Quantification of the prevalence of angular and flexural limb deformities in a population of Standardbred and Thoroughbred foals in New Zealand

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Abstract

Aim: To quantify the prevalence of angular and flexural limb deformities in a population of Standardbred and Thoroughbred foals in New Zealand in their first week after birth and to describe the influence of several risk factors on the prevalence of these deformities.

Methods: Data were collected at two Standardbred stud farms and two Thoroughbred stud farms located in the Canterbury (n=1) and Waikato (n=3) districts. Angular and flexural limb deformity data of the 2010 foal crop were collected from the first week after birth to 15 months of age. Foals were scored at three different visits in their first year. At visit 1 general foal information was recorded consisting of: name of the sire and dam, horse name, foal number or parity, last day of service, date of birth, gender of the foal and the name of the stud farm. Other foal information was recorded at every visit such as visit number and date, name of the recorder, the conformation and size of the foal and the condition score. Limb deformity information was also recorded at every visit as well as severity of the deformity. All the recordings mentioned above were made on a *proforma* limb deformity sheet for every individual foal.

Results: Of the 345 foals included in the study only 313 foals had complete limb deformity information. 253/313 foals had at least one problem recorded during their first visit and 196/253 had more than one problem recorded at the same visit. Outward from the knee was the deformity most often recorded (162/313; 52%). Fourteen percent (44/313) of the foals were recorded to have contracted tendons on either the front or hind legs and 10.5% (33/313) were recorded to be windswept. Foals with a higher condition score and born mid season were respectively 0.26 times less likely and 7.20 times more likely to be windswept compared to their reference group. Thoroughbred foals were 0.35 times less likely to have contracted tendons on the front legs than Standardbred foals. Larger foals and foals born mid season were 2.80 and 3.28 times more likely to have contracted tendons on the front legs compared to medium foals and foals born early in the season respectively. Finally, Thoroughbred foals were 0.21 times less likely to be inward from the knee than Standardbred foals and fillies were 2.74 times more likely to have this deformity compared to colts.

Conclusion and clinical relevance: The prevalence found in this study for some of the limb deformities varies from the prevalence found in studies performed in other countries. Associations were found between 5/7 risk factors and 3/11 limb deformities. This study provides preliminary work where future studies could build on and it could provide a reference point for the New Zealand industry. Furthermore it could give an opportunity to examine if angular and flexural deformities are associated with racing and sale performances.

Introduction

Thoroughbred breeding and racing are major enterprises in the New Zealand equine industry. During the breeding season of 2009/2010 4,132 foals were bred and 6,488 mares were served. In the same season 1,510 Thoroughbred horses were exported, with Australia (61.4%) being the largest export market for the New Zealand Thoroughbred industry (Anonymous 2010a). The New Zealand yearling sales aggregate during 2009/2010 was 93.6 million NZ dollars (Anonymous 2010b). Harness racing is responsible for 24.6% of the racing industry's total value added to the gross domestic product (Anonymous 2010a). The New Zealand Standardbred Breeders' Association reported 2,783 foals in the breeding season of 2006/2007 and a number of 4124 mares were served. Racing contributes more than NZ$1,558.41 million in value to the New Zealand economy. With Thoroughbred racing adding a total value of NZ$1,155.97 million and Harness racing a total value of NZ$402.44 million (Anonymous 2010a).

There is an increasing interest in issues relating to health of racehorses due to increasing public awareness of animal health and direct and indirect costs associated with injuries and conditions that interfere with training and racing of horses (Perkins *et al.* 2005). An important cause for wastage in Thoroughbred racing in New Zealand and other countries is musculoskeletal injury (Dyson *et al.* 2008; Bolwell *et al.* 2012). Joint disease, particularly with regard to the metacarpophalangeal and carpal joints, and stress fractures are considered to be the most important causes of lameness in racehorses (Wilsher *et al.* 2006). In recent years several studies have been performed in order to gain further understanding about the pathogenesis and risk factors that underlie exercise induced injuries and to improve efforts to reduce their incidence (Dyson *et al.* 2008).

In deciding to purchase a young racehorse conformation is an important factor. The term conformation is best described as the structural arrangement of body segments relative to each other (Unt *et al* 2010). It is often used as an indicator of the future performance, athletic ability and resistance to orthopedic injuries of an individual (Unt *et al.* 2010). Several studies have investigated the relationship between conformation, orthopedic health and performance in racehorses. Results of a study in a cohort of National Hunt racehorses show that performance decreases with increasing girth, length of the hind digit and valgus conformation of the metacarpophalangeal joint. Increasing metacarpophalangeal joint angle and carpal valgus increased the risk of suffering from superficial digital flexor tendon injury. The risk of pelvic fracture increased with valgus conformation of the tarsus (Weller *et al.* 2006). However, a study examining the role of conformation in 3-year-old Thoroughbreds demonstrated that an increase in carpal angle as viewed from the front may serve as a protective mechanism as the odds for a carpal fracture and carpal effusion decreased with an increase in the carpal angle (Anderson *et al.* 2004b). Despite the widespread anecdotal evidence that a relationship between conformation and performance exists, there is a lack of scientific data and studies on conformation in the racing Thoroughbred (Weller et al. 2006).

Common orthopedic developmental disorders are angular limb deformities and flexural deformities. Flexural deformities can be either congenital or acquired and have been reported to account for up to one half of all congenital defects found at necropsy in foals. A flexural deformity (FD) is present when a joint is positioned in a state of hyperflexion, either permanently or intermittently. Congenital flexural deformities most often present themselves in the carpus or fetlock joint whereas acquired deformities most often present themselves in the distal interphalangeal joint or the metacarpophalangeal joint (Adams *et al.* 2011). Angular limb deformities (ALD) are a common orthopedic developmental disorder of Thoroughbred horses with reported prevalence for those requiring intervention as high as 4.7% (Baker *et al.* 2011). The most common deformity in young foals is carpal valgus (Brauer *et al*. 1999). An angular limb deformity is often defined as a deviation of the limb from a straight line that bisects the long bones of the limb when viewed from the frontal plane. A lateral deviation of the limb distal to the location of the deformity is called valgus and a medial deviation of the limb distal to the location of the deformity is called varus (Auer 2006). As the limb of a young foal elongates, deviations up to 3° or 5° usually correct without intervention needed. A study was performed to describe the conformation of the carpus and the fetlock of Thoroughbred foals from birth to yearling sales in the USA (Santschi *et al.* 2006). Results from this study concluded that carpal and fetlock conformation change greatly in Thoroughbred foals up to 18 months of age. Evaluating foals at an early stage after birth and on a regular basis in their first weeks to months helps in deciding if intervention is needed (Santschi *et al.* 2006). In a study regarding the prevalence, heritability and significance of musculoskeletal conformational traits in Thoroughbred yearlings, several limb deformities were assessed (Love *et al.* 2006). The prevalence of conformational defects in horses in the UK was reported, with turned out feet as the most commonly recorded deformity. Of a sample of 3916 Thoroughbred yearlings examined at the sales 30% were scored as having turned out feet (Love *et al.* 2006). Little is known about the prevalence of angular limb deformities and flexural deformities in the Thoroughbred and Standardbred population in New Zealand.

When assessing angular limb deformities and flexural deformities several risk factors could play an important role. A survey of reproductive performance in Thoroughbred mares and morbidity, mortality and athletic potential of their foals showed that angular limb deformity was the health problem most commonly reported in foals receiving unacceptable physical assessment (Morley *et al.* 1997). The relative risk of ALD was evaluated for difficult birth and extremely difficult birth. During the first 14 days post partum the relative risk for ALD after a difficult birth was 3.2 (95%CI 1.3-8) and after an extremely difficult birth the relative risk was 13.1 (95%CI 4-47) (Morley *et al.* 1997). One study assessing the heritability of conformational traits in Thoroughbred yearlings found that all conformational traits examined showed considerable evidence of heritability (Love *et al.* 2006). Heritability indices (h^2) were 0.16-1.00, with the traits back at the knee (0.66) and tied below the knee (1.00) having the strongest genetic influence (Love *et al.* 2006). In a study describing carpal and fetlock conformation of the juvenile Thoroughbred in the USA, heavier birth weights were associated with carpal offset and fetlock inward conformation at most ages. Heavier yearlings were more likely to show carpal valgus (Santschi *et al.* 2006). Hypothyroidism is considered a predisposing factor for developing angular limb deformities and flexural deformities (Savage *et al.* 2002, Bertone *et al.* 2002). Further research is needed to gain more knowledge about the association of risk factors and limb deformities.

The aim of this study is to quantify the prevalence of angular limb deformities and flexural deformities in a population of Standardbred and Thoroughbred foals in their first week after birth. Variations in terms of severity of the deformity will also be quantified. This study also aims to describe the influence of several risk factors such as gender, breed, size, condition score, gestation length, season and parity of the mare on the prevalence of ALD and FD. This would provide a reference point for the New Zealand industry and an opportunity to examine if ALD and FD are associated with racing and sale performances.

Hypothesis

It was hypothesized that the severity of angular limb deformities and flexural deformities would not be significantly different between the Thoroughbred and Standardbred foals or between different limbs affected. However it was hypothesized that several risk factors such as parity of the mare, gestation length, season, size and condition score of the foal would have a significant effect on the prevalence of limb deformities in a base population of Standardbred and Thoroughbred foals in New Zealand.

Materials and Methods

Study design

This study is part of a long term cohort study that aims to describe the prevalence of flexural and angular limb deformities in Standardbred and Thoroughbred foals in New Zealand. Data on angular and flexural deformities were collected in the 2010 foal crop from birth to 15 months of age.

Sample Set

This study obtained angular and flexural limb deformity information on a total of 345 foals on four different stud farms on the North and South Island of New Zealand. The farms were located in Waikato and Canterbury districts. Two of the selected farms were Standardbred farms and two farms selected were Thoroughbred farms. All farms were selected by a convenience sample, based on their willingness to take part in the study and their location. Recordings were made on all foals that were on the farm during the period the study was conducted.

Data collection

Data were collected during the 2009/2010 and the 2010/2011 breeding season. Foals were scored at three different visits in their first year. Visit one was performed at week 0-1, visit two at week 6-8 and visit three was performed at 3-6 months after the foal was born. A planned fourth visit at 12-15 months was not carried out due to a reduction in the timeframe of the study.

General foal information and angular and flexural limb deformity data were recorded on a limb deformity scoring sheet. General information about the foal consisted of: name of the sire and dam, horse name, foal number or parity, last day of service, date of birth, gender of the foal and the name of the stud farm. This information was recorded at visit one. Mares recorded to be maiden mares were mares of which the particular foal was their first foal. Mares recorded to have parity 1 were mares of which the particular foal in this study was their second foal. This means that they already had one foal at foot. Other foal information had to be recorded at every visit such as visit number and date, name of the recorder, the conformation and size of the foal and the condition score. The conformation of the foal could be recorded as being correct or incorrect. Furthermore, size could be recorded as small, medium or large. Condition score was scored on a scale from 0-5, with every number corresponding to a categorical word scale: 0) very thin,1) thin, 2) fair, 3) good, 4) fat, 5) very fat.

Angular and flexural limb deformities were scored using a qualitative scale. More specifically, conformational traits of the front limbs were: contracted tendons/club foot, over at the knee, back at the knee, down on pasterns, inward from fetlock, outward from fetlock, inward from the knee, outward from the knee or other deformity. A similar scale was used for the hind limbs: contracted tendons/club foot, curbed/sickle hocks, down on pasterns, post legged/straight hocks, cow hocks, bow legged, windswept or other deformity. Each side affected, right or left was recorded separately. For every recorded limb deformity a severity score of 1-3 had to be recorded. As with condition score this scale corresponds with a categorical word scale: 1) slight deformity and no veterinary attention required, 2) moderate deformity and veterinary attention required in the future, 3) severe deformity and veterinary attention required immediately.

If a foal required veterinary attention and treatment was necessary this was recorded on a treatment sheet for that particular foal. This sheet described the proposed treatment, the initial and follow up treatment date.

Scoring was performed by stud masters, stud workers or a student employed for data entering and recording. Written instructions were given on how to enter data on the scoring sheets. Instructions said to use a separate sheet for each foal and to note the name of the recorder and the date for every visit. It was also explained to cross the box/boxes applicable to the horse, to score the foals according to the definitions given and to use the column ‘other’ to describe deformities not listed in the table.

Data processing and statistical analysis

Data were entered using Microsoft Access 2003 and Microsoft Office Excel 2007. All analyses were performed using STATA vs.11.1. Descriptive statistics were generated using Microsoft Office Excel 2007. Categorical data were evaluated using univariable logistic regression to generate odds ratios with a 95% confidence interval and significant association $p<0.20$. Multivariable logistic regression was used to examine the significant association ($p<0.05$) of several risk factors and different categories of limb problems. This method was also used in order to generate odds ratios with a 95%CI.

Condition score initially ranging from 0-5 was categorized as light (0-2), normal (3) and heavy (4-5) foals. Because 219/313 foals with recordings for visit 1 had been scored as condition score 3, this score was used as a reference. 204/313 foals were scored as being medium sized at their first visit and therefore medium was also used as a reference. Parity initially ranged from 0-13 with zero being a maiden or primiparous mare. This scale was categorized as young (parity 0-4) and old (parity 5-13) mares. Rogers *et al.* 2009 describe that the relationship between mare age and parity can be described by the equation: Parity = -3.41 + 0.6age (years). The first foal is expected at age 6 and that on average mares produce 0.5 foals per year, although this relationship becomes less consistent after 15 years of age. Last date of service and date of birth were recorded at visit one, gestation length was calculated for all foals that had both of these recordings. The mean gestation length in the Southern hemisphere has been stated to be longer than that in the Northern hemisphere (Van Rijssen *et al.* 2010; Dicken *et al.* 2012). The average gestation length is suggested to be of 340 ± 20 days in the Southern Hemisphere (Van Rijssen *et al.* 2010). A normal distribution was made for the gestation length found in this population. This distribution showed that the foals in this population had average to longer than average gestation length. Based on the normal distribution gestation length was not categorized, but used as a continuous variable. In New Zealand, foals are most often born from August till December. Mares bred later in the season have a shorter gestational length (Van Rijssen *et al.* 2010). Foals born in the period from August first till October fifteen were classified as early season foals in this study. Whereas foals born in the period from October sixteen till December thirty-one were classified as mid season foals.

Results

Base population

Data were collected on 345 foals born in the 2010/2011 season on four different stud farms that were located in the Waikato and Canterbury districts. The study included 110 (31.88%) Thoroughbred and 235 (68.12%) Standardbred foals. Of the 345 foals, 175 (50.72%) were colts and 170 (49.28%) were fillies (Table 1).

Table 1 *Distribution of gender and breed of the base population of 345 foals*

Breed	**Colt**	**Filly**	**Total**
Standardbred	118	117	**235**
Thoroughbred	57	53	**110**
Total	**175**	**170**	**345**

The date of birth was recorded for 342 foals. A total of 119 (34.80%) foals were born early in the season (August-mid October) and 220 (64.33%) were born mid season (Mid October-December). Of the remaining 3 foals (0.88%) no recordings were made regarding date of birth. Foal number or parity, was recorded for 304 foals (Table 2). Few mares were primiparous (41;11.88%) prior to study and 263 (76.24%) mares were multiparous prior to study. In 41 (11.88%) cases no records were made on foal number or parity.

During visit 1 the conformation of the foal was recorded as being either correct or incorrect. Due to missing data only 313/345 foals had complete data for the first visit. Out of these 61/313 foals (19.49%) were recorded as having a correct conformation. Data shows that 218/313 (69.65%) foals at visit 1 had an incorrect conformation and for 34/313 (10.86%) foals no recordings were made regarding conformation. The majority of the foals had a condition score of 3 (197/313, 62.94%) and were recorded as medium sized foals (204/313, 65.18%) (Table 3).

Table 2 *Distribution of foal number or parity of the base population of 345 foals*

Foal number/Parity	**Foals**	**%Foals**
Primiparous/Maiden	41	11.88
1	60	17.39
2	35	10.14
3	36	10.43
4	24	6.96
5	31	8.99
6	23	6.67
7	13	3.77
8	15	4.35
9	9	2.61
10	7	2.03
11	5	1.45
12	3	0.87
13	2	0.58
Blank	41	11.88
Total	**345**	**100**

Table 3 *Distribution of 345 foals and condition score at visit 1*

Condition	**Size**				**Total**
	Blank	Small	Medium	Large	
Blank	12				**12**
1			1		**1**
2		3	7	2	**12**
3	1	42	128	26	**197**
4		6	68	12	**86**
5				5	**5**
Total	**13**	**51**	**204**	**45**	**313**

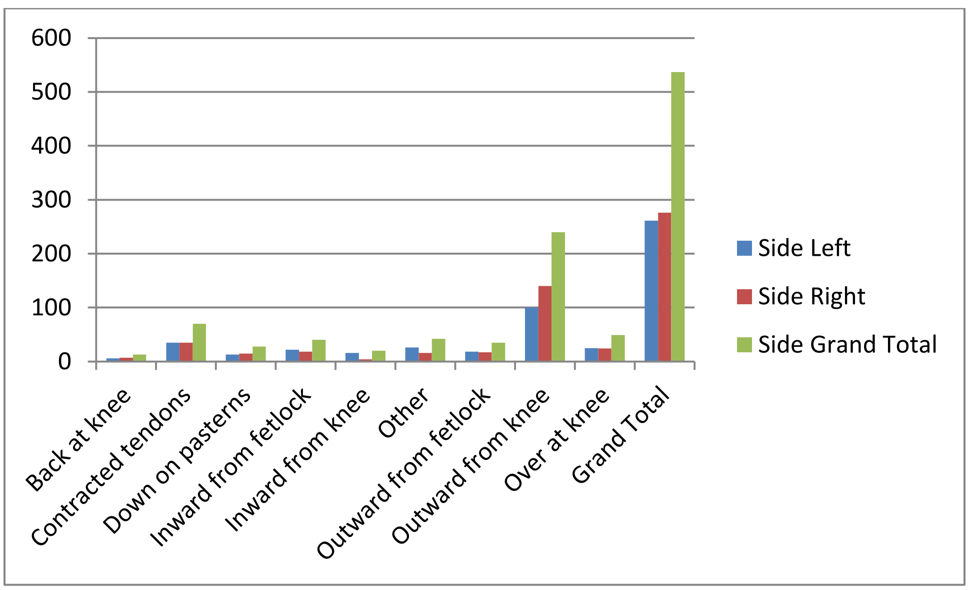
Angular and flexural limb deformities

The majority of the foals (253/313, 80.83%) had one or more limb deformities recorded on the score sheet; 60 (19.17%) had no recordings for limb deformities. Of the 253 foals that had at least one problem recorded 196 (77.47%) foals had more than one problem recorded at visit 1. Data shows that a total of 537 problems were recorded on the front legs alone and that 261 (48.60%) of these problems occurred on the left side and 276 (51.40%) occurred on the right side. The category "outward from the knee" was the problem most often recorded, with a total of 240 (44.69%) recordings. The category "back at the knee" was the problem least often recorded, with a total of 13 (2.42%) recordings (Table 4, Figure 1).

Table 4 *Distribution of problems of foals with limb deformities on the front legs recorded at visit 1*

Front legs				
Problem	Side *Left*	Side *Right*	Total	%Total
Back at knee	6	7	13	2.42
Contracted tendons/ club foot	35	35	70	13.04
Down on pasterns	13	15	28	5.21
Inward from fetlock	22	18	40	7.48
Inward from knee	16	4	20	3.72
Other	26	16	42	7.82
Outward from fetlock	18	17	35	6.52
Outward from knee	100	140	240	44.69
Over at knee	25	24	49	9.12
Total	**261**	**276**	**537**	**100%**

Figure 1 *Distribution of problems of foals with limb deformities on the front legs recorded at visit 1*

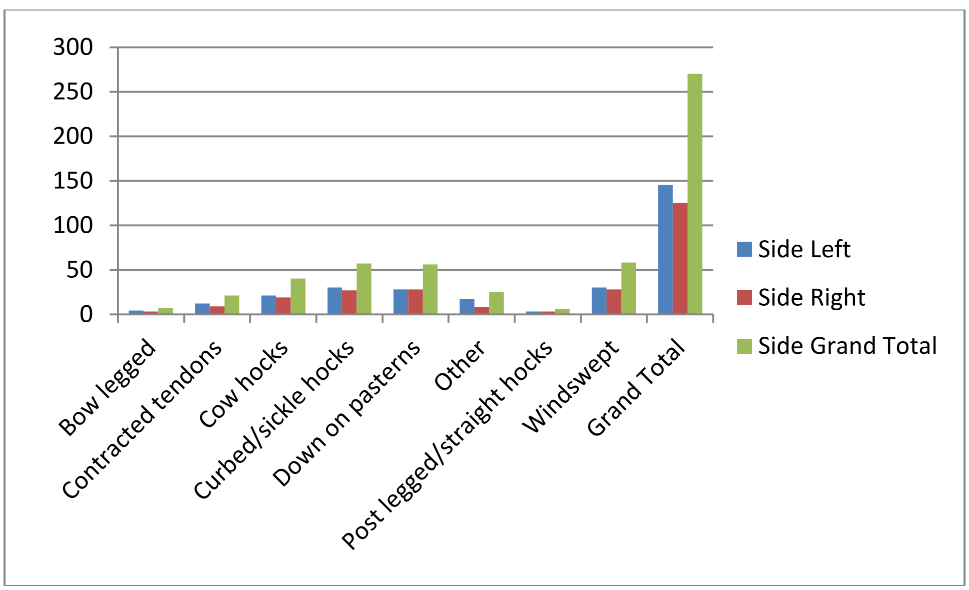


In the hind limbs there were 270 problems recorded. Of these 145 (53.70%) problems were recorded on the left side and 125 (46.30%) problems were recorded on the right side. Windswept was the category most often recorded in the hind legs, with 58/270 (21.48%) recordings. Curbed/sickle hocks were recorded 57/270 times (21.11%). Bow legged and post legged/straight hocks were the two categories recorded the least, 7/270 (2.59%) and 6/270 (2.22%) respectively (Table 5, Figure 2).

Table 5 *Distribution of problems of foals with limb deformities on the hind legs recorded at visit 1*

Hind legs				
Problem	Side *Left*	Side *Right*	Total	%Total
Bow Legged	4	3	7	2.59
Contracted tendons/club foot	12	9	21	7.78
Cow hocks	21	19	40	14.81
Curbed/sickle hocks	30	27	57	21.11
Down on pasterns	28	28	56	20.74
Other	17	8	25	9.26
Post legged/ straight hocks	3	3	6	2.22
Windswept	30	28	58	21.48
Total	**145**	**125**	**270**	**100%**

Figure 2 *Distribution of problems of foals with limb deformities on the hind legs recorded at visit 1*



Of the 253 foals recorded as having limb deformities at their first visit 162 were recorded as being outward from the knee, 78 were bilaterally affected and 84 unilaterally affected. Nineteen foals were recorded as being inward from the knee, with 18 being unilateral and 1 foal being bilateral. Thirty-three foals were recorded as being windswept. Eight of these were unilateral and 25 were bilateral (Table 6).

Table 6 *Distribution of foals and limb deformities at visit 1*

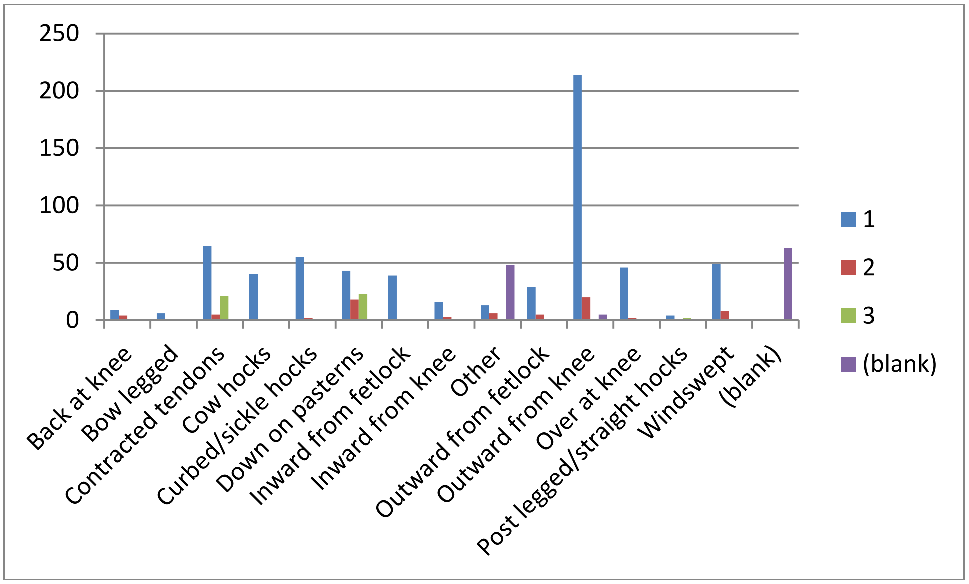
Problems	**Unilateral**	**Bilateral**	**3 legs**	**4 legs**	**Total**	**%Total****
Back at knee	1	6			7	2.2
Bow legged	1	3			4	1.3
Contracted tendons/club foot	9	28	2	5	44	14.1
Cow hocks	19	3			22	7.0
Curbed/sickle hocks	1	28			29	9.3
Down on pasterns	2	24		8	34	10.9
Inward from fetlock	14	13			27	8.6
Inward from knee	18	1			19	6.1
Other	35	15			50	16.0
Outward from the knee	84	78			162	51.8
Outward from fetlock	23	6			29	9.3
Over at knee	7	21			28	9.0
Post legged/straight hocks		3			3	1.0
Windswept	8	25			33	10.5
Total	**222**	**254**	**2**	**13**	**491***	**156.9%***

*One foal can have multiple problems recorded

**Total% is calculated with 313 being the total population

In the 253 foals that were recorded to have limb deformities at their first visit a total of 807 problems were found. This number includes problems on both front and back legs. Of the 807 problems found 628 (77.82%) were graded with severity 1, 75 (9.29%) cases were graded as being severity 2 and 50 (6.20%) as being severity 3. The remaining 54 (6.69%) problems had no records regarding severity (Figure 3). This either means that the foals had a correct conformation and had no recordings for deformities or that an incorrect conformation did not have accompanying deformity records.

Figure 3 *Distribution of severity over 807 recorded problems at visit one*



Risk factors

Of the 807 problems recorded the categories: outward from the knee, contracted tendons and windswept were the categories most often scored. Following these the categories; down on pasterns, curbed/sickle hocks, cow hocks, inward from the fetlock, outward from the fetlock and inward from the knee were also frequently recorded. For each of the categories stated above seven risk factors were analysed. Table 7 shows the results of the univariable logistic regression. If the P value showed to be significant a multivariable logistic regression was performed for the particular deformity and risk factors. The deformities outward from the knee and curbed/sickle hocks showed no significant association in the multivariable logistic regression test and are therefore not displayed in Table 8. Risk factors that showed significant association with the different limb deformities were: breed, gender, condition score, size and season in which the foal was born (Table 8).

Table 7 *Results of univariable logistic regression*

Outward from the knee				
Variable	Number of foals with problem	Number of foals without problem	Odds ratio (95% CI)	LRS P-value
Breed				
Thoroughbred	26	83	0.15 (0.09-0.27)	0.00
Standardbred	136	68	Ref	
Condition score				
Light	6	7	1.04 (0.34-3.21)	0.945
Heavy	64	27	2.88 (0.1.69-4.89)	0.00
Middle	89	108	Ref	
Size				
Large	20	25	0.64 (0.34-1.23)	0.185
Small	25	26	0.77 (0.42-1.43)	0.415
Medium	113	91	Ref	
Gender				
Filly	84	72	1.18 (0.76-1.84)	0.461
Colt	78	79	Ref	
Parity				
Old aged	56	47	0.93 (0.57-1.52)	0.783
Young aged	97	76	Ref	
Gestation length			1.07 (1.05-1.09)	0.00
Season born				
Mid	112	85	1.78 (1.12-2.85)	0.015
Early	48	65	Ref	
Windswept				
Breed				
Thoroughbred	6	103	0.38 (0.15-0.96)	0.040
Standardbred	27	177	Ref	

Condition score				
Light	1	12	0.52 (0.07-4.20)	0.543
Heavy	3	88	0.21 (0.06-0.73)	0.013
Middle	27	170	Ref	
Size				
Large	8	37	2.23 (0.90-5.52)	0.082
Small	4	47	0.88 (0.28-2.72)	0.824
Medium	18	186	Ref	
Gender				
Filly	16	140	0.94 (0.46-1.94)	0.869
Colt	17	140	Ref	
Parity				
Old aged	11	92	0.91 (0.42-1.20)	0.823
Young aged	20	153	Ref	
Gestation length			1.02 (0.99-1.04)	0.208
Season born				
Mid	28	169	6.07 (1.80-20.47)	0.004
Early	3	110	Ref	
Contracted tendons front legs				
Breed				
Thoroughbred	5	104	0.27 (0.10-0.71)	0.008
Standardbred	31	173	Ref	
Condition score				
Light	0	13	-	-
Heavy	6	85	0.44 (0.18-1.12)	0.085
Middle	27	170	Ref	
Size				
Large	7	38	1.90 (0.74-4.87)	0.180
Small	8	43	1.92 (0.78-4.71)	0.153
Medium	18	186	Ref	

Gender				
Filly	16	140	0.78 (0.39-1.57)	0.492
Colt	20	137	Ref	
Parity				
Old aged	9	94	0.57 (0.25-1.27)	0.167
Young aged	25	148	Ref	
Gestation length			1.01 (0.99-1.04)	0.225
Season born				
Mid	31	166	4.03 (1.52-10.70)	0.005
Early	5	108	Ref	
Contracted tendons hind legs				
Breed				
Thoroughbred	9	100	2.97 (1.03-8.58)	0.044
Standardbred	6	198	Ref	
Condition score				
Light	1	12	1.28 (0.15-10.72)	0.817
Heavy	1	90	0.17 (0.02-1.34)	0.092
Middle	12	185	Ref	
Size				
Large	5	40	3.06 (0.95-9.85)	0.060
Small	1	50	0.49 (0.06-4.01)	0.506
Medium	8	196	Ref	
Gender				
Filly	5	151	0.49 (0.16-1.46)	0.198
Colt	10	147	Ref	
Parity				
Old aged	6	97	1.28 (0.43-3.79)	0.661
Young aged	8	165	Ref	
Gestation Length			0.98 (0.95-1.02)	0.353
Season born				
Mid	8	189	0.75 (0.26-2.23)	0.611
Early	6	107	Ref	

Down on pasterns front legs				
Breed				
Thoroughbred	5	104	1.18 (0.38-3.69)	0.779
Standardbred	8	196	Ref	
Condition score				
Light	2	11	3.80 (0.73-19.74)	0.113
Heavy	1	90	0.23 (0.03-1.86)	0.169
Middle	9	188	Ref	
Size				
Large	3	42	2.36 (0.57-9.80)	0.238
Small	2	49	1.35 (0.26-6.89)	0.720
Medium	6	198	Ref	
Gender				
Filly	5	151	0.62 (0.20-1.93)	0.406
Colt	8	149	Ref	
Parity				
Old aged	4	99	1.12 (0.31-4.08)	0.858
Young aged	6	167	Ref	
Gestation length			0.98 (0.95-1.02)	0.290
Season born				
Mid	8	189	1.15 (0.34-3.92)	0.819
Early	4	109	Ref	
Down on pasterns hind legs				
Breed				
Thoroughbred	6	103	0.46 (0.18-1.16)	0.100
Standardbred	23	181	Ref	
Condition score				
Light	1	12	0.63 (0.08-5.08)	0.665
Heavy	2	89	0.17 (0.04-0.74)	0.018
Middle	23	174	Ref	
Size				
Large	5	40	1.38 (0.48-3.94)	0.554

Small	3	48	0.69 (0.19-2.44)	0.562
Medium	17	187	Ref	
Gender				
Filly	20	137	0.42 (0.18-0.95)	0.038
Colt	9	146	Ref	
Parity				
Old aged	7	96	0.77 (0.30-1.95)	0.579
Young aged	15	158	Ref	
Gestation length			1.00 (0.98-1.03)	0.850
Season born				
Mid	19	178	1.23 (0.54-2.83)	0.620
Early	9	104	Ref	
Curbed/sickle hocks				
Breed			-	-
Condition score				
Light	0	13	-	-
Heavy	8	83	0.85 (0.36-2.02)	0.717
Middle	20	177	Ref	
Size				
Large	5	40	1.22 (0.43-3.45)	0.712
Small	3	48	0.61 (0.17-2.14)	0.439
Medium	19	185	Ref	
Gender				
Filly	12	144	0.69 (0.32-1.49)	0.341
Colt	17	140	Ref	
Parity				
Old aged	5	98	0.39 (0.14-1.07)	0.069
Young aged	20	153	Ref	
Gestation length			1.02 (1.00-1.05)	0.096
Season born				
Mid	24	173	3.78 (1.28-11.19)	0.016
Early	4	109	Ref	

Cow Hocks				
Breed				
Thoroughbred	7	102	0.86 (0.34-2.19)	0.759
Standardbred	15	189	Ref	
Condition score				
Light	2	11	2.38 (0.48-11.79)	0.289
Heavy	6	85	0.92 (0.34-2.48)	0.873
Middle	14	183		
Size			-	-
Large	4	41	1.32 (0.41-4.23)	0.636
Small	4	47	1.16 (0.36-3.67)	0.807
Medium	14	190	Ref	
Gender				
Filly	10	146	0.83 (0.35-1.98)	0.670
Colt	12	145	Ref	
Parity				
Old aged	5	98	0.54 (0.19-1.53)	0.243
Young aged	15	158	Ref	
Gestation length			0.99 (0.97-1.02)	0.614
Season born				
Mid	11	186	0.55 (0.23-1.31)	0.176
Early	11	102	Ref	
Outward from fetlock				
Breed				
Thoroughbred	10	98	1.16 (0.53-2.55)	0.713
Standardbred	18	186	Ref	
Condition score				
Light	3	10	3.39 (0.85-13.60)	0.084
Heavy	10	80	1.40 (0.61-3.21)	0.432
Middle	16	180	Ref	
Size			-	-
Large	5	40	1.47 (0.51-4.24)	0.477

Small	8	43	2.19 (0.88-5.44)	0.092
Medium	16	187		
Gender				
Filly	14	141	0.93 (0.43-2.00)	0.860
Colt	15	142	Ref	
Parity				
Old aged	11	92	1.60 (0.68-3.78)	0.280
Young aged	12	161	Ref	
Gestation length			0.98 (0.96-1.00)	0.188
Season born				
Mid	14	183	0.54 (0.25-1.18)	0.123
Early	14	99	Ref	
Inward from fetlock				
Breed	3	105		
Thoroughbred			0.21 (0.06-0.72)	0.013
Standardbred	24	180	Ref	
Condition score				
Light	1	12	1.09 (0.13-9.00)	0.937
Heavy	11	79	1.80 (0.78-4.13)	0.167
Middle	14	182	Ref	
Size				
Large	4	41	1.07 (0.34-3.36)	0.903
Small	5	45	1.20 (0.42-3.41)	0.738
Medium	17	186	Ref	
Gender				
Filly	19	136	2.58 (1.09-6.09)	0.030
Colt	8	149	Ref	
Parity				
Young aged	10	93	0.92 (0.12-6.82)	0.93
Old aged	15	158	Ref	

Gestation length			1.02 (0.99-1.04)	0.152
Season born				
Mid	22	175	2.72 (1.00-7.38)	0.050
Early	5	108	Ref	
Inward from the knee				
Breed				
Thoroughbred	4	104	0.65 (0.23-1.86)	0.425
Standardbred	14	190	Ref	
Condition score			-	-
Light	2	10	3.07 (0.61-15.61)	0.175
Heavy	5	86	0.98 (0.33-2.92)	0.975
Middle	11	186	Ref	
Size				
Large	5	40	2.19 (0.72-6.66)	0.166
Small	2	48	0.72 (0.15-3.34)	0.671
Medium	11	202	Ref	
Gender				
Filly	10	145	1.13 (0.44-2.85)	0.802
Colt	9	148	Ref	
Parity			-	-
Old aged	4	99	0.46 (0.15-1.43)	0.180
Young aged	14	159	Ref	
Gestation length			1.01 (0.98-1.04)	0.365
Season born				
Mid	15	182	2.24 (0.73-6.94)	0.160
Early	4	109	Ref	

CI = 95% confidence interval. LRS = Likelihood ratio statistic. Ref = reference level for comparison

Table 8 *Results of multivariable logistic regression analysis*

Variable	Odds ratio	95% CI	Wald test P-value
Windswept			
Condition score			
Light	2.85	0.23-34.14	0.409
Heavy	0.26	0.08-0.90	0.033
Middle	Ref		
Season born			
Mid	7.20	1.66-31.16	0.008
Early	Ref		
Contracted tendons front legs			
Breed			
Thoroughbred	0.35	0.12-0.98	0.045
Standardbred	Ref		
Size			
Large	2.80	1.03-7.61	0.044
Small	2.04	0.80-5.17	0.134
Medium	Ref		
Season			
Mid	3.28	1.16-9.29	0.026
Early	Ref		
Inward from fetlock			
Breed			
Thoroughbred	0.21	0.06-0.72	0.013
Standardbred	Ref		
Gender			
Filly	2.74	1.14-6.55	0.032
Colt	Ref		

CI = Confidence interval. Ref = reference level

Discussion

Base population

Four different stud farms located in the Waikato and Canterbury districts were selected by a convenience sample. One Standardbred stud farm located in the Canterbury district was responsible for 212/345 foal records. Another Standardbred stud farm located in the Waikato district was responsible for 23/345 foal records. Similar divisions can be found for the two Thoroughbred farms. With one stud farm being responsible for 99/345 foal records and the second Thoroughbred stud farm being responsible for 11/345 foals.

This division of foals on the four different farms could bias the effect of breed and therefore the effect breed has on angular and flexural deformity recordings. Of the 345 foals available for this study information on only 313 foals could be used due to missing data. A larger base population could give a more reliable outcome on quantifying the prevalence of limb deformities in New Zealand.

The majority (94.78%) of the population in this study was born from October 15th till the end of December. The Thoroughbred breeding season starts on the first of August and ends in mid-December. Previous research shows that mares covered early in the breeding season have a longer gestation length compared to mares covered later in the season (Van Rijssen *et al*. 2010). From an economic point of view it is desirable to have mares foal as early in the season as possible, as older foals could have advantages from their size and maturity at the sales (Van Rijssen *et al*. 2010).

The distribution of parity found in this study, showed that the majority of mares were maiden or young multiparous mares. Foals of multiparous mares show a consistent trend to have lower birth weight than foals of younger mares. Moreover, smaller and lighter yearlings are also reported to achieve lower auction sales prices than yearlings of similar pedigree and type which are of medium height and weight (Rogers *et al.* 2011). This could be a reason for the bias in distribution as stud masters prefer to breed with younger mares than aged multiparous mares.

This study is part of a long term cohort study that was aiming to record foals at four different visits from birth till 15 months of age. Due to missing data, information on the second, third and fourth visit could not be used for this study. The development of recorded deformities on the first visit could therefore not be examined. Results and analyses reported are for the first visit (week 0-1) only.

Angular and flexural deformities

Only 313/345 foals had information on their first visit, of these only 253 had recordings for limb deformities. The remaining 60 foals had no recordings on angular or flexural limb deformities, this could either be due to missing data or because these foals were sound.

The problem most often recorded was "outward from the knee". This corresponds with the present literature, where carpal valgus is stated to be the most common orthopedic developmental disease in young foals (Brauer *et al*. 1999). Furthermore, it has been reported that deformities from 3° up to 5° degrees in foals are very common and correct themselves without intervention. This being said, deformities recorded at visit one could still be present at the following visit or could have corrected themselves with the elongation of the limbs (Smith *et al.* 2010). The aim of this study, however, was to quantify the prevalence of angular and flexural limb deformities during the first week after birth. The developmental character of limb deformities, in terms of correcting over time, could be important for a stud masters decision about the future career of the foal. The problem most often recorded in the hind legs was "windswept". Twenty-seven out of 33 foals that were windswept were Standardbred foals. The high number of recordings could be biased by the large number of foals from the stud farm located in the Canterbury district. This stud farm had multiple cases of foals reported with hypothyroidism. Hypothyroidism is stated to be a predisposing factor for foals being windswept (Savage *et al.* 2002). Lowis et al. (2005) found 41 (3.8%) cases of windswept foals in 1077 Thoroughbred foals, in which all 41 were bilaterally affected. This study found 33 (10.54%) cases of windswept foals in which 25 cases were affected bilaterally and 8 cases were affected unilaterally. The same study from Lowis et al. (2005) found that the prevalence of valgus knees was 52%. This is similar to what this study found with valgus knees occurring most often (51.76%). The prevalence found in this study for contracted tendons was 14.06%, whereas the study performed in Australia found a prevalence of 27.9%. Differences in found prevalence of limb deformities might be explained by the smaller sample (313 foals) used in this study compared to the sample size (1077 foals) used in Australia by Lowis et al. in 2005.

Distributing foals and deformities being unilateral, bilateral or affecting three or four legs resulted in a total of 491 counts of individuals (Table 6). This total is higher than the total number of foals participating in the study. This can be explained by the fact that one foal could have more than one problem recorded and was therefore counted more than once.

Of the 807 total problems recorded 628 were recorded as a category severity 1, *i.e.* no veterinary attention required. Again this corresponds with the understanding that slight deformities often correct without intervention. A study assessing leg abnormalities in Thoroughbreds performed in Australia, shows that most abnormalities were managed non-surgically and only 3.6% required surgery by five weeks of age (Lowis *et al.* 2005).
In this current study the recorder scaled the severity by an observation of the foal. Severity could be measured more precise if the grade of severity would correspond with certain degrees of deviation measured. Unt et al. (2010) measured variation in frontal plane joint angles in horses using an infrared motion analysis system. Anderson et al. 2004a used image analysis to examine the longitudinal development of equine conformation from weanling to age 3 in the Thoroughbred. This method of collecting data gave them more information about degrees of joint angles. The results found in this study relating to severity, based on observation alone, are therefore difficult to compare with results found in the above mentioned studies.

Risk factors

Breed of the foal was associated with being inward from the fetlock and having contracted tendons on the front legs. Thoroughbred foals were 0.35 times less likely to have contracted tendons on the front legs than Standardbred foals. They were also 0.21 times less likely to be inward from the fetlock compared to Standardbred foals. Most Standardbred foals in the population came from a stud farm where multiple foals had hypothyroidism, which is a predisposing factor for being windswept. However, no association was found between breed and being windswept. The effect of breed could be biased by the limited distribution of farms selected in this study. Thoroughbreds and Standardbreds used in this study were represented by two stud farms only. Moreover, the number of foals used in this study in combination with the distribution on the different farms was limited.

Gender showed a significant association with being inward from the fetlock. Fillies were 2.74 times more likely to be inward from the fetlock compared to colts. In previous research gestation length for colts was significantly longer than for fillies (Van Rijssen *et al.* 2010). Intrauterine malpositioning is suggested to be a factor of influence on the development of flexural limb deformities (Adams *et al.* 2011). However, this is not thought to be a predisposing factor for angular limb deformities such as inward from the fetlock. No association between gender and being inward from the fetlock is described in current literature. Further research is needed to investigate the influence of gender on the limb deformity inward from the fetlock.

Higher condition score was associated with foals being windswept. A foal with a condition score of 4 or 5 was 0.26 times less likely to be windswept compared to foals that had a score of 3, although a causative association is not proven. Santschi et al. (2006) found in 119 Thoroughbred foals that heavier birth weights were associated with carpal offset and fetlock inward conformation at most ages. It was also found that heavier yearlings were more likely to be carpal valgus. Similar literature about condition score in association with flexural limb deformities is limited. Congenital flexural deformities are thought to occur in cases of intrauterine malpositioning, abnormal nervous or musculotendinous development inutero, teratogenic insults and genetic abnormalities. The pathogenesis of acquired flexural deformities is focused on the pain withdrawal responses in the affected limbs (Adams *et al.* 2011). It should be noted that condition score was scored by subjective measurements, performed by the person in charge of the scoring sheets. This could lead to a greater variation in condition scores and therefore influence the ability to identify the effect condition score has on limb deformities in this study.

Larger foals were 2.80 times more likely to have contracted tendons on the front legs compared to medium foals. This could be explained by larger foals having limited space in utero and therefore could get malpositioned more easily. Intrauterine malpositioning is a proposed mechanism in the development of congenital flexural deformities (Adams *et al.* 2011).

Foals born mid season were 3.28 times more likely to have contracted tendons on the front legs than foals born early in the season. These foals were also 7.20 times more likely to be windswept compared to foals born early in the season. Unbalanced nutrition, especially trace minerals are suggested to be a factor in developing angular limb deformities. It might cause excessive growth or aberrant growth at the level of the physis or epiphysis. The nutritional balance in the feed that mares take up while carrying a foal could be varying in the different seasons. However, these pathogenic factors would play a more important part at a later postparturient stage (Auer 2006). In this study foals were seen in their first week after birth. No association between season and flexural deformities has been described in current literature.

Data validity

To collect limb deformity information a limb deformity sheet was designed for the long term cohort study and this sheet was also used for this study. This sheet could be improved for future study purposes. Terminology used on the sheet was often not described precisely enough to prevent subjective interpretation. Correct conformation was recorded in several cases accompanied by recordings of limb deformities. This would contradict the foal being of correct conformation. It can be concluded that the term conformation was too subjective in order to get information about foals being sound or not. In 60 cases out of 313 foals no recordings were made regarding limb deformities. This could either mean that data is missing or that the foals are sound. This should be taken into consideration for further research on limb deformities. Size of the foal was described by a word scale and this could lead to a subjective recording of this parameter. Measurements of girth height could be a more objective way to record information on the size of the foal. The same can be said for the condition score of the foal where birth weight could give a more accurate measurement of the condition of the foal.

Recordings were made by one person or two people on the same stud farm, meaning that scoring on each stud farm was carried out by different recorders. This inconsistency could lead to biased data. Pilot testing could have given information about the validity of different recorders scoring the foals. One recorder for all the different farms with sufficient knowledge about limb deformities could lead to a less biased outcome.

Conclusion

The aim of this study was to quantify the prevalence of angular limb deformities and flexural deformities in a population of Standardbred and Thoroughbred foals in their first week after birth. Furthermore, this study aimed to describe variations in severity of the different deformities and describe the influence of several risk factors on the prevalence of limb deformities in foals. The deformity most often recorded was outward from the knee (52%). This corresponds with what is stated in the current literature. Two other often recorded problems were contracted tendons (14%) and windswept (11%). The prevalence found of some limb deformities in this study varied from studies performed in other countries. This might be explained by the smaller sample set used in this study. Most of the problems recorded were graded as a slight deformity with no veterinary attention required. The risk factors that showed a significant association with 3/11 of the limb deformities statistically analysed were: breed, gender, condition score, size and season in which the foal was born. This study provides preliminary work where future studies could build upon and it could provide a reference point for the New Zealand industry. Furthermore it could give an opportunity to examine if angular and flexural deformities are associated with racing and sale performances.

References

Adams, S.B. and Lescun, T.B. (2011) Chapter 48 Flexural Deformities. In: *Equine Reproduction.* 2nd ed. Ed: McKinnon, A.O., Squires, E.L., Vaala, W.E., Varner, D.D. West Sussex: Willey Blackwell, p 441-445.

Anderson, T.M. and McIlwraith, C.W. (2004a) Longitudinal development of equine conformation from weanling to age 3 years in the Thoroughbred. *Equine Veterinary Journal* **36**, 563-570.

Anderson, T.M., McIlwraith, C.W. and Douay, P. (2004b). The role of conformation in musculoskeletal problems in the racing Thoroughbred. *Equine Veterinary Journal* **36**, 571-575.

Anonymous, N.Z.R.B. (2010a) Size and Scope of the New Zealand Racing Industry.

Anonymous, N.Z.T.R. (2010b) New Zealand Thoroughbred Racing Fact Book.

Auer, J.A. (2006) Section 12 Angular Limb Deformities. In: *Equine Surgery*. 3rd ed. Ed: Fathman L. and Gower J. Missouri W.A. Saunders Company p1130-1136.

Baker, W.T., Slone, D.E., Lynch, T.M., Johnson, C.R. and Baker, W.A. (2011) Racing and Sales Performance after Unilateral or Bilateral Single Transphyseal Screw Insertion for Varus Angular Limb Deformities of the Carpus in 53 Thoroughbreds. *Veterinary Surgery* **40**, 124-128.

Bertone, A.L. (2002) Lameness, The Carpus. In: *Adams' Lameness in Horses*. 5th ed. Ed: Stashak, T.S. Philadelphia: Lippincott, Williams and Wilkins, p830-833.

Bolwell, C.F., Rogers, C.W., French, N.P. and Firth, E.C. (2012) Exercise in Thoroughbred yearlings during sales preparation: A cohort study. *Equine Veterinary Journal*, **44 (1)**, 20-24.

Brauer, T.S., Booth, T.S. and Riedesel, E. (1999) Physeal growth retardation leads to correction of intracarpal angular deviations as well as physeal valgus deformity. *Equine Veterinary Journal* **31**, 193-196.

Dicken M., E.K.G., C.W. Rogers, I.G. Mayhew (2012) Gestation length and incidence of daytime foaling of Standardbred mares on two stud farms in New Zealand, Institute of Veterinary, Animal an Biomedical Sciences, Massey University, Palmerston North. *New Zealand Veterinary Journal*, **60**, 42-6.

Dyson, P.K., Jackson, B.F., Pfeiffer, D.U. and Price, J.S. (2008) Days lost from training by two- and three-year-old Thoroughbred horses: A survey of seven UK training yards. *Equine Veterinary Journal* **40**, 650-657.

Love, S., Wyse, C.A., Stirk, A.J., Stear, M.J., Calver, P., Voute, L.C. and Mellor, D.J. (2006) Prevalence, heritability and significance of musculoskeletal conformational traits in Thoroughbred yearlings. *Equine Veterinary Journal* **38**, 597-603.

Lowis, TC. (2005) Assessment and management of leg abnormalities in 1077 young Thoroughbred foals born over five years. *Australian Equine Veterinarian Journal* **24**, 1.

Morley, P.S. and Townsend, H.G.G. (1997) A survey of reproductive performance in Thoroughbred mares and morbidity, mortality and athletic potential of their foals. *Equine Veterinary Journal* **29**, 290-297.

Perkins, N.R., Reid, S.W.J. and Morris, R.S. (2005) Profiling the New Zealand Thoroughbred racing industry. 1. Training, racing and general health patterns. In: *New Zealand Veterinary Journal*, **53 (1)**. pp 59-68.

Rogers C.W and Gee E.K., V.E. (2009) Retrospective examination of the breeding efficiency of the New Zealand Thoroughbred and Standardbred, Institute of Veterinary Animal and Biomedical Sciences Massey University, Department of Animal Sciences Wageningen Agricultural University Palmerston North. *Proceedings of the New Zealand Society of Animal Production* **69**,126-131.

Rogers, C.W., Gee E.K. (2011) Selection decisions in Thoroughbred broodmares. *Proceedings of the New Zealand Society of Animal Production* **17**.

Santschi, E.M., Leibsle, S.R., Morehead, J.P., Prichard, M.A., Clayton, M.K. and Keuler, N.S. (2006) Carpal and fetlock conformation of the juvenile Thoroughbred from birth to yearling auction age. *Equine Veterinary Journal* **38**, 604-609.

Savage, C.J. and Lewis, L.D. (2002) The role of nutrition in musculoskeletal development. In: *Adams'Lameness in Horses.* 5th ed. Ed: Stashak, T.S. Philidelphia: Lippincott, Williams and Wilkins, p381.

Smith, L. (2010) Treatment of angular limb deformities in foals. *In Practice* **32**, 156-162.

Unt, V.E., Evans, J., Reed, S.R., Pfau, T. and Weller, R. (2010) Variation in frontal plane joint angles in horses. *Equine Veterinary Journal* **42**, 444-450.

Van Rijssen J.D., E.K.G., C.W. Rogers, J.R. O'Brien (2010) Brief communication: Factors influencing gestation length and interval from foaling to conception in mares managed on a commercial Thoroughbred studfarm, Faculty of Veterinary Medicine, Utrecht University, The Netherlands. Institute of Veterinary, Animal and Biomedical Sciences Massey University., Palmerston North. *Proceedings of the New Zealand Society of Animal Production* **70**, 146-148

Weller, R., Pfau, T., Verheyen, K., May, S.A. and Wilson, A.M. (2006) The effect of conformation on orthopaedic health and performance in a cohort of National Hunt racehorses: preliminary results. *Equine Veterinary Journal* **38**, 622-627.

Wilsher, S., Allen, W.R. and Wood, J.L.N. (2006) Factors associated with failure of Thoroughbred horses to train and race. *Equine Veterinary Journal* **38**, 113-118.