians are represented by horizontal lines with the 75th percentiles at the top and the 25th percentiles at the bottom of the box. Range is represented by the whiskers, while outliers are represented by the circles.

2.4.1.2 Management

For the first one or two days following birth 3/5 (60%) farms had foals in individual small paddocks (mean 1275 m^2). In comparison, 2/5 (40%) farms routinely boxed foals for the first 1-2 days; this was a flexible system which meant that foals with FLD would have priority over those that were normal.

When foals had FLD, 3/5 (60%) farms boxed all foals until improvement was shown regardless of type or severity of the deformity, whilst 2/5 (40%) farms adjusted confinement for the type of deformity; foals with contracture remained in small paddocks where possible (only foals knuckled over or unable to stand were boxed), while those with laxity are routinely boxed. Stable bedding varied by farm with 2/5 (40%) farms using straw, 1/5 (20%) farms used woodchips and 1/5 (20%) shavings. The remaining farm (20%) provided a shredded paper or sawdust bedding on top of rubber flooring.

Mare and foal treatment and movement decisions were made by the foaling and stud managers on 3/5 (60%) farms, one farm relied mainly on veterinary opinion and on one farm the decision maker was dependant on the severity of the deformity. Mares and foals were moved around 4/5 (80%) farms by in-hand walking; the remaining farm (20%) moved mares and foals around the farm in herds by quad bike. On 3/5 (60%) farms, foals were under the care of the staff until they left the property, whilst on the two larger farms the foals were under the specialist care of the foaling team for the first week following foaling.

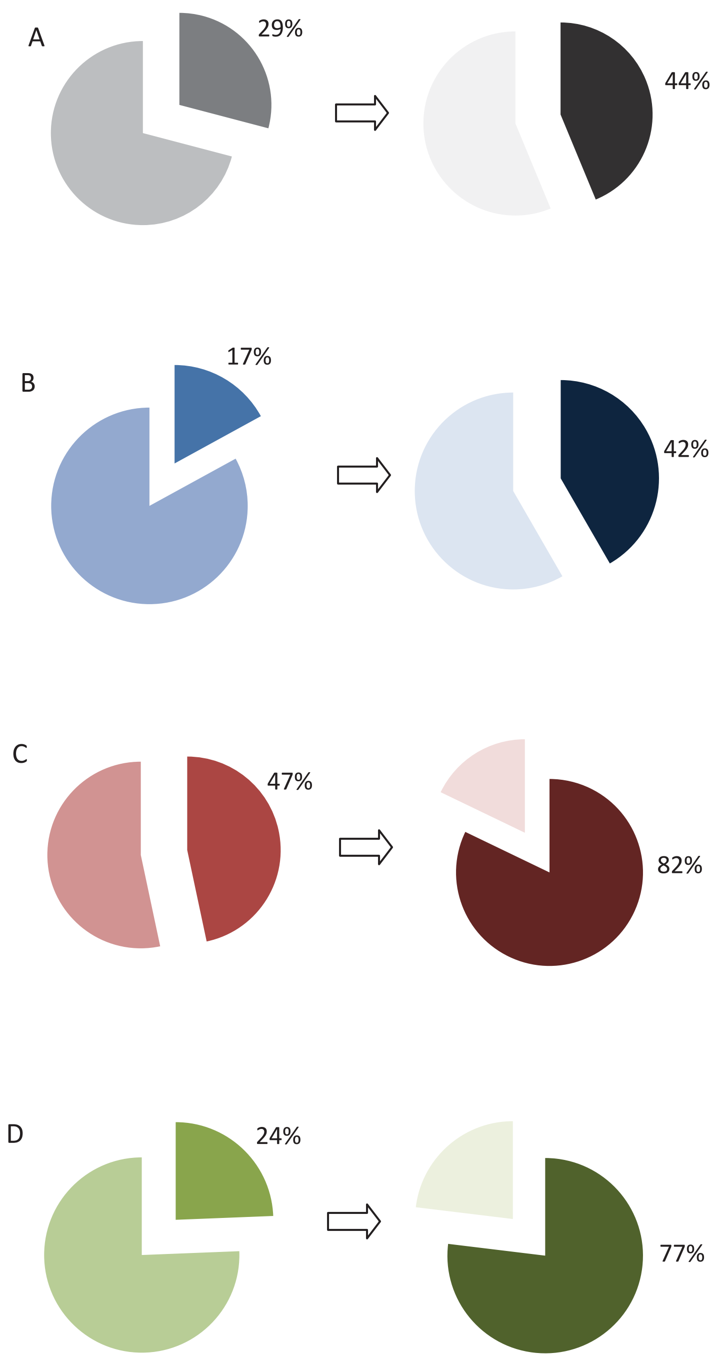
Mares and foals were checked twice daily and kept in mobs of six (or less) in large (mean 12,760 m^2) paddocks on 4/5 (80%) farms. The fifth farm (20%) checked mares and foals daily when feeding and additionally if brought in for the farrier/vet; mares with foals were kept in mobs of up to ten (paddock dependant). Supplementary feed was provided regularly to mares and foals on 2/5 (40%) farms, 3/5 (60%) farms only supplemented feed when necessary (e.g. when boxed).

Veterinarians were either on-site or employed full time on 2/5 (40%) farms, the other three farms (60%) utilised veterinarians via a service agreement with local specialist veterinary clinics. Hoof care was conducted by farriers that were employed full time on 2/5 (40%) stud farms, trimming was completed by farm staff and followed up by the farrier on another 2/5 (40%) farms, the remaining farm (20%) had all hoof care work conducted by a contracted farrier.

2.4.2 The effects of farm, gender, birth month and mare age

2.4.2.1 Farm

The percentage of FLD differed significantly across farms (P<0.001) (Figure 2-5). Farms A and B had a moderate percentage of FLD, while farms C, D and E each had a high percentage of FLD.



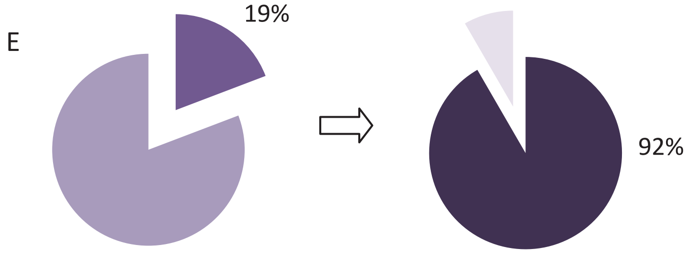


Figure 2-5: The proportion of foals scored by farm (A-E). Two pie charts are shown for each farm; the first pie chart represents the total number of foals that were scored on farm, of all the foals that were born on farm. The second pie chart represents the number of foals that were scored with FLD out of all the foals scored on that farm.

2.4.2.2 Gender

Of the 203 foals scored, 92 were colts and 110 were fillies (1 foal gender missing). There was a significant effect of gender on the percentage with FLD (P<0.001). In total, 79% (73/92) of colts had FLD, while 56% (61/110) of fillies had FLD.

2.4.2.3 Birth Month

Of the 203 foals scored, 201 had birth dates recorded. There was no significant effect of birth month on the percentage with FLD (P=0.483) (Figure 2-6).

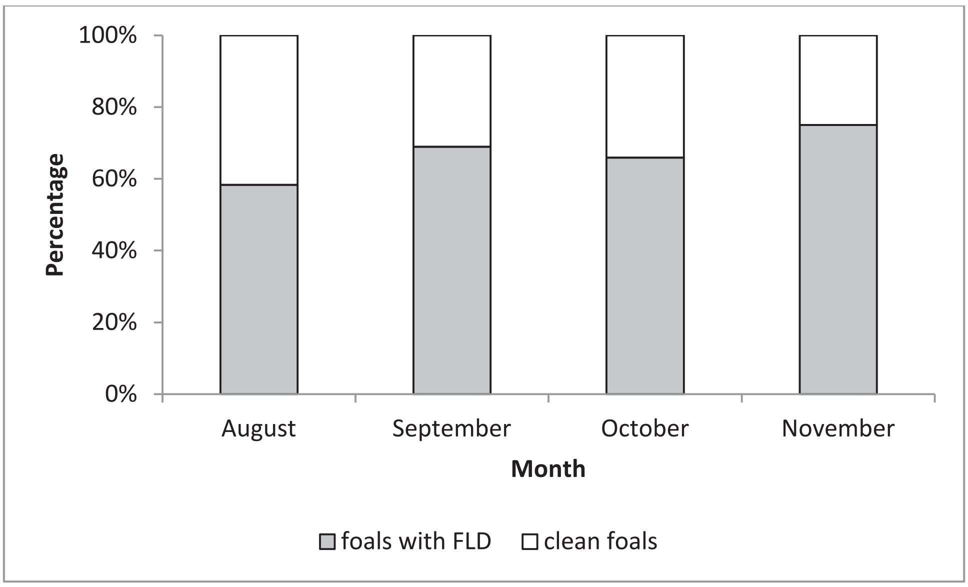


Figure 2-6: The observed proportions of foals scored with a flexural limb deformity (FLD) by month of birth.

2.4.2.4 Mare age

Of the 203 mares, 151 (74%) were under the age of 12 when served in the 2012/2013 season and 52 (26%) mares were 12 years or older when served in the 2012/2013 season. In total, 62% (93/151) of mares aged <12 had foals with FLD compared to 79% (41/52) of mares ≥12 years of age (P=0.024).

2.4.3 Number of Deformities

Of foals with FLD, 87/135 (58%) presented with laxity, 57/135 (38%) with contracture and 6/135 (4%) were back at the knee (nine foals had multiple deformities).

Foals were back at the knee on a total of nine occasions; five were observed in the RF carpus and four were observed in the LF carpus (three foals were bilaterally affected).

Laxity was observed most frequently (205 times) and affected the hindlimbs to a greater extent than the forelimbs. Fifty-eight foals were bilaterally affected by laxity in the hindlimbs, eight foals were solely affected in the RH limb and eight foals were solely affected in the LH limb. In the forelimbs, 33 foals were bilaterally affected by laxity, three foals were solely affected in the RF limb and four were solely affected in the LF limb.

Contracture was observed to affect hoof-ground contact on 43 occasions. Eight foals were bilaterally affected in the forelimbs, three foals were affected in the RF and four foals were affected in the LF. Seven foals were bilaterally affected in the hindlimbs; two foals were affected in the RF, while four foals were affected in the LF.

Contracture was observed in the fetlock and carpal regions on 66 occasions (Table 2-2). Five foals were observed with contracture in both the fetlock and carpal regions. Eight foals were observed with contracture affecting hoof-ground contact and the fetlock region, while three foals were observed with contracture affecting hoof-ground contact and the carpal region.

Table 2-2: The number of cases of contracture in the carpal and fetlock regions scored 2 or 3 (out of a 3 point scale) observed in foals between birth and 2 days of age. The number of foals affected bilaterally is shown in brackets.

<table>
<tr><th></th><th colspan="4">Affected Limb</th><th></th></tr>
<tr><th>Location</th><th>RF</th><th>LF</th><th>RH</th><th>LH</th><th>Total</th></tr>
<tr><td>Carpus</td><td>13</td><td>13</td><td>-</td><td>-</td><td>26</td></tr>
<tr><td></td><td colspan="2">(13)</td><td colspan="2"></td><td></td></tr>
<tr><td>Fetlock</td><td>4</td><td>3</td><td>17</td><td>16</td><td>40</td></tr>
<tr><td></td><td colspan="2">(3)</td><td colspan="2">(7)</td><td></td></tr>
</table>

2.4.4 Scoring

Scores were provided by stud farm personnel for 156/203 (77%) foals at birth, the remaining 47 (23%) scores provided for foals at birth were provided by study personnel. Follow up scoring throughout treatment and at two and six weeks tended to be lost and is discussed in greater detail in Chapter Four.

2.4.4.1 Distribution of scores

Laxity

The median score for foals with laxity was 2 (IQR 2-2) (Figure 2-7), indicating a mild laxity; the observed effect upon foals is shown in Figure 2-8b. A score of three was a moderate laxity (Figure 2-8c), which was observed on fewer occasions. Figure 2-8d shows an example of a foal for which a severe laxity was observed; very few cases of severe flexural laxity (four) were observed throughout the entire trial (Figure 2-7).

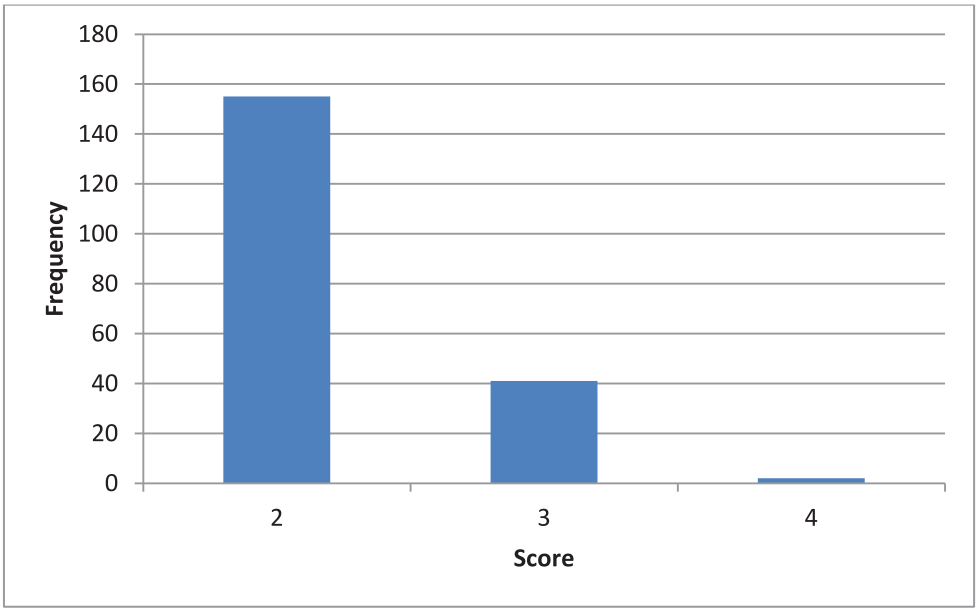


Figure 2-7: The distribution of flexural laxity severity scores in foals from birth - 2 days of age.

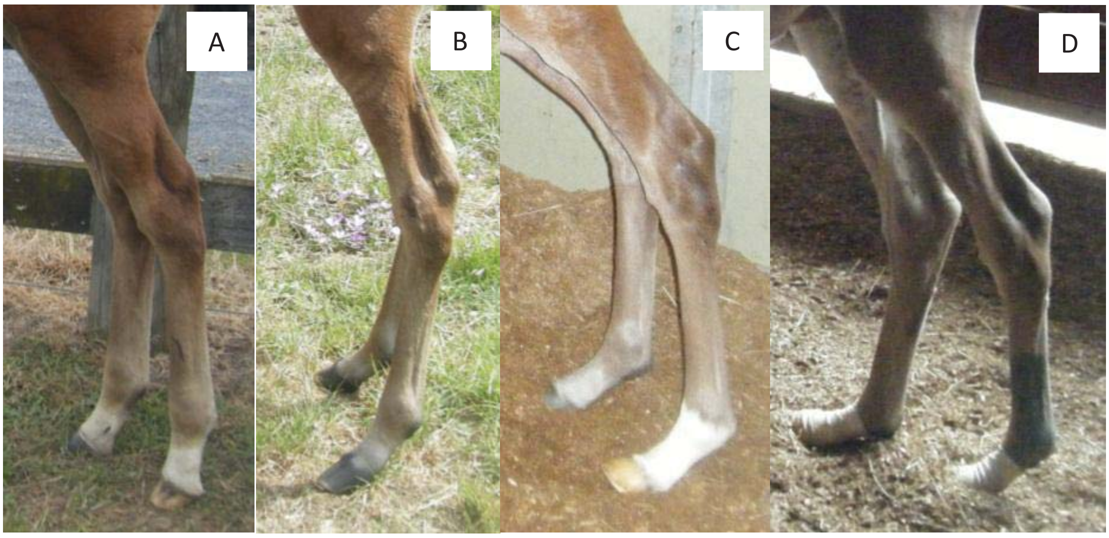


Figure 2-8: Examples of scores given to foals with apparent flexural laxity. Foal A - score 1, Foal B (left hind) – score 2, Foal C (left hind) - score 3 and Foal D (right hind) – score 4.

Contracture

The median score for contracture affecting hoof-ground contact was 2 (IQR 2-3) (Figure 2-9). A score of two was a moderate contracture; observed less frequently, a score of three was a severe contracture.

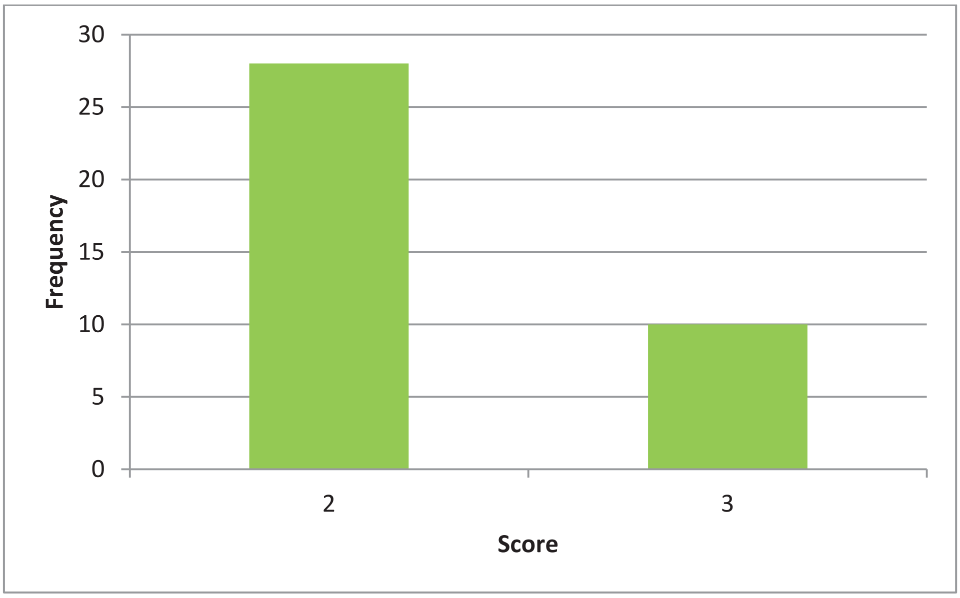


Figure 2-9: The distribution of severity scores for contracture affecting hoof-ground contact in foals from birth - 2 days of age.

The median score for contracture observed in the fetlock and carpal regions was 2 (IQR 2-2)(Figure 2-10), indicating a moderate contracture; the observed effect upon foals is shown in

Figures 2-11b (carpus) and 2-12b (fetlock). A score of three was a severe contracture and was observed on fewer occasions in both the carpal (Figure 2-11c) and fetlock regions.

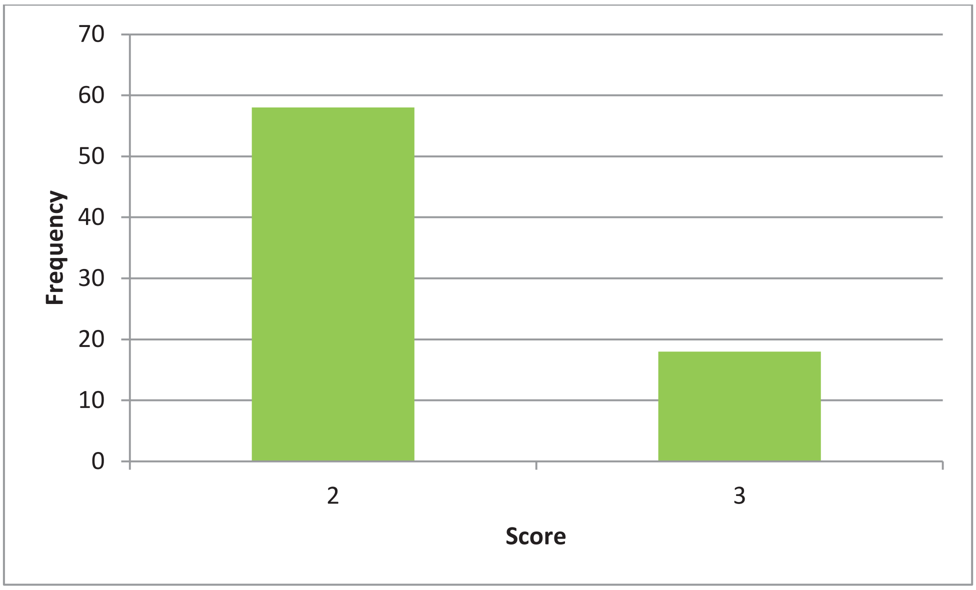


Figure 2-10: The distribution of score severity identifying the severity of contracture observed in the carpal and fetlock regions of foals from birth - 2days of age.

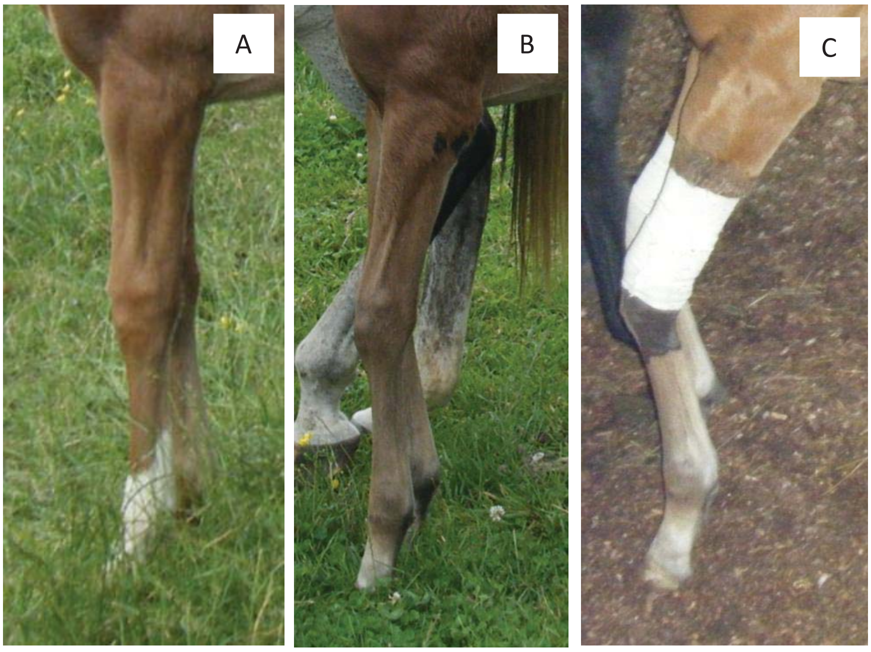


Figure 2-11: Examples of scores given to foals with apparent carpal contracture. Foal A - score 1, Foal B – score 2 and Foal C - score 3.

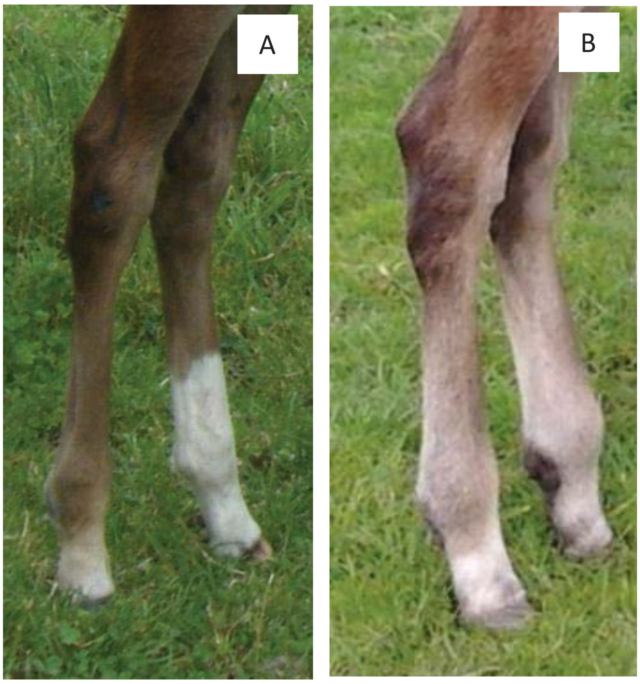


Figure 2-12: Examples of scores given to foals with apparent contracture of the fetlock region. Foal A - score 1 and Foal B (left hind) - score 2.

Twenty-six foals were observed with abnormal hoof-ground contact as a result of contracture, nine of these foals also had moderate and severe contractures in the fetlock or carpal regions (Table 2-3).

Table 2-3: Variations of hoof-ground contact was seen alongside apparent contracture of the fetlock and carpal regions in nine foals.

	Fetlock Score			Carpus Score		
Hoof-Ground Contact Score	1	2	3	1	2	3
1	-	-	-	-	-	-
2	-	4	-	-	2	-
3	-	1	6	-	-	2

2.4.4.2 Improvement in score

Only a select group of foals had scoring available at birth-2 days of age and at later time points. As a result of this, improvement in scores based on initial scoring and final scoring was taken irrespective of time point, providing a greater number of foals for comparison. Of the 153 foals observed with a FLD at any time point, 69 (45%) foals were rescored on later visits. Of the 69 foals rescored, 64 (93%) showed improvement in FLD scores, the remaining 5 foals (7%) showed no improvement in score.

Back at the knee

When accounting for improvement in score, 5/5 (100%) cases of back at knee went from being present (yes) to absent (no).

Laxity

For those foals with laxity, 1/97 (1%) improved from 3 (out of 4) to 2, 20/97 (21%) improved from 3 to 1, and 70/97 (72%) improved from 2 to 1; a small proportion of laxity scores (6.2%, n = 6) did not improve (Figure 2-13). Figure 2-14 shows improvement in laxity scores observed over a two week period.

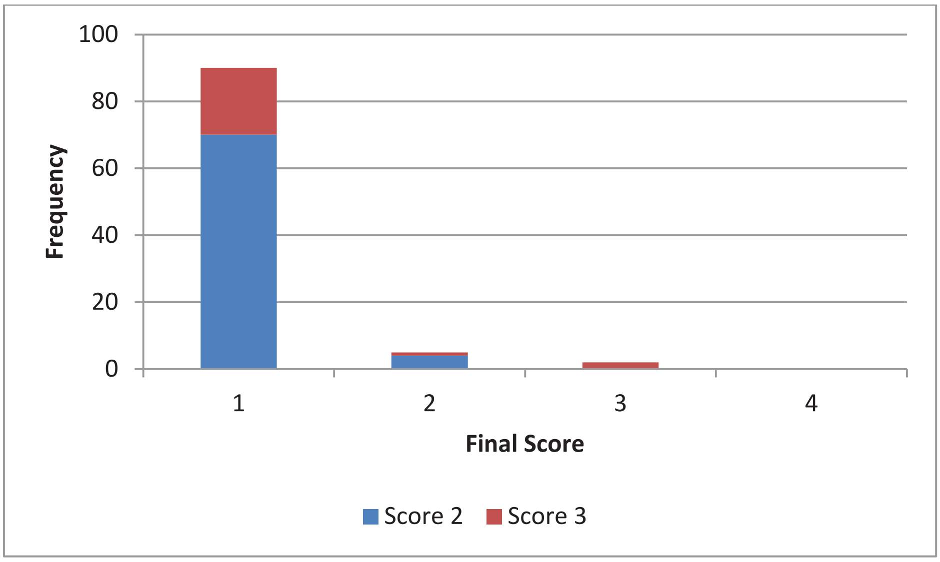


Figure 2-13: Changes in the scores observed for flexural laxity severity in foals on follow up visits.

Figure 2-14: This foal was bilaterally lax in the hind limbs at birth and was initially given scores of 3 at birth by the farm. Scoring by study personnel the following day gave the foals scores of 4 (A). Two weeks later (B), the foal was much improved and the hind hooves now scored 1.

Contracture

For the foals where contracture was observed to affect hoof-ground contact, 6/17 (35.3%) foals improved from a score of 3 (out of 3) to 1, while the remaining 11/17 (64.7%) improved from scores of 2 to 1.

For foals observed with contracture in the fetlock and carpal regions, 7/51 (13.7%) foals improved from 3 (out of 3) to 1 and 38/51 (74.5%) improved from 2 to 1; a small proportion (11.8%, n = 6) of contractures in the carpal and fetlock regions did not improve (Figure 2-15). Figure 2-16 shows a lack of improvement in the scores for contracture in the carpal regions during the study capture period.

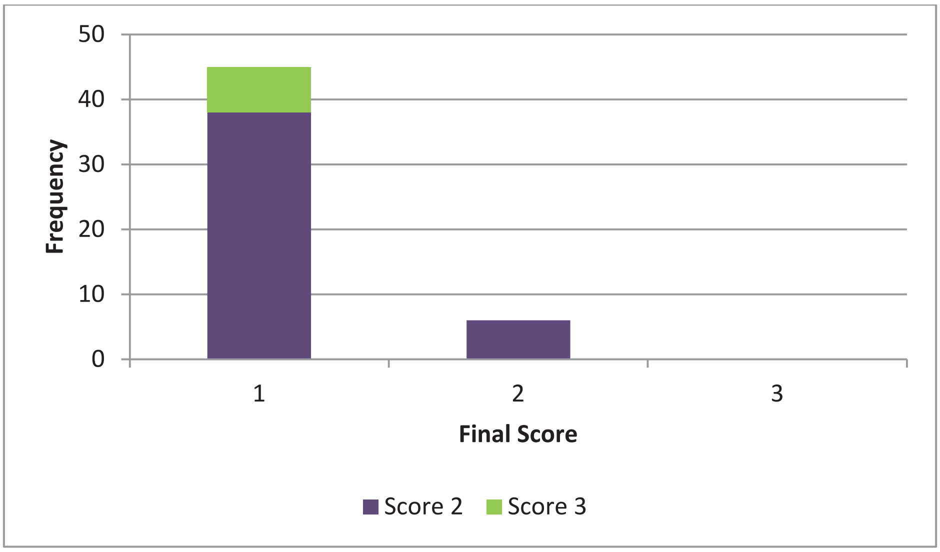


Figure 2-15: The changes observed in the severity of contracture score observed in the fetlock and carpal regions for foals on follow up visits.

Figure 2-16: This foal was observed with apparent bilateral contraction at the carpus and given severity scores of 2 (A), with no improvement shown the foal underwent bilateral check ligament desmotomy. Post-surgery (B) the foal struggled to stand by itself, the contracture worsening the longer it stood still (given severity scores of 3). Two weeks post-surgery (C), the foal was standing better however was still given severity scores of 3 – again deformity was observed to worsen the longer the foal stood still. Reports from the farm indicate that this foal recovered and severity scores of 1 would be appropriate.

2.5 Discussion

It is suggested that limb deformities may have an adverse effect on the future athletic careers of young foals (Stowers et al., 2010; Platt, 1979). With data recently captured in Standardbreds in New Zealand, the next step was to do the same in Thoroughbreds in New Zealand. Data were collected on five farms, of which a select sample of foals (n=203) were enrolled in the study (foals with FLD present and scored vs. foals scored clean[4]). While this was not a completely representative sample of the Thoroughbred foal population in New Zealand during the 2013/2014 season, this study provides new information on the descriptive epidemiology of flexural deformities in a population of Thoroughbred foals, which has not been previously documented.

It was intended that all foals would be assessed and subsequently scored if FLD was present. The foaling season is a very busy time on all breeding farms, particularly towards the peak of the season in September and October. In addition to this, it was not feasible for study personnel to be on each of the farms daily to collect data. As a result, this had an effect on the ability of stud farm personnel to fill in the required form for all foals born on the property and resulted in a considerably reduced number of foals available for analysis. The effects of this were observed with peak scoring occurring in September and then dropping right off. Had time not been such a factor, considerably more foals would have been scored in October and overall.

The effects of time and personnel available for data collection also tended to result in a selection bias by staff on most farms towards the foals with limb deformities, preferentially scoring them over foals without. This appears to have skewed our sample of foals, producing what is perceived to be a higher percentage of deformities than if all foals on each farm were scored. Therefore, comparisons with previous literature discussing the prevalence of limb deformities with the percentage of foals scored with limb deformities in this study, are difficult.

Gender had a significant effect on the percentage of FLD, with a greater proportion of colts with FLD being scored. Previous literature has reported varying effects of gender upon the presence of limb deformities. Recently, Stowers et al (2010) observed no effect of gender on the prevalence of angular and flexural contracture deformities in Standardbreds in New Zealand. In contrast, O'Donohue et al (1992) reported that a significantly lower incidence of

[4] Foals referred to as clean, were observed to have no limb deformities (flexural or angular) and were given scores of 1 in all limbs.

DOD was observed in Irish Thoroughbred fillies during the congenital and suckling phase. No attempt was made to identify the types of DOD which were included in this analysis by O'Donohue et al (1992), so it is unclear as to whether a significantly lower incidence of contracted tendons was observed in this group of fillies. As foals were often scored opportunistically on our farms, it is unlikely that they were particularly biased towards either gender. This tends to suggest that there may in fact be an effect of gender on the prevalence of FLD. Given however that this population of foals does not represent the entire population of foals in the 2013/2014 season it is difficult to determine the true effect and as such more work is required to determine if gender plays a significant effect upon prevalence.

It is well reported that older breeding mares have lower conception rates and/or have complications with pregnancies (Hanlon et al., 2012a; Jeffcott et al., 1982). In New Zealand, recent research completed on the reproductive performance of Thoroughbred mares in New Zealand (Waikato) by Hanlon et al (2012a) observed that mares older than 14 years had the highest rate of pregnancy loss. It has been observed that the median age of Thoroughbred mares bred in New Zealand is between 11 and 12 years (depending on stallion fee) (Rogers et al., 2009). The majority of mares that foaled were under the age of 12 years when bred in this study and appear to reflect the preference of breeders towards younger mares. There was a significant effect of mare age on the percentage of foals with FLD in this study, with older mares having a greater proportion of foals with FLD. While breeder preference for mares under the age of 12 is likely to be correlated to reproductive performance, there may also be some correlation to the prevalence of limb deformities. Platt (1979) suggested that older mares tend to have more foals with extensor and flexor limb deformities; however, little work has since been completed to further assess this. As with foal gender, the population of foals sampled in this study do not represent the entire 2013/2014 foal crop and as such further research is required to determine the true effect of mare age on the prevalence of FLD.

Previous literature regarding the observation of flexural limb deformities in foals is very limited. In a selective sample of Standardbreds in New Zealand, Stowers et al (2010) reported that 19% of foals were observed with a limb deformity (angular and flexural contracture). Crowe and Swerzek (1985) report similar values to Stowers et al (2010), however, their study investigated a population of 608 foals submitted for necropsy of which 122 (20%) were observed with miscellaneous limb contracture. In contrast, O'Donohue et al (1992) established that 193/1711 of Irish Thoroughbreds between 0-18 months had DOD and required treatment, only 18 of these 193 horses treated had contracted tendons. The percentage of FLD reported in this study is higher than these three studies and is a result of the unique differences between studies when defining, scoring and ultimately sampling limb deformities in the horse, making comparisons difficult. To allow accurate comparisons to occur amongst study populations, a standard protocol for data collection is required and study personnel must ensure that 100% of foals born are recorded.

When accounting for FLD separately in this study, the greatest proportion of foals were observed to have flexural laxity. Unfortunately, little mention is made of the numbers of cases of laxity observed in the current literature. Two studies do report observing laxity, but figures were either combined with contracture (Galvin & Corley, 2010) or combined with other 'limb defects' (Platt, 1979) and then provided as incidence rates, not prevalence. This tends to suggest that researchers have generally believed flexural contractures to be of more concern or importance, particularly given the fact that most cases of flexural laxity spontaneously resolve without interference (Lescun & Adams, 2011).

Despite variation in the number of foals scored each month, there was no effect of birth month on FLD; similar proportions of foals were observed with FLD each month. In addition to this, a large proportion of the foals observed with FLD were given scores of two (mild). These observations appear to reflect anecdotal suggestion that most foals are born with some degree of FLD. The semi-quantitative nature of the scoring systems required farms to score the foal based upon our criteria for FLD and not their own criteria. This is important as not all clinicians or stud farm personnel will consider deformities to be present or as severe as others – particularly between farms.

As stated, the majority of FLD cases resulted in scores of two. For laxity, this corresponds to what literature has classed as mild deformities; some cases were moderate (three), very few being severe (four) (Lescun & Adams, 2011). Cases of apparent contracture in the fetlock and carpal regions are more difficult to describe; most of the foals in this study corresponded to what literature has described as moderate (two) deformities, very few had severe (three) deformities (Adams & Lescun, 2011). The description of mild contractural deformities[5] in the carpal and fetlock regions requires work as it essentially describes a normal horse and using our scoring system they are scored as such. Fifteen foals were regarded as normal using this scoring method, but were observed to be upright or still showing some slight contracture, particularly in the carpal region. A study conducted by Anderson & McIlwraith (2004) described the conformation and development of Thoroughbred horses from weaning to three

[5] The foal is able to stand and nurse unassisted; ambulation occurs without any additional stress placed on the other limbs (Adams & Lescun, 2011).

years of age. Their findings showed that carpal conformation changes progressively from ‘back at the knee’ to ‘over at the knee’ with age; as such it was advised that one should be careful with individuals that are ‘over at the knee’ at a young age as this is likely to worsen. As such categorising these foals as ‘normal’ may give the perception that the deformity will not be of harm and will not worsen. There is an opportunity here to further develop this scoring system to better account for this.

Previous descriptions of flexural contracture concentrated on the ability of the foal to stand or of clinicians to extend the limb. We felt it necessary to take this scoring further, allowing for the effect of contracture on hoof-ground contact; particularly given that for some foals this was the only form of FLD present. In doing so, this system accounts for the effect contracture may have on the distal interphalangeal joints. The addition of this scoring system proved helpful when determining the full effect contracture had on the limb of the foal.

While FLD can be unilateral or bilateral (Trumble, 2005), the majority of foals with deformities in this study were bilaterally affected. It is quite common for deformities to be bilateral, particularly contracture in the carpus and laxity in the hind limbs (Lescun & Adams, 2011; Kidd & Barr, 2002). The mechanism behind this is currently unknown however it is likely that these foals simply had FLD as a result of intrauterine positioning/overcrowding; more research into this area is required as so little is known as to the causes.

A number of foals were also observed with contracture affecting hoof-ground contact. While this is how the deformity was best described in the scoring system to show how the foal was physically affected, the contracture itself likely originates from the region of the distal interphalangeal joint and not the hoof. In doing so this affects the degree to which the hoof stays in contact with the ground surface. The problem has been described as relatively uncommon (Munroe & Chan, 1996), but as observed in this study, will present in association with other contractures. Neither farm nor study personnel scored a foal with contracture observed in the distal interphalangeal joint region (particularly the pastern); it is likely that these foals are represented in the scoring of hoof-ground contact.

The majority of FLD are widely observed to dissipate with time and if required, treatment (Kidd, 2012; Adams & Lescun, 2011; Auer, 2006). As a result it was not surprising that with time (and treatment) the deformities observed in this population of foals were observed to show improvements in score. Foals that do not follow this normal pattern of score dissipation with time may suffer from more significant problems (e.g. contracted foal syndrome). It was intended that the treated foals were followed more often in order to observe any changes in score. However, the workload of the stud farm personnel during the busy breeding season prevented daily scoring of foals. Future studies should make this a priority as this will provide a greater insight into the changes observed in each deformity and the time over which these changes are observed.

The median time taken for foals to stand in this study were shorter than the median time to stand of 65 (IQR 45-100) minutes reported by Dicken et al (2012) in a selective population of Standardbreds in New Zealand (Southland). Differences between the breeds (TB and SB) and possible differences in their management could influence the times observed. Foaling staff in this study tended to watch mares and foals in the first few hours following birth, with some farms moving mares and foals to boxes soon after (particularly if FLD observed); in doing so farms may inadvertently encourage foals to stand earlier.

Some farms in this study regularly assisted foals to feed as part of standard practice. Results show that these farms were more proactive with feeding foals with FLD. The time to feeding for foals that did not receive feeding assistance was similar to those reported by Whittaker et al (2012) in average weight foals (103.2 ± 56.7 minutes). This difference is likely to result from the awareness that foals with FLD were more likely to have problems standing and ambulating, reducing their ability to feed and in doing so absorb colostrum efficiently.

Foaling management practices on the farms in this study were also assessed to establish whether any differences might be observed that may influence the management of foals with FLD. While some minor differences were observed in management (mainly between the smaller and larger farms), practices were in general very similar. It is well documented that the management of weanlings and yearlings on commercial Thoroughbred farms, is relatively consistent around New Zealand (Bolwell et al., 2010b; Stowers et al., 2009; Rogers et al., 2007). It is likely that the foaling management practices observed on these five farms would also be observed on other similar farms in the Auckland/Waikato region.

2.6 Conclusion

This study has identified the observed percentage of flexural limb deformities in New Zealand Thoroughbred foals to be higher than that of other studies. However, of the foals with flexural deformities, most were only mildly affected. More research is required to give a more accurate representation of the problem and in doing so provide a more conclusive answer about the prevalence of flexural deformities. Farm compliance was low after the initial scoring at birth, and future studies would benefit from having someone visiting farms daily to collect data, removing the obligation of staff to complete the paperwork. This will reduce the recall and selection bias of staff, while increasing sample size and in doing so producing an accurate record of the true prevalence of flexural limb deformities.

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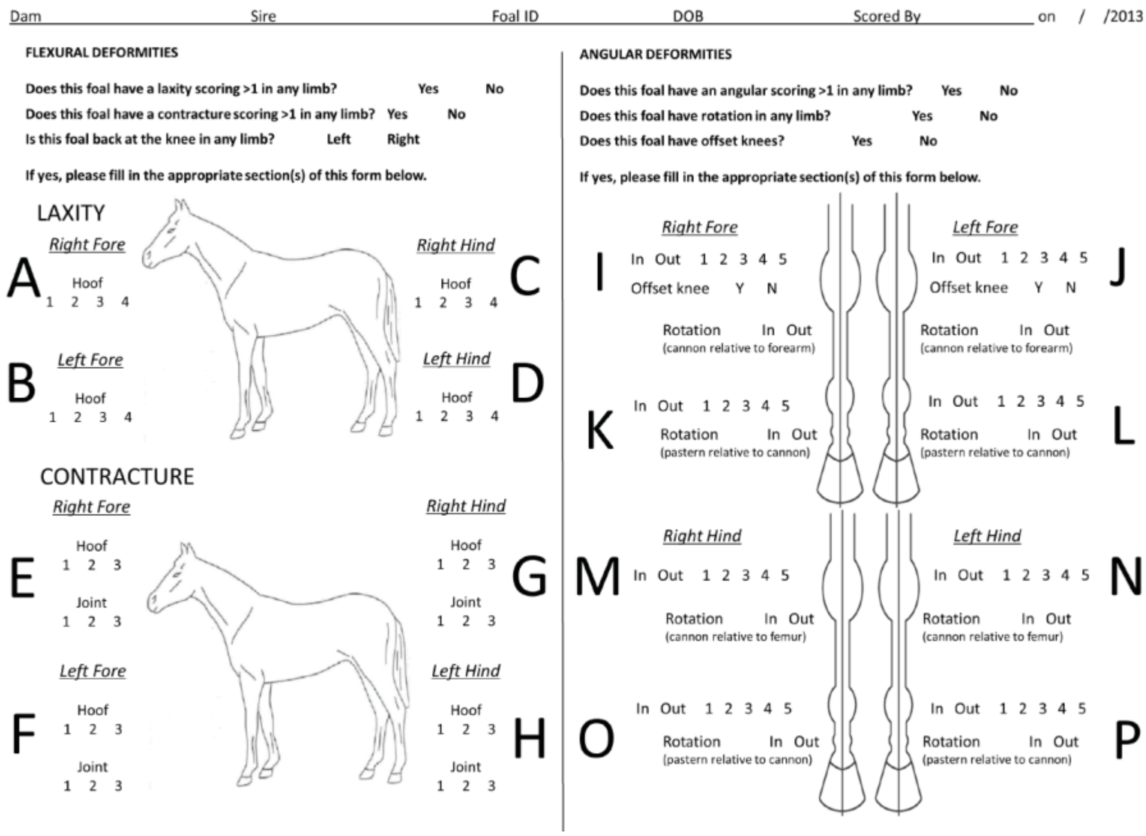
2.8 Appendix A


Dam Sire Foal ID DOB Scored By on / /2013

FLEXURAL DEFORMITIES

Does this foal have a laxity scoring >1 in any limb? Yes No
Does this foal have a contracture scoring >1 in any limb? Yes No
Is this foal back at the knee in any limb? Left Right

If yes, please fill in the appropriate section(s) of this form below.

LAXITY

A Right Fore Hoof 1 2 3 4
B Left Fore Hoof 1 2 3 4
C Right Hind Hoof 1 2 3 4
D Left Hind Hoof 1 2 3 4

CONTRACTURE

E Right Fore Hoof 1 2 3 Joint 1 2 3
F Left Fore Hoof 1 2 3 Joint 1 2 3
G Right Hind Hoof 1 2 3 Joint 1 2 3
H Left Hind Hoof 1 2 3 Joint 1 2 3

ANGULAR DEFORMITIES

Does this foal have an angular scoring >1 in any limb? Yes No
Does this foal have rotation in any limb? Yes No
Does this foal have offset knees? Yes No

If yes, please fill in the appropriate section(s) of this form below.

Right Fore

I In Out 1 2 3 4 5 Offset knee Y N Rotation In Out (cannon relative to forearm)
K In Out 1 2 3 4 5 Rotation In Out (pastern relative to cannon)

Left Fore

J In Out 1 2 3 4 5 Offset knee Y N Rotation In Out (cannon relative to forearm)
L In Out 1 2 3 4 5 Rotation In Out (pastern relative to cannon)

Right Hind

M In Out 1 2 3 4 5 Rotation In Out (cannon relative to femur)
O In Out 1 2 3 4 5 Rotation In Out (pastern relative to cannon)

Left Hind

N In Out 1 2 3 4 5 Rotation In Out (cannon relative to femur)
P In Out 1 2 3 4 5 Rotation In Out (pastern relative to cannon)

Figure 2-17: An example of the *pro forma* recording sheet provided to farms for scoring flexural and angular deformities.

Chapter 3 Agreement amongst observers of three semi-quantitative scoring systems for flexural limb deformities in Thoroughbred foals.

3.1 Abstract

The aim of this study was to evaluate the level of agreement between stud farm personnel and study personnel when scoring flexural limb deformities using scoring systems developed for this study. Data were collected on 203 foals from five thoroughbred stud farms during the 2013/2014 season. Foals were scored by stud farm and study personnel using semi-quantitative three and four point scale scoring systems designed specifically for the trial at birth, 2 weeks and 6 weeks of age.

Inter-observer agreement (between study personnel) was strong when scoring flexural laxity (κ=0.95), contracture affecting hoof-ground contact (κ=1.00) and contracture in the joint regions (κ=0.85). Inter-observer agreement (between study personnel and stud farm personnel) was lower when scoring flexural laxity (κ=0.69) and when scoring contracture in the fetlock and carpal regions (κ=0.14).

All three scoring systems proved to be easily implemented on farm and showed good reliability between assessors. Intra-observer agreement and comparison to a 'gold standard' were not possible in this study and are required to further test the reliability of the scoring systems. These systems will prove helpful when identifying the severity of flexural limb deformities observed in foals in future studies.

3.2 Introduction

Scoring systems are used widely to assess different aspects of horse health, including body condition, gastric ulcers, lameness, and injury (Bell et al., 2007; Grogan & McDonnell, 2005; Pleasant et al., 1997; Henneke et al., 1984). Before being widely implemented, evaluation must occur to ensure the reliability of the scoring system (Fuller et al., 2006). Testing typically occurs on an inter- and intra-observer basis; inter-observer testing ensures agreement among observers, while intra-observer testing ensures agreement within an observer (Mejdell et al., 2010; Fuller et al., 2006). In addition to this, the agreement between observers and a 'gold standard' can be tested (Mejdell et al., 2010). This ensures reliability of the system as a whole and any individual who uses the system can be confident in the results produced.

Anecdotally, breeders and clinicians have described the severity of limb deformity cases as mild, moderate and severe; little guidance has been given to identify between these scores leaving decisions up to subjective personal opinion. Severity of flexural contracture is frequently determined by a foal's ability to stand, feed and ambulate without assistance. Some scorers also take into account the extent of joint contraction and hoof-ground contact (Adams & Lescun, 2011; Auer, 2006). In contrast, severity of flexural laxity typically relates to the extent to which a foal's fetlock drops when bearing weight and the effect this has on hoof-ground contact (Adams & Lescun, 2011; Munroe & Chan, 1996). Despite this, there does not appear to be an established scoring system in place for flexural limb deformities.

The aim of the current chapter is to evaluate the agreement amongst personnel, when using the scoring systems provided in this study to score flexural limb deformities in foals.

3.3 Materials and Methods

3.3.1 Recruitment of Studs/Foals

The selection of stud farms and foals for this project has been described previously (Chapter Two). Briefly, five Thoroughbred breeding stud farms in the Auckland and Waikato regions took part in the trial and collected data on foals born on farm in the 2013/2014 season. These five Thoroughbred stud farms provided a population of 203 foals to follow and capture data from.

3.3.2 Scoring System

The scoring systems used in this study have previously been described in detail in Chapter Two. Briefly, three semi-quantitative scoring systems were generated to describe flexural contracture and laxity in foals. Flexural contracture was evaluated with a scale describing the hoof ground contact and a separate score to quantify the severity of the flexural contracture in the fetlock and carpal regions. The severity of flexural laxity was quantified by a single score based on a criteria focusing on its effect on the hoof. All foals were scored in the first 48 hours of birth; foals identified to require treatment for a deformity were scored again throughout or following treatment, where possible.

3.3.3 Data Collection

The process of data collection for this study has been described previously (Chapter Two). Briefly, data were recorded on *pro forma* recording sheets by stud farm personnel or by study personnel. These datasheets recorded foal identification and included an assessment of foal limb conformation as to the presence or absence of congenital limb deformities.

Each of the five farms enrolled were assigned to one of the two study personnel. To establish agreement between each of the studs and the study personnel (observer A and observer M), one of these five studs was also established as a crossover farm. Both study personnel visited this farm fortnightly to score the same foals. Further crossover was established towards the end of the season on an additional farm. Completed datasheets were collated and checked for consistency and errors before being entered into the customised Microsoft Access database.

3.3.4 Statistical Analysis

Data for foals that were scored at the same time by multiple personnel were extracted from the customised Microsoft Access Database (2010; Microsoft Corporation, Washington, USA) and analysed in Stata 12.0 (StataCorp LP, Texas, USA). Kappa tests were used to establish the inter-observer agreement amongst study personnel and the inter-observer agreement amongst study personnel and stud farm personnel.

3.4 Results

3.4.1 Laxity

There was good agreement between study personnel (observer A & observer M) when scoring the severity of laxity (κ=0.95, P<0.001). The level of agreement did not vary across the scoring categories (Table 3-1), and agreement was observed in all but two cases.

Table 3-1: Agreement between study personnel (observer A and M) was strong when scoring the severity of laxity.

		Observer M			
	Severity score	1	2	3	4
Observer A	1	90	1	-	-
	2	1	13	-	-
	3	-	-	6	-
	4	-	-	-	2

There were few scores to test agreement between study personnel and stud farm personnel. There was significant but lower agreement between the study personnel and stud farm personnel for scoring of laxity, than between study personnel (κ=0.69, P<0.001; n=9). The lower level of agreement was in part due to variation in the agreement at the lower end of the range between scores 1 and 2.

3.4.2 Contracture

3.4.2.1 Hoof-ground contact

There was good agreement between study personnel (observer A & observer M) when scoring contracture affecting hoof-ground contact (κ=1.00, P<0.001). Variation in agreement did not occur across the scoring categories (Table 3-2).

Table 3-2: Agreement between study personnel (observer A and observer M) was strong when scoring contracture affecting hoof-ground contact.

		Observer M		
	Severity Score	1	2	3
Observer A	1	74	-	-
	2	-	2	-
	3	-	-	-

3.4.2.2 Joint region

There was good agreement between study personnel (observer A & observer M) when scoring contracture in the fetlock or carpal regions (κ=0.85, P<0.001). Minor variation in agreement was observed across the scoring categories (Table 3-3).

Table 3-3: Agreement between study personnel (observer A and observer M) was strong when scoring contracture in the fetlock or carpal regions.

		Observer M		
	Severity Score	1	2	3
Observer A	1	82	1	-
	2	2	15	-
	3	-	2	2

There were few joint region scores to test agreement between study personnel and stud farm personnel. There was little agreement between study personnel and stud farm personnel for scoring of contracture in the fetlock or carpal regions (κ=0.14, P=0.24; n=8). Variation in agreement occurred at the lower end of the range between scores 1 and 2.

3.5 Discussion

Three new scoring systems were developed for this study and were based on previous descriptions of the severity of congenital flexural contracture and laxity in foals. The reason behind development of new scoring systems was that previous FLD descriptions were subjective and may permit inconsistency in interpretation by multiple evaluators. Within the literature there has been limited standardized description of flexural deformities with scoring consisting of mild, moderate or severe, the criteria for which were dependent on the evaluator. This has made it difficult to not only compare figures reported in the literature, but to also quantify the impact of FLD and determine the need for work in the area.

The scoring systems used in this study were semi-quantitative and allowed for little misinterpretation of what should have been observed in the foal for each score. There is however still some room for improvement as problems with previous scoring were carried over into one of the three systems due to poor description of what was observed in the foal with mild contracture of the fetlock or carpal regions.

Inter-observer agreement amongst study personnel and stud farm personnel was tested in order to determine whether these three systems were able to accurately define the same deformities on all farms, regardless of the scorer. It is suggested that Kappa values of less than 0.4 can be considered “clinically unacceptable” (Fuller et al., 2006; Sim & Wright, 2005), while Kappa values greater than 0.8 are usually regarded as providing excellent agreement in clinical observations (Kristensen et al., 2006). Inter-observer agreement between the two study personnel proved to be good in all three systems ($\kappa > 0.8$). As a result, these initial tests suggest that these scoring systems provided a reliable form of measuring the severity of FLD in this study.

Further agreement testing between the two study personnel and stud farm personnel for flexural laxity was good, however could have been much better. The difficulty with assessing inter-observer agreement with farms was due to low numbers and resulted from the fact that many of the farms were not scoring foals on the same day as study personnel, either as a result of being unable to score foals on those particular days or having already scored them the previous day. Many foals were scored by study personnel within 24 hours of stud farm personnel but due to the plasticity of flexural limb deformities scoring would have been expected to be different as a result of improvement. This plasticity may have also been the source of poor agreement between observers scoring on the same day. Stud personnel scored foals at around 8am in the morning (Chapter One) and some of the visits by study personnel were not until late in the afternoon; some foals may have shown signs of improvement (or worsening) by the time study personnel had scored them. Despite this increased level of poor agreement, it was encouraging to still observe a good kappa value. Had study personnel been equipped to visit all farms daily and score foals at the exact times stud farm personnel did, this value for agreement would have been expected to improve due to the nature of scoring system leaving little room for misinterpretation.

Inter-observer agreement was poor ($\kappa<0.2$) between study personnel and stud farm personnel when scoring contracture in the fetlock and carpal regions. This scoring system was the most likely to be open to interpretation due to the descriptions provided and the lack of diagrams or images depicting what was expected within each category. The other two scoring systems provided diagrams for each of the scores and provided little question as to whether a foal was one score or another. In addition, very few opportunities were provided where study personnel were able to score alongside stud farm personnel at the same time, providing the same problems observed in inter-observer agreement for flexural laxity between study and stud farm personnel. If images or diagrams been provided for contracture observed in the fetlock or carpal regions, inter-observer agreement would be expected to be higher.

When testing scoring systems for inter-observer agreement, observers can be tested against a 'gold standard' – this is often someone involved with creating the scoring systems or training those who use it (Burn & Weir, 2011; Mejdell et al., 2010). In the case of equine scoring systems, this person is often a veterinary clinician or trainer (Mejdell et al., 2010). When agreement between the 'gold standard' and observers is high it provides a greater assurance of the reliability of the scoring systems when used by others (Mejdell et al., 2010). To provide a greater assurance of the reliability of these three scoring systems, future studies would benefit from comparing observers to a 'gold standard'.

Other studies testing the agreement and reliability of scoring systems have also tested intra-observer agreement for observers in addition to inter-observer agreement to provide further validation to their scoring systems (Mejdell et al., 2010; Fuller et al., 2006; Kristensen et al., 2006). It was not feasible to test intra-observer agreement for study personnel or stud farm personnel in this study given the nature of data collection. Working in the field on commercial farms, did not allow standardised photos or videos for every foal scored to be captured easily, which would have allowed testing of intra-observer agreement at later stages of the study when study personnel were no longer familiar with the scores they had given. In addition, photos or video do not always capture the real extent of severity and may result in underestimation of scoring. The time that would have been required to execute testing with stud farm personnel was also a factor; more often than not, study personnel scored foals in the absence of stud farm personnel due to the busy workload on the farm. Finding time to get stud farm personnel to rescore images of foals would have proven very difficult. The other difficulty that would have become apparent is that stud farm personnel get to know mare and foal pairs very well and would therefore be inclined to remember the scores given to these foals when testing intra-observer agreement based on photos or video footage. Future studies would have to establish a protocol that would feasibly allow the collection of suitable data from which intra-observer agreement could later be tested accurately.

3.6 Conclusions

The three scoring systems produced for this study proved to be highly reliable when comparing scores recorded by study personnel. Poor agreement with stud farm personnel when using these systems was observed, which was a combination of the nature of data collection and low numbers with which to test agreement. Before these scoring systems can be regarded as a 'go to' for scoring FLD, further testing of inter- and intra-observer agreement is required to determine if the results in this study are repeatable and if this is a valid method of scoring. Adjustments to the scoring of contracture in the fetlock and carpal regions would firstly be advised to remove any remaining subjectivity.

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Chapter 4 Identification of the interventions used when treating flexural deformities and their success in Thoroughbred foals in New Zealand.

4.1 Abstract

The aim of this study was to identify and describe the methods used by stud farms to treat flexural deformities in Thoroughbred foals in New Zealand. In addition, we aimed to determine at what point stud farms considered treatment to be complete or successful. Data were collected on 203 foals from five thoroughbred stud farms during the 2013/2014 season. Of the foals scored with FLD (135/203), 40/135 (30%) had treatment records provided.

Treatment for mild and moderate cases of flexural contracture and flexural laxity tended to be conservative (confinement). In contrast, treatments provided for severe cases of flexural contracture were more invasive and several treatments were often used in conjunction. Improvement in FLD scores were observed for 28/42 (67%) cases of contracture observed to effect hoof-ground contact, 33/43 (77%) cases of contracture affecting the fetlock and carpal regions and 36/56 (64%) cases of laxity. Of the deformities to have shown improvement, 11 cases of contracture affecting hoof-ground contact, 28 cases of contracture affecting the fetlock and carpal regions and 14 cases of laxity were identified as having completed treatment.

Treatments varied according to the type and severity of deformity. Mild and moderate cases of flexural laxity and contracture primarily resolved with confinement, whilst severe deformities required more invasive treatments.

4.2 Introduction

The percentage of FLD in a selective population of Thoroughbred foals in New Zealand was reported to be 67% (Chapter Two). Flexural limb deformities are the result of a deviation in the sagittal plane that results in persistent hyperextension or hyperflexion of the joints and musculotendinous units in the limb (Auer, 2006; Munroe & Chan, 1996). Intervention is often required for as foals are unable to stand correctly (Kidd & Barr, 2002). Treatment type, length, success and prognosis are all ultimately determined by the location and severity of the deformity (Auer, 2006; Hardy & Latimer, 2003; Munroe & Chan, 1996). From an athletic perspective, prognosis is regarded to be favourable if the foal responds well to treatment within the first two weeks and is active without assistance (Hunt, 2011). Prognosis is less favourable when treatment proves unsuccessful or where surgical procedures prevent an athletic future (Lescun & Adams, 2011).

When treating flexural contracture, the aim is often to encourage the musculotendinous units to relax and stretch, allowing the foal to bear weight normally (Kidd, 2012; Trumble, 2005; Munroe & Chan, 1996). Treatments used widely include: controlled exercise and physiotherapy (Adams & Santschi, 1999; Orsini & Kreuder, 1994), administration of oxytetracycline (Kidd, 2012), toe extensions, splints or casts (Baxter, 2011a; Auer, 2006), and surgery (Kidd, 2012; Adams & Lescun, 2011). In comparison, when treating flexural laxity, the aim is often to encourage strengthening of the musculotendinous units (Kidd, 2012; Lescun & Adams, 2011; Munroe & Chan, 1996). Treatment methods include: close monitoring from birth and restricted exercise (Auer, 2006), light bandaging (Kidd, 2012; Auer, 2006), heel extensions, and surgery (Lescun & Adams, 2011).

While treatment methods are widely described, there is a paucity of data regarding their use on farm to correct flexural limb deformities, and the success rate of such treatments. The aim of the current study is to determine the treatment methods regularly utilised on commercial Thoroughbred stud farms in New Zealand to treat flexural deformities in foals and to determine the success of these treatments on farm.

4.3 Materials and Methods

4.3.1 Recruitment of Studs/Foals

The selection of stud farms and foals for this project has been described previously (Chapter Two). Briefly, five Thoroughbred stud farms (farms A-E) in the Auckland and Waikato regions took part in the trial and provided a sample of 203 foals to follow in the 2013/2014 season.

4.3.2 Deformity Scoring System

The scoring systems utilised to capture limb deformity data and the changes in severity in this study have previously been described in Chapter Two. Briefly, the scoring systems produced for this study provided objective methods for scoring foals. Two scores (hoof-ground contact and severity of contracture observed in the carpal or fetlock regions) were required for cases of flexural contracture, while one score was required for cases of flexural laxity (laxity severity). Where possible, foals were scored at birth, during/after treatment and at two and six weeks of age.

4.3.3 Treatment Data Collection

In addition to the data collection described previously (Chapters Two and Three), stud farm personnel filled out *pro forma* recording sheets detailing treatments provided to foals with deformities. Where possible, foals were rescored at a later date to record any changes in deformity score. Stud farm personnel were asked to identify the deformity, which treatments were provided and the duration of treatment, whether the deformity was showing improvement and at what point they deemed treatment to be complete. Additional information regarding treatment could be provided in free text boxes. Datasheets were collected from the stud farms and checked for consistency and errors before being entered into the customised Microsoft Access Database (2010; Microsoft Corporation, Washington, USA).

4.3.4 Statistical Analysis

Categorical variables farm and gender were summarised as numbers and percentages based upon availability of treatment records. Treatments provided to foals were grouped by type of FLD and reported as numbers and percentages. The number of deformities for which these treatments were provided were summarised by score severity and improvement. The number of treatment cases recorded as complete were grouped by type of FLD and reported as numbers and percentages.

4.4 Results

4.4.1 Descriptive Data

Of foals observed to have FLD at birth (Chapter Two), 40/135 (30%) received treatment. Of these foals, 23/40 (52%) presented with laxity, 19/40 (43%) with contracture and 2/40 (5%) were back at the knee (four foals had multiple types of deformities).

4.4.1.1 Farm

Of the foals scored with FLD on farm A, 46% (13/28) had treatment records. On farm B, 40% (4/10) of the foals with FLD are recorded as having received treatment. On farm C, treatment records were provided for 17% (4/23) of the foals with FLD. On farm D, treatment records were available for 23% (7/30) of the foals with FLD. Treatment records were available for 27% (12/44) of the foals with FLD on Farm E.

4.4.1.2 Gender

Of the foals treated for FLD 24/40 (60%) were colts and 16/40 (40%) were fillies.

4.4.2 Treatment types

The treatment methods utilised by stud farms varied, with 12/40 (30%) foals receiving multiple treatments. Treatments recorded by the farms included confinement, oxytetracycline, splints, toe extensions, bandaging, surgery, casts, exercise, physiotherapy, trimming and euthanasia.

4.4.3 Number of deformities observed and their treatment

Two foals received treatment for back at the knee, both were confined, one foal was exercised in addition to confinement. Treatments provided for foals with flexural laxity (n=23) included confinement (23/23; 100%), exercise (1/23), hoof trimming (1/23) and bandages (1/23) (4%). Most of the foals (20/23; 87%) had multiple cases of laxity deformity for which treatment was provided. Scores for the deformities observed in the 23 foals are shown in Table 4-1.

Table 4-1: Severity of laxity deformities (scores 1-4) at birth and the number of these deformities observed by treatment type. The number of deformities which were recorded to improve following treatment is also shown.

	Score Severity				
	1	2	3	4	Improved
Confinement	-	39	9	2	32
Trimming	-	4	-	-	4
Bandages	-	-	2	-	-

Treatments provided for foals with contracture affecting hoof-ground contact (n=9) included confinement (8/9; 89%), administration of at least one course of oxytetracycline (3/9) and toe extensions (3/9) (33%). In addition, splints (2/9; 22%), bandages (1/9), casts (1/9) and surgery (1/9) (11%) were also utilised. Most of the foals (7/9; 78%) had multiple cases of contracture affecting hoof-ground contact for which treatment was provided. Scores for the deformities observed in these nine foals are shown in Table 4-2.

Table 4-2: Severity of flexural contracture on the degree of hoof-ground contact (scores 1-3) at birth and the number of these deformities observed by treatment type. The number of deformities which were recorded to improve following treatment is also shown.

	Score Severity			
	1	2	3	Improved
Bandages	-	-	2	1
Casts	-	-	2	2
Confinement	2	9	10	12
Oxytetracycline	-	4	3	4
Splints	-	-	3	3
Surgery	-	-	2	2
Toe Extensions	-	-	5	4

Treatments provided for foals with contracture affecting the fetlock and carpal regions (n=12) and included confinement (10/12; 83%), splints (5/12; 42%), administration of at least one course of oxytetracycline (3/12; 25%), surgery (2/12) and toe extensions (2/12) (17%). In addition, bandages (1/12), casts (1/12), physiotherapy (1/12) and euthanasia (1/12) (8%) were also provided. Six of the foals (50%) had multiple cases of contracture affecting the fetlock and carpal regions for which treatment was provided. Scores for the deformities observed in these 12 foals are shown in Table 4-3.

Table 4-3: Severity of apparent flexural contracture on the fetlock and carpal regions (scores 1-3) at birth and the number of these deformities observed by treatment type. The number of deformities which were recorded to improve following treatment is also shown.

	Score Severity			
	1	2	3	Improved
Bandages	-	-	2	1
Casts	-	-	2	2
Confinement	-	10	5	12
Euthanasia	-	-	5	-
Oxytetracycline	-	2	3	4
Physiotherapy	-	2	-	2
Splints	-	2	3	5
Surgery	-	2	2	4
Toe Extensions	-	-	3	3

4.4.4 Treatment completion

Treatment completion was recorded for 15 cases of laxity; 11/15 (73%) were treated with confinement, while 4/15 (27%) were trimmed.

Treatment was recorded as complete for 11 cases of contracture observed to affect hoof-ground contact; 3/11 (27%) were treated with toe extensions, 2/11 (18%) were confined, 2/11 (18%) were splinted, 2/11 (18%) were administered at least one course of oxytetracycline and 2/11 (18%) were treated with surgery. Treatment was not recorded as completed at the time of recording for five cases of contracture observed to affect hoof-ground contact. The treatments for these cases included casts (2/5), administration of at least one course of oxytetracycline (2/5) and splints (1/5).

Treatment was recorded as complete for 28 cases of contracture observed in the fetlock or carpal regions; 7/28 (25%) were treated with confinement, 5/28 (18%) were euthanized, 4/28 (14%) were treated with surgery and 4/28 (14%) were treated with splints, 3/28 (11%) received toe extensions and 3/28 (11%) were administered at least one course of oxytetracycline. An additional 2/28 (9%) cases were treated successfully with physiotherapy. Treatment was not recorded as complete for seven cases of contracture observed in the fetlock or carpal regions. The treatments for these cases included casts (2/7), confinement (3/7), administration of at least one course of oxytetracycline (1/7) and splints (1/7).

4.5 Discussion

Intervention is often required for foals born with flexural limb deformities in order that they may stand correctly (Kidd & Barr, 2002). While the treatments available for flexural limb deformities are widely discussed in the literature, there is a paucity of data regarding their use on farm and the resulting success rates – particularly in New Zealand.

The paucity of "real world" data on the efficacy of different treatment regimens may reflect the challenges of data capture during what is a very busy and condensed breeding season in the Southern Hemisphere (Rogers et al., 2007). The effects of workload on stud farm were observed on the broad evaluation of limb deformities throughout the project and the constraints of time also had an effect on record keeping compliance during the treatment period. These constraints were observed in the relatively low number of foals with completed treatment sheets available for detailed analysis, despite the bias of farms to score foals with deformities.

Most of the flexural deformities scored at birth were classified as mild or moderate (Chapter Two). A deformity scored as a two or three for laxity or a two for contracture, often resolved well with limited/conservative treatment. Conservative management is often advocated for foals with mild and moderate forms of FLD (Auer, 2006; Kidd & Barr, 2002). Conservative treatment is typically of low cost to the owner, and usually results in resolution of the problem so more invasive (and expensive) treatments are not required.

The most conservative form of treatment is confinement to a small paddock or box as it restricts foal activity and exercise (Lescun & Adams, 2011). Confinement was used by stud farms for all foals with flexural laxity as it not only restricted exercise, but also provided cushioning to protect the caudal hoof/fetlock from injury. While literature widely recommends treatments such as trimming, bandages, shoes and extensions for flexural laxity, farms preferred instead to confine foals first, utilising other methods if required at a later stage of treatment. Trimming of the heel is advocated with mild deformities as it provides a greater surface area for which the foal is able to weight bear on (Lescun & Adams, 2011; Kaneps & Smith, 1998); only one foal in this study received trimming. Moderate cases of laxity are suggested to benefit from glue on shoes and/or extensions (Lescun & Adams, 2011; Auer, 2006; Kaneps & Smith, 1998), however stud farms in this study chose not to utilise either of these options in any of their foals. One foal in this study required bandaging for flexural laxity and was initially identified as moderately deformed (three), however on day two following birth the foal was regarded as severely deformed (four). The provision of bandages is generally only recommended for severe cases of laxity (Lescun & Adams, 2011; Auer, 2006; Kaneps & Smith, 1998). In the case of this foal, bandaging was provided solely to protect the caudal aspect of the fetlock. While multiple treatments are advocated for treating flexural laxity, confinement was the most common form of treatment New Zealand farms; other treatments provided were more to prevent further injury rather than to improve deformity.

Treatments provided for cases of flexural contracture were more varied. Mild cases of contracture are said to resolve spontaneously with little interference, however intervention is recommended for moderate and severe deformities (Adams & Lescun, 2011). As with flexural laxity, confinement was commonly implemented to most foals; other treatments were then provided alongside when deemed necessary. Confinement again allowed farms to monitor these foals closely and provided foals with cushioning when required.

Physiotherapy in combination with exercise is suggested as being beneficial for mild and moderate forms of contracture (Hunt, 2011; Orsini & Kreuder, 1994). This is however a time consuming process and it is suggested that manipulation of the limb should occur 4-6 times a day for between five and ten minutes (Rodgerson, 2008; Orsini & Kreuder, 1994). For this reason it is likely that stud farms prefer not to utilise physiotherapy where possible. Only one foal received physiotherapy in this study; this foal was one of the first foals born on one of the larger farms and also suffered from flexural laxity – as such, oxytetracycline was not used for fear of laxity worsening. Had this foal been born later in the season, the time required for physiotherapy would not have been freely available and other treatment methods would have instead been utilised.

Contrary to our expectations, only a small number of the foals treated for contracture received oxytetracycline. This is a widely utilised drug to treat contractures as it increases the ability of the foal to bear weight on the developing tendons and ligaments (Kidd, 2012; Adams & Lescun, 2011; Trumble, 2005). The deformities observed in the foals for which we have details may not have been considered serious enough to require the treatment of oxytetracycline; particularly given that most foals were still weight bearing on the caudal foot. The response of the musculotendinous unit to oxytetracycline has been described as rapid, but transient (Adams & Lescun, 2011; Trumble, 2005) and may also be a reason for the reduced usage observed in this study. In addition, while oxytetracycline provides complete correction for milder deformities, the response is reported as minimal for severe deformities (Kidd, 2012; Auer, 2006). For those with severe contracture, farms may have chosen to opt for more invasive treatments (e.g. splints, casts or surgery) that would seemingly provide a more conclusive end to treatment.

Bandages, casts and splints are commonly recommended for treatment of both moderate and severe deformities (Adams & Lescun, 2011; Auer, 2006; Kidd & Barr, 2002) – with such treatments indicated for longer periods in foals with severe deformities compared to moderate deformities (Adams & Lescun, 2011). These treatments apply a constant pressure to the musculotendinous unit, straightening the limb and allowing the musculotendinous unit to relax (Trumble, 2005). Splints tend to be preferred over casts as they are easily removed/reapplied for short periods of treatment (Auer, 2006; Kidd & Barr, 2002). Bandages, casts and splints tended to be provided more to foals with severe deformities on the farms in this study.

Surgery is rarely used (Adams & Lescun, 2011; Auer, 2006; Kidd & Barr, 2002) and tends to be reserved for contracture deformities that have not responded to other treatments (Trumble, 2005). This was observed on the farms in this study which had foals that underwent surgery; previous treatments had proved ineffective and surgery was their only remaining option. Unexpectedly, the use of surgery was also recorded for the treatment of moderate contracture deformities, however the foals for which this was recorded also had severe deformities (three) in another region which were treated with surgery. Treatment records were not clear as to which deformity treatment was for and it is likely that surgery was primarily for the severe deformity.

One foal with severe contracture in all four limbs which was deemed untreatable was euthanized. Not always avoidable, euthanasia is recommended for cases in which foals are severely deformed (Rodgerson, 2008) and in which treatment does not significantly improve the foal (Trumble, 2005). This is something all commercial stud farms wish to avoid if possible due to the time and money involved in producing these foals with an end goal of producing the yearling sales in February. The wide variation observed in the types of treatment provided for severe cases of contracture suggests that stud farms provide multiple forms of treatment in an attempt to reduce severity at a rapid rate and avoid euthanasia at all costs.

With such small numbers for which treatment records were provided and large variation in the treatments provided, it was not possible to determine which treatments were more effective, or in the case of contractural deformities, which treatments were more commonly provided over others (apart from confinement). Loss of follow up data following scoring was unfortunate as many foals receiving treatment had incomplete or missing records; had complete records available we may have been able to gain a better idea of what occurred. Stud farms also tended to provide multiple treatments at once in an effort to encourage contracture deformities to improve at more rapid pace, but in doing so removed our ability to determine which were more effective.

It was unusual for a foal to show no signs of improvement in score following treatment for flexural laxity as, except in severe cases, these foals are expected to recover with little assistance. The use of treatments by stud farms on foals with mild and moderate deformities tends to suggest they prefer to be cautious and/or proactive doing as much to assist a return to normal as soon as possible. The same can be said for contracture deformities – most improved with limited interference. Of those for which treatment improvement was not recorded, it is likely these foals did in fact improve, but that additional records were lost to follow up. The same is true for records of treatment completion.

4.6 Conclusion

Data produced from this study suggests that treatment of FLD in Thoroughbred foals by New Zealand stud farms is pragmatic. Stud farms aim to resolve the effects of flexural limb deformities in mildly and moderately effected foals with limited interference; confinement working well for most of these foals. In contrast, when foals present with severe deformities, the opposite effect is observed and multiple invasive treatments are instead provided. Despite the differences in these approaches, improvement in the severity of flexural limb deformities occurs in most cases.

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Chapter 5 General Discussion

The primary aim of this thesis was to determine the prevalence of congenital flexural deformities (laxity and contracture) in Thoroughbred foals in New Zealand at birth (within 48 hours post-partum). Within the literature there has been poor consensus on repeatable descriptors of flexural deformities in the foal. This has resulted in a wide variety of case definitions, sampling frames, scoring methods and ultimately the prevalence values reported. Case definitions for deformity have included combinations of angular and flexural deformities (Stowers et al., 2010), forms of flexural contracture (Platt, 1979), flexural contracture and laxity (Galvin & Corley, 2010) and developmental orthopaedic disease (O'Donohue et al., 1992). Sampling frames have included 24 hours (Stowers et al., 2010), 0-2 months (Platt, 1979), 0-12 months (Galvin & Corley, 2010) and 0-18 months (O'Donohue et al., 1992) and in doing so may have accounted for both congenital and acquired forms of limb deformities. To the authors knowledge this is the first study to try and identify the prevalence of flexural limb deformities using semi-quantitative scoring methods.

Data collection relied heavily upon stud farm personnel for the scoring of flexural limb deformities. Due to the effects of workload and limited time available for stud farm personnel to complete the scoring, there was a selection bias towards the foals with flexural limb deformities. The perception by stud farm personnel appeared to be that these foals were of most interest; while true, this did not remove the fact that it was also important to capture data on the foals that were not affected in order to obtain true prevalence. As a result, true prevalence was unable to be calculated and instead the percentage of foals affected by FLD was reported. As such, observations reported in regards to this group of foals (e.g. the significance of gender upon the presence of FLD) must be interpreted carefully as were deformity scores available for all foals born in this season, different results may well have been observed.

Until now, identification of deformities has proven to be subjective; the terms mild, moderate and severe are extensively used (Adams & Lescun, 2011; Lescun & Adams, 2011; Munroe & Chan, 1996), however few have discussed the observed effect on the foal in relation to these terms. This has left assessment of severity to the perception of the individual and can be a source of bias and poor inter-observer agreement. The lack of a consistent scoring system means that previous literature has likely considered the presence of flexural deformities to different degrees, making comparison difficult. The semi-quantitative scoring systems presented in this thesis have attempted to move closer to the validation of such a scoring system, and allow greater accuracy when identifying the presence of flexural limb deformities. Scoring for flexural laxity remained similar to previous definitions of the deformity (Lescun & Adams, 2011), however visual diagrams were also provided for reference. When scoring flexural contracture, this study provided a point of difference to previous descriptions and rather than simply describing the ability of a foal to stand (Adams & Lescun, 2011), considered the effects of contracture upon hoof-ground contact and the joint regions. Visual references were provided for the effect of contracture upon hoof-ground contact. The effect of contracture upon the joint regions relied solely upon descriptors and further work is required to better account for mild forms of contracture.

Of the foals that had flexural contracture and flexural laxity, median scores of two were observed and as such reflected the presence of mild to moderate deformities; very few foals presented with severe deformities. Initial tests suggest that these scoring systems were fairly robust, with only minor disagreement observed between study personnel. Disagreement observed between study personnel and stud farm personnel was higher and was likely the result of low numbers of scorings available for comparison and differences in the times at which foals were scored. The inability to take standardized photos or videos of foals at the time of scoring prevented the testing of inter-observer agreement with a 'gold standard' and intra-observer agreement.

Numerous treatments are recommended when treating foals for flexural contracture and/or laxity. Despite this, there was a lack of literature on which treatments were utilised effectively on New Zealand stud farms. In this study, confinement proved to be the most commonly used procedure for all forms of laxity and the mild and moderate forms of contracture. Severe forms of contracture tended to receive multiple treatments (e.g. splints followed by surgery) in combination with confinement. Stud farms were pragmatic in their approach to treatment and in doing so, appeared to provide the most cost effective solution to treatment. The level of treatment success observed on farm was difficult to assess given the small number of foals for which treatment records were available and complete. For those foals for which treatment records were complete, it was established that treatments provided on farm were relatively successful in reducing the severity of deformities observed.

Several limitations to this study were made apparent throughout data collection and data analysis and as a result require addressing before additional research is undertaken. Stud farm personnel time constraints and a bias towards foals with flexural limb deformities prevented the calculation of prevalence and resulted in a small sample size and a loss of follow-up data.

Study personnel need to be on farms daily to collect data, as it is not feasible to get stud farm personnel to do so for all foals and subsequently reduces the pool of foals available for analysis. This would improve the level of follow-up with treatment data and provide greater understanding into the treatments provided on farm and the time required for improvement to be shown and treatment to be complete. In addition, future research opportunities will require standardisation of scoring systems and collection protocols before data can be collected, which will remove subjectivity and will allow accurate comparisons of the prevalence of congenital flexural limb deformities amongst foal populations. Following the establishment of true prevalence of FLD in New Zealand further research into the apparent effects of FLD and treatment on racing career could be undertaken.

This thesis provides some insight into the severity of flexural deformities observed in Thoroughbred foals in New Zealand and the treatments provided by stud farms. Initial results suggest that most foals observed with deformities are only mildly or moderately affected and improve following treatment. Acceptance of the study by stud farm personnel was good and suggests that with improvements to study design and collection the industry would welcome further investigation into the issue and subsequent effects on racing performance.

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