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# THE EFFECTS OF PARTIAL STABLE CONFINEMENT ON THE VOLUNTARY ACTIVITY OF WEANLING THOROUGHBRED FOALS

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## Abstract

This thesis discusses an observational study, which evaluates the effects of partial stable confinement on the voluntary activity of weanling Thoroughbreds kept at pasture. Despite the current knowledge identifying the need for early exercise and pasture access in young Thoroughbreds, there is little information on pasture activity, and none on the effects of partial stable confinement on the amount of, and type of, activity when at pasture. It has previously been stated that young horses confined to a stable at night, spend more time cantering and trotting in the paddock during the day, when compared to their unconfined counterparts- the authors suggested this may be compensation for the lack of activity carried out whilst in confinement. Unfortunately, no further research has been carried out to support this theory, and it is therefore unknown how much confinement is required before horses will carry out compensatory activity, and how length of confinement and the subsequent volume of compensatory activity may affect total average daily activity.

A study was carried out on a small commercial Thoroughbred stud farm in the Manawatu, to determine the effects of partial stable confinement on the amount, and type of activity six weanling Thoroughbreds carried out on a daily basis. The horse's remained under normal management conditions, and were kept at pasture, and confined in loose boxes for an average of three hours a day, on mornings decided by the Stud Master, for handling and yearling sales preparation. Activity was monitored for 141 days using a Heyrex biosensor. The sensor containing a tri-axial accelerometer was attached to each horse's halter, and the data were recorded as Delta-G; the change in acceleration between respective samples. The data were recorded in 15 minute increments, resulting in approximately 576 records per day and possible 13,536 data points per horse (there was a range of 3,456 - 10,272 usable data points per horse). A total of 39,372 15-minute data points were used in the data analysis.

Each horse's activity profile, including total daily activity, average daily activity and proportion of high- and low-energy activity, when at pasture and during confinement was analysed. Total average daily activity varied between horses (70,385 – 95,331,  $P < 0.001$ ), however each horse's total daily activity was highly repeatable across days with no significant difference between horses between days. Partial confinement resulted in a reduction in average daily activity in all horses (67,682 – 84,737,  $P < 0.0088$ ), except Colt 3 who was more active during days of confinement, than on days of no confinement ( $89903 \pm 5073$  and  $84813 \pm 2163$ , respectively).

Partial stable confinement had no significant effect on the proportion of total activity which was high-energy activity (8.69% on days of confinement, vs 12.23% on days of no confinement) except for Colt

3, who carried out a high proportion of high-energy activity during a day of confinement, then on a day of no confinement (18.23% vs 9.14% respectively). This may be a form of compensation, however it was only noted in one horse, and therefore is more likely to be a behavioural response to being isolated to a stable. The proportion of high-energy activity between the hours of 9am-12pm, when confinement would occur, was also not effected by confinement when compared to days of no confinement (8.64% vs 9.80%, respectively), except in Colt 2, who carried out no high-energy activity whilst in confinement between 9am-12pm.

The partial confinement of these weanlings appeared to reduce their overall average daily activity, however it did not affect the amount of high-energy activity. Thus partial confinement may not restrict the all-important osteo-inductive high speed activity required to promote optimal musculoskeletal development in weanlings. However, we lacked the experimental design to examine if there was any association of length of confinement and any compensatory activity. Further studies should examine if the length of partial confinement alters the subsequent activity at pasture.

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## List of Abbreviation

ADG	Average daily gain
DMD	Dorsal Metacarpal Disease
DOD	Developmental Orthopaedic Disease
GAG	Glycosaminoglycan
GDP	Gross Domestic Product
MSI	Musculoskeletal injuries
NZRB	New Zealand Racing Board
OC	Osteochondritis
OCD	Osteochondritis Dissecans
VHF	Very High Frequency Radio

## Introduction

Internationally, New Zealand is renowned for both the breeding of, and racing of Thoroughbred horses (Fennessy, 2010). Although there is increasing concern surrounding the declining numbers in foal crops, horses racing, and public attendance to race days, New Zealand still currently ranks 13<sup>th</sup> in the world for the number of races held, and 11<sup>th</sup> for the number of horses racing on the flat (Anon, 2017). New Zealand's Thoroughbred industry is also well established internationally. There are an increasing number of New Zealand-bred horses that are accomplishing racing milestones such as Group One, and Black Type wins on the international racing circuit. Last seasons (2015/2016) New Zealand Thoroughbred exports were worth an estimated \$135 million (Anon, 2016f), with over 1600 horses being exported to countries throughout Asia, and Europe, as well as to Australia; almost half of which were 0-2 year olds (J. Walker, Personal communication., November 2016). Although New Zealand's Thoroughbred market is not as large as the likes of its Australian or Asian counterparts, average sale prices suggest the overall quality of New Zealand's bloodstock is of a high quality, hence the renowned international attention.

Due to the countries temperate climate, New Zealand's equine industry is largely pasture-based, which acts as an advantage for the production of the countries high quality young stock; from birth foals are able to grow and develop naturally, with minimal restrictions on behaviour and activity. This, in-hand with the management practises used in New Zealand, has been found to result in larger, better developed foals, in terms of their musculoskeletal (MS) health (Brown-Douglas and Pagan, 2016; Morel et al., 2007), thus creating the appeal for the export market. The access to pasture and physical activity from an early age has also been related to improved 2- and 3-year-old racing careers (Rogers et al., 2008a).

The ability for New Zealand to breed and raise foals in a pasture based system is significant due to the impacts that modern domestication of horses has on their natural activity. In a feral situation, a horse may travel approximately 17 kilometres in one day, with new-born foals covering up to 10km/day. However it has also been noted that even in an unrestricted area, the modern domesticated horse still carries out less physical activity than a feral horse (Hampson et al., 2010b). This reduction in voluntary locomotion is of concern due to the knowledge that any early age exercise is beneficial for the growth and development of young stock, thus it should be encouraged.

To date, studies have reported paddock access and free exercise to be more beneficial for the horses development when compared to stable-confinement and forced exercise (Rogers et al., 2008b; van

Weeren et al., 2000). The amount of, and types of, exercise have been found to influence the foals bones, tendons and articular cartilage from birth, thus highlighting the importance of early age management. However, despite now knowing the fundamental importance of early exercise, there is little information surrounding the specifics of how much, and what type of exercise a young horse should be exposed to for optimal development. Additionally, we have not yet quantified the activity an average foal does voluntarily in a domestic situation.

This thesis consists of two chapter. The first chapter consists of an introduction and literature view. The literature review firstly provides an overview of the New Zealand Racing Board, and the New Zealand Thoroughbred Industry- both the racing and breeding aspects. It then reviews the relevant literature surrounding the management of a Thoroughbred horse in New Zealand, from weaning through to its early racing career, including the issue of wastage. The normal growth of a young Thoroughbred is then discussed. The chapter also covers the physical growth of a Thoroughbred, and the factors which influence this, such as geographical location. Lastly, the literature review evaluates the current knowledge surrounding the natural physical activity of a horse, both feral and domesticated, and also highlights the areas which require further research. The second chapter discusses the trial, and findings of this thesis. The amount of activity carried out by a typical yearling Thoroughbred, under typical stud farm management is discussed, as are the areas which require further investigation.

## Chapter 1: Literature Review

### 1.2. New Zealand Racing Industry

The New Zealand racing industry is a multibillion-dollar industry which is primarily supported by wagering turnover, and is controlled by the New Zealand Racing Board (NZRB)- New Zealand's official racing and sports betting agency (Grace et al., 2002). The New Zealand racing industry includes Thoroughbred, Standardbred, and greyhound racing, and contributes 0.90% towards the country's total Gross Domestic Product (GDP). In the 2009/2010 season, over \$463.8 million worth of bets were made on Thoroughbred racing (Anon, 2010), contributing significantly to the \$39 million worth of wagering tax received by the government from total racing and sports betting in 2010 (IER, 2010). More recent data indicates a decrease in total wagering turnover, with a total of \$427,416,054 worth of wagering placed on Thoroughbreds during the 2015/2016 season on both flat and jumps races (Anon, 2016e).

In 2010, the racing industry was estimated to support 52,732 positions of employment and participation (IER, 2010). Approximately 41,412 of these positions were people involved in the production of these racing animals, such as breeders, trainers and owners, and their employees. The remaining 11,320 positions were people involved in the production of racing itself, such as volunteers, jockeys/drivers, wagering staff, and general Race club/industry staff. In economic terms the value added to the country's economy by the New Zealand Racing industry (\$1,635 mil) is comparable in size to both the Wine, and Seafood industry (IER, 2010)

#### 1.2.1. New Zealand Thoroughbred Racing Industry

The New Zealand Thoroughbred racing industry is beginning to come under financial strain, mainly due to a consistent pattern over the last decade of rising industry costs, and declining income (Anon, 2016a). Although total stakes have been increasing gradually, as has prize money per race (Anon, 2016a), so have industry costs (Fennessy, 2010). During the 2014/15 season, \$52.8 million was paid in prize money (Anon, 2016g). In 2015/2016, the Thoroughbred racing industry had an average \$23,000 increase in race stakes, resulting in \$53.9 million being paid in prize money, with median prize money per race being \$18,357 (Anon, 2016g). Other aspects however, such as yearly foal crop size, number of individual starters, number of race days and races held have all been gradually declining, as have total public attendance to race days (Anon, 2016e). These trends, as well as additional unforeseen costs resulted in New Zealand racing ending the year with a financial loss of \$1.1 million in the 2015/16

season (Anon, 2016a). The 2015/16 season also saw a decrease of 2.5% in the number of horses starting in comparison to the previous season, with a five year average growth rate of -1.8% (Anon, 2016e). Similar trends are also evident overseas; Australian racing stakes have risen, but foal crop size, number of horses starting, and number of races held have all declined (Anon, 2015b).

Despite the unfavourable industry trends occurring, New Zealand is still ranked highly on the international scale for both racing, and breeding. During the 2015/16 season 5,177 horses started, throughout 329 race meetings, during which 2,790 races were conducted (Anon, 2016g, 2017). The total wagering turnover for the season was \$437.5 million, with a gross betting revenue of \$78.1 million. In the 2014/15 season, these numbers were all slightly lower, however New Zealand was still ranked 13<sup>th</sup> in the world for the number of races held (2,777), and 11<sup>th</sup> for number of horses racing on the flat (5,127) (Anon, 2017) with 5,382 horses in total, including jumpers (Anon, 2017). In comparison, Great Britain, with a population 14 times the size of New Zealand, had just 9,580 horses racing on the flat. Australia, with a population of 6 times the size of New Zealand, had over 36,000 flat race runners, whilst the USA, which has a population size 80 times that of New Zealand, had only 51,310 (Anon, 2017)

Additional to the domestic performance of the country, there is a strong presence of New Zealand Thoroughbreds overseas. In the 2015/2016 season alone, over 1600 horses were exported from New Zealand, with a total estimated worth of over \$135 million (Anon, 2016f). The majority of these exported horses went to Australia (921), China (248), Hong Kong (124) and Singapore (219). A small number of horses also went to countries such as Malaysia (29), Macau (47), Japan (6), Korea (8) and some European countries (Walker, 2016). Consequently, New Zealand-bred horses have become relatively successful internationally. Since the establishment of the Australian Melbourne Cup, 43 winners have been New Zealand bred horses, 19 of which were New Zealand owned horses. During the 2014/2015 racing season, New Zealand had 47 Australian stakes wins, as well as 9 Group One race wins (Anon, 2016b) , with another 11 in the 2015/2016 season (Anon, 2016c). There are also eight New Zealand bred horses in the Australian Racing Hall of Fame (Anon, 2015a).

In addition to the success in Australia, New Zealand bred horses won 28 black type races in Asia during the 2014/2015 season, plus one Group One winner in Hong Kong/Japan (Anon, 2016c).

### **1.2.2. New Zealand Thoroughbred Breeding Industry**

The New Zealand Thoroughbred industry is dependent upon its export market. Its breeding industry is renowned for producing high quality Thoroughbreds, despite its small size on an international scale, with the national yearling sales attracting horse buyers from worldwide, yearly. In the 2014/15 season,

960 lots were sold at the 2015/2016 National Yearling sales. The average selling price was \$88,042, whilst the top selling price for the year was \$1.3 million (Anon, 2016d) The highest selling price in New Zealand in the last 15 years was \$2.0 million in 2010. In comparison, the Australian Yearling sales had a top price of \$AUS 2.2 million, however the average sales price was only \$AUS 40,000 (Anon, 2015b); suggesting a larger domestic market compared to New Zealand.

The New Zealand breeding industry has two main sectors. The export sector focuses on producing high quality horses for the export market and uses shuttle stallions or expensive sires. The other sector is focused on providing horses for the domestic racing market, using less valuable stallions, with cheaper stud fees (Bolwell et al., 2015). Over recent years, the number of horses being exported has remained relatively unchanged, however the number of mares covered, and foals born has been declining (Anon, 2016f; Rogers et al., 2009a). In the 2014/15 season, 3,774 foals were produced, whilst only 3,530 were produced in the 2015/16 season. Although this decrease is not dramatic, it is continuous (Bolwell et al., 2015; Rogers and Gee, 2011; Rogers et al., 2009a; Waldron et al., 2011). This may be due to both the economic strain on the industry, as well as attempt to remove/cull off less valuable bloodstock, improving overall reproductive performance (Rogers et al., 2009b). This may contribute to the trend of declining number of domestic racing horses New Zealand.



## 1.3. Thoroughbred Management

### 1.3.1. Weaning and weanling management

The production of Thoroughbred young stock in New Zealand is primarily pasture-based. This is in contrast to the northern hemisphere, which utilise far more intensive systems, with indoor confinement and concentrate feeds being a major component of their systems (Rogers et al., 2007). Foals are generally kept with their dams until they are 4-6 months old (Rogers et al., 2004; Warren et al., 1998). They are then weaned from their dams, either gradually or abruptly, and begin to experience small amounts of handling before preparation for the annual yearling sales begins. The foals are introduced to concentrate feeds and covers, and tasks such as hoof trimming and drenching (Rogers et al., 2004; Stowers et al., 2009). The process of weaning, and its associated activities are thought to put foals under both physical and physiological stress. Physical responses such as vocalisation, and locomotor activity have been used to gauge the response of the foal to weaning (McCall et al., 1985). Studies have also gauged weaning responses via stress-related hormone levels; multiple studies have found an increase of 40-50% in both cortisol and thyroxin levels in foals during weaning (Hoffman et al., 1995; Holland et al., 1996; McCall et al., 1987; Qureshi et al., 2013).

#### **Weaning methods**

The majority of studies have focused on three different aspects of the weaning process: whether the removal of the dam is gradual or abrupt, whether the foal is weaned by itself, in a pair or in a group, and whether the foal is in a pastoral or non-pastoral environment. In New Zealand, overall management practices are similar throughout regions and farm sizes (Rogers et al., 2007; Stowers et al., 2009).

#### ***Dam Removal***

Abrupt weaning involves the removal of all dams from the foals at once (Apter and Householder, 1996). Some farms opt have leave a 'nanny mare' or an older, unrelated mare in with the foals, with the belief that the mare has behavioural influences on the weanlings (Rogers et al., 2004). In contrast, gradual weaning involves removing a dam from the herd every 1-3 days, until there are only foals remaining (Rogers et al., 2004).

It has been reported that foals weaned abruptly are more active during the weaning process than their gradually weaned counterparts (Holland et al., 1996; McCall et al., 1985; 1987). Holland et al. (1996) defined vocalisation, trotting, cantering, aggression and repeated pattern behaviours such as weaving and pawing as mild distress, as did McCall et al. (1985); (1987). The authors determined the level of

stress of the foals by the frequency and length of time these behaviours were carried out for. McCall et al. (1985); (1987) also reported that the more active foals had increased levels of ACTH suggesting increased stress. Cortisol levels were greater post-weaning in the Holland et al. (1996) study, however there was no significant difference in levels between gradually and abruptly weaned foals.

Gradual/ partial weaning is proposed to be less stressful for foals, with studies reporting less stress responses both physically and metabolically. (Heleski et al., 2002; Holland et al., 1996; McCall et al., 1985; 1987). An additional method which involves exposing foals to short periods (~ 5 minutes) of separation from their dam before weaning, has been thought to potentially have a habituating effect, and thus aid in reducing the stressfulness of separation at weaning (Haupt et al., 1984), however Haupt et al. (1984) concluded this was not the case. When compared to foals that had not been exposed to previous separation the authors found that the prior exposure actually resulted in a more stressful weaning for the foals. A more recent study found that separation exposure resulted in a greater stress response from foals at weaning (Moons et al., 2005).

### ***Confinement and Isolation***

A foals behaviour, growth and development, and transition to 'adult' diet, can all be influenced by the environment into which it is weaned. Weaning foals in a stable/boxed situation is common practice, however it can be associated with the development of stereotypical behaviours. These behaviours include activities such as crib biting and box weaving, which are thought to be coping mechanisms, to help the animal deal with sub-optimal conditions (Waters et al., 2002). A previous trial found that these behaviours increase in frequency over time, and were more common in confined foals, than foals at pasture (Heleski et al., 2002). An increase in these stereotypical behaviours has been linked to a decrease in welfare (Waran et al., 2008).

A previous study looked into the effect of weaning Shetland foals in isolation, or in pairs (Haupt et al., 1984). They measured the foals response to weaning by 'emotionality' (actions such as vocalisation, movement and defecation) and concluded that weaning foals in pairs resulted in a less 'emotional', or stressful, experience for the foals. However, two later studies (Hoffman et al., 1995; Malinowski et al., 1990) both found that paired weaning lead to an increase in aggressiveness in foals, potentially making the experience more stressful than necessary.

Additional to the development of stereotypical behaviours, and increased stress levels, it is becoming increasingly accepted that stable confinement has a negative impact on the musculoskeletal development of young horses (Rogers et al., 2007). Boxed foals were reported to spend more time lying down, and less time standing, resting, and/or 'investigating' when compared to pasture-based

foals (Heleski et al., 2002), thus resulting in less stimulation of the musculoskeletal system, and hindering development. These studies concluded that weaning foals in a pasture-based environment was more advantageous than in a confined indoor environment. Despite the studies surrounding both the physical and physiological effects of isolation during weaning, box confinement is still the most common method both internationally, and in New Zealand (Rogers et al., 2007; Stowers et al., 2009).

***Effects of age and diet at weaning on growth***

From just a few weeks old, foals begin grazing small amounts of forage, whilst still continuing to be nutritionally dependent upon their mothers (Waran et al., 2008). If available, foals will also eat the dams supplementary concentrate feed; this is known as creep-feeding. If a foal is healthy, and growing rapidly, weaning as early as 2 months old is a viable option, provided the necessary post-weaning feed is available. However, if the foal is under grown, of poor health, or growing slowly, early weaning can risk both sickness and injury (Apter and Householder, 1996). Additionally, future performance may be impaired, thus impacting economic return. However, weaning a foal earlier in life may have an influence on its behaviour. It is thought that attributes such as dominance, temperament and aggression are learned behaviours from the dam, therefore, depending on the dams nature, removing the foal may be advantageous, before the foal learns any adverse behaviours (Haupt and Wolski, 1980). Having said this, weaning at an older age of 4-6 months is more common.

Despite the wide acceptance that average daily gain (ADG) declines with age (Hintz et al., 1979) and weaning, a previous study found that weaning foals at an older age of either 4.5 months of age, or 6 months of age, resulted in no significant difference in their ADG during or post-weaning (Warren et al., 1998). In addition to age having little effect on weight loss, it has been found that the method of weaning itself also has no effect. Two previous studies (Rogers et al., 2004; Warren et al., 1998) have noted significant, similar average weight loss in the two different aged groups of foals in their studies, even when weaned via different separation methods (Rogers et al., 2004). Rogers et al. (2004) reported a considerable amount of variation in weight loss between individual foals. It was therefore suggested that weight loss may be due to each individual horses ability to cope with weaning, rather than a direct link between weaning and stress (Waran et al., 2008). It is likely that most weight loss is due to the stressfulness of weaning, and a loss of appetite (Haupt et al., 1984)

In a previous study, foals which had not been exposed to creep-feeding pre-weaning have been found to gain more weight post weaning than those which had been exposed (McCall et al., 1987). However, this only occurred during the first two weeks post weaning and was suggested to be due to compensatory weight gain, as the total post-weaning weight gain of all treatments were similar at the end of the trial. It has been reported that creep-fed foals appeared to cope with weaning, both

behaviourally, and hormonally, better than those which were not creep-fed (McCall et al., 1985), including foals which were weaned abruptly (Hoffman et al., 1995). It was suggested that foals which had not been creep-fed prior to weaning may initially be unable to meet their nutritional demands due to lack of exposure to concentrate feed, and therefore a lack of ability to utilise all feed on offer (McCall et al., 1985)

### **Physical health at weaning**

The growth and development of foal's bones are rapid during the first year of its life, and therefore any management practises that may alter bone development can have a long term impact (Bell et al., 2001; Rogers et al., 2012b; Thompson, 1995), thus making management practises during a foal's early life important. Despite being mainly pasture-based, it is common for foals to spend periods of time in confinement during weaning and sales preparation and therefore consume an increased amount of concentrate, and less forage. Although this is necessary whilst in confinement, it has been suggested it is not whilst on pasture. Stowers et al. (2009) found that on average, the weanling in this trial were capable of achieving adequate growth rates on pasture alone, without any supplementary feeding. However, the general uncertainty of pasture quality and composition results in the additional feeding of foals from as early as 5 months old, despite the economic inefficiency. According to the NRC (2007) published requirements, concentrates provided during this study, met approximately 80% of the young horses daily energy requirements, thus resulting in poor utilisation of pasture. Stowers et al. (2009) suggested that improving pasture quality, and optimising pasture efficiency would result in a lower cost per unit on farm, thus increasing returns in sales, whilst still producing high quality horses.

Confinement not only requires an increase in an unnatural diet, it is also known to impact the animals natural physical activity, and negatively influence musculoskeletal health- as previously mentioned (Bell et al., 2001). This is due to the fact that bone mass (and strength) increases as mechanical loading, in the form of physical activity, increases. Studies have reported decreased bone formation, increased bone resorption, and decreased bone mineral content in young horses kept in confinement, when compared to control subjects (Bell et al., 2001; Hoekstra et al., 1999). This is most likely due to the lack of mechanical loading on the limbs of the confined horses. In addition to the potentially long term negative impacts of box confinement, there is an increased risk of viral and/or bacterial infection, especially if horses are boxed for long periods of time continuously (Rogers et al., 2007).

Commercial stud farms in New Zealand tend to only confine foals for parts of the day, however most international studs, especially in the northern hemisphere, are far more intensive; their systems consist of continuous confinement. Bell et al. (2001) compared horses left on pasture at all times, to horses confined for 12 hr/day, and horses confined continuously; they found that both of the pasture-

exposed groups had a similar total bone mineral content. The two groups also had increased cannon bone circumference when compared to the confined group, perhaps due to increased bone strength. The authors concluded that pasture rearing, or 12-hour daily turnout is beneficial for the bone mineral content of weanlings. This not only supports the large amount of research that states physical activity to be beneficial for bone development, but also suggests there is a certain amount of activity required before the effects become evident, which not necessarily 24 hours of paddock containment (as an alternative to box confinement). Further research concerning the effects of larger stalls in relation of bone development may be useful for overseas indoor commercial operations. However, it is evident that long periods of stable confinement, from a young age, are not beneficial for foal's future development.

### **1.3.2. Yearling sales and preparation**

Every year, around 1,500 Thoroughbred yearlings go through the New Zealand Bloodstock sales ring. Prior to the sales event however, yearlings undergo a period of 'preparation', which involves both education and exercise in an aim to condition the foals for the sales by late January.

#### **Yearling sales**

The New Zealand Bloodstock yearling sales are an annual calendar event spread over 5 days. There are three categories of horses within the sale; Premiere, Select and Festival. Horses are allocated to one of these groups depending upon the horses pedigree, conformation, and type (Bolwell et al., 2012a), with the yearlings in the Premiere category usually selling for the highest prices, and often to international buyers. The price a yearling will sell for is not solely dependent upon genetic and conformational factors however. A previous European study concluded that both age and gender also play a role in price (Robbins and Kennedy, 2001). Authors found older yearlings, and colts were valued more highly than their younger or female counterparts were. This agrees with the findings of both Rogers and Gee (2011) and Bolwell et al. (2012a). Price may also be influenced by the results of a physical examination by a vet (Robbins and Kennedy, 2001).

Within the New Zealand breeding industry, there are two main areas of focus as previously outlined; the first is the export sector, which focuses on producing high quality yearlings for export, which are usually sold in the premiere or select categories at the yearling sales. The second is the domestic sector, the less genetically valuable horses produced by lower cost sires, which are aimed at the domestic market (Bolwell et al., 2015), although colts or geldings of lesser value are often still considered for export if they go on to win a trial or maiden race domestically. Lower value fillies however, are generally not considered for export (Bolwell et al., 2010b).

## **Yearling Preparation**

The decision to sell yearlings at the yearling sales is made in March around weaning, or in August as the animals approach 1-year-old. This coincides with the timing of the nominations for the sales (Bolwell et al., 2010a). Yearling preparation typically begins approximately 12-13 weeks prior to the sales (Bolwell et al., 2010a; Rogers et al., 2007), although this varies between farms; large-scale commercial farms tend to begin yearling preparation earlier. This is not only due to the larger number of yearlings nominated for the sales, but also due to the quality of horses being prepared, with premier-category yearlings undergoing a longer preparation than festival horses, such as those found on a smaller non-commercial farm (Bolwell et al., 2012a).

Education, such as handling, covering, drenching etc, are usually introduced at weaning, (Stowers et al., 2009), however activities such as hand walking, lunging, and walking on a mechanical walker are introduced during sales preparation. Scheduled exercise is also put in place on most farms (Bolwell et al., 2010a; Gibbs and Cohen, 2001). Approximately 80% of New Zealand yearling farms having some form of scheduled exercise in addition to the horses voluntary exercise during their time in the paddock (Bolwell et al., 2010a). This is obvious contrast to a typical northern hemisphere system, such as those surveyed by Gibbs and Cohen (2001), where only 64% of Texas based farms were reported to expose their yearling Thoroughbreds and Quarter horses to any scheduled exercise at the age of 14-18 months. Voluntary exercise during paddock access was made possible in 93% of the farms surveyed (Gibbs and Cohen, 2001). In New Zealand, most scheduled exercise during yearling preparation is done at a walk, with colts generally receiving a greater amount of scheduled exercise than fillies on average (Bolwell et al., 2012a). This may be because exercise is often increased for any horses considered ill-mannered or bored (typically colts). Colts may also receive increased focus during preparation due to the increased demand for high quality potential breeding prospects, posing opportunity for greater financial returns at the sales (Parsons and Smith, 2008; Robbins and Kennedy, 2001). This provides the incentive to prepare and condition colts to a greater degree than fillies.

Overall, the exercise and education of yearling preparation appears to be focused on the short term goal of producing the young horses to be ready for the sales, rather than the long term goal of producing horses for training and racing (Bolwell et al., 2012a). Stud masters all consider each yearling on an individual basis, and preparation is tailored to meet the needs of each horse, however management tactics can often change, depending on staffing, weather and viewing demands of potential buyers (Bolwell et al., 2012a)

### ***Exercise during yearling preparation***

As with training and racing, lameness is a common problem in yearlings during their sales preparation (Bolwell et al., 2012a). Not only does it usually require the adjustment of the yearling's exercise program, usually hindering its progress, it can also result in the removal of the horse from the sales event, thus resulting in a loss of returns.

Due to musculoskeletal injuries (MSI) and lameness being one of the most common causes of interruption and/or wastage in the racing industry, it is becoming more accepted that musculoskeletal conditioning from a young age is important (Barneveld and van Weeren, 1999; Firth, 2006; Rogers et al., 2008b). For this reason, it has become necessary to identify management practises that may aid in the conditioning of young racehorses, and help minimise MSI risks and lameness in the future.

One study has looked at the effects of early intervention of young Thoroughbreds exercise, and both the immediate, and long-term effects on their 2- and 3-year-old racing careers (Rogers et al., 2008a; Rogers et al., 2008b). The horses were kept at pasture, and exercise was increased gradually by an additional 30% from 3 weeks old to 19-21 months old. The authors concluded that the increase in the foal's workload had no negative impact on the animal's welfare, nor on their musculoskeletal health during or after the trial. The foals exposed to the increased exercise in fact showed indications of some positive effects during their training/ early racing careers when compared to the control subjects of the trial, which were not exposed to additional exercise. A study by Hiney et al. (2004) found similar results when observing the effects of short duration sprints compared to access to free exercise in weanling foals.

The outcomes of these studies suggest there is room for further investigation in early exercise management. Additionally, it suggests implantation of early exercise programs on farms may be beneficial, however until studies have further proven the success of the tactic, introduction to the industry will be difficult (Bolwell et al., 2012a)

### **1.3.3. Pre training and 2YO+ racing**

Most Thoroughbred horse's careers begin at 15-24 months of age, during which they are educated both on the ground, and 'broken into the saddle', to be ridden (Perkins et al., 2005b). At the end of this education, they may go into a stable to begin training, or have a spell (period of rest) (Bolwell et al., 2010b; Perkins et al., 2005a). This decision is usually made by the trainer, and often duration depends upon the physical maturity of the horse, although Bolwell et al. (2010b) reported some trainers to have a standard procedure in place, with a set duration of spelling after break-in education for every horse.

After being broken in and spelling, the horses move on to training in a racing stable in preparation for racing. A training preparation lasts for approximately 12 weeks, with the aim of sending the horse to the trials by the end of the preparation (Bolwell et al., 2010b). The training entails the horse working 6 days a week (Firth et al., 2004; Perkins et al., 2005a) to further improve both their education and conditioning, enabling the horse to learn to race, and gain the fitness required for racing (Bolwell et al., 2010b; Tanner, 2011). Each horse moves through a training program which involves building up to, and learning the different gaits of a racehorse; trot, canter, half-pace, three-quarter pace, and gallop (Bolwell et al., 2012b; Rogers and Firth, 2004). Training typically begins with ~4 weeks of slow canter work (Firth et al., 2004; Perkins et al., 2005a), then stepping up gradually to introduce half-pace and then three-quarter pace 5-8 weeks into training (Bolwell et al., 2010b; Rogers and Firth, 2004). Gallop work is introduced any time between 7 and 11 weeks into training (Rogers and Firth, 2004) depending on whether the trainer had a standard training program for all horses, or a program for each individual (Bolwell et al., 2010b). The horses also learn to load into, and jump out of the barriers (starting gates), and will then go on to have a Jump out (jump out of the barriers, and run a short distance at speed, usually with other horses). Once the horses can do this satisfactorily, they are ready for a trial, and then a race (Bolwell et al., 2012b).

### **2-year-old+ racing**

A study which surveyed the stables of the central and lower North Island found that stables were dominated by 2- and 3-year-old horses, with more fillies than geldings/colts until 5-years-old (Perkins et al., 2005a). The higher proportion of female horses domestically is probably due the increased international demand for young NZ-bred Thoroughbred colts. Additionally, female horses tend to exit racing earlier than males, for breeding purposes, thus altering the proportion of females: males in the stable at later ages.

Multiple New Zealand based studies have found differences in training tactics depending on stable size (Bolwell et al., 2010b), location (northern district or central district), and age of the horse when entering training (Bolwell et al., 2010b; Perkins et al., 2004a, b, 2005b; Perkins et al., 2005c, d). Trainers based in the northern district tended to have more 2-year-old horses in training than those based in the central district, as did stables that contained 40+ horses. Young horses in the bigger stables also had a shorter median duration to their first trial, by doing ~1 week less canter work than other stables (Bolwell et al., 2010b). This may be related to pressure from owners to get young horses racing earlier, however, most trainers state the main aim of beginning training earlier is for educational purposes; only some trainers signalled the 2-year-old races to be the main incentive for early training (Bolwell et al., 2010b).



Additional to the opportunity of starting horses in a race at a younger age, 2-year-old training is also thought to have long-term benefits. A previous Australian based study has stated horses which start their racing careers as 2-year-olds generally have a longer, more successful career than those which start at a later age (Bailey et al., 1999b). This agrees with a more recent study (Tanner et al., 2013) which concluded horses which trained as 2-year-olds had a positive association with a career outcome. Authors suggested that horses that are trained and/or raced as 2-year-olds may have better musculoskeletal health throughout their lives, than those which started later.

When compared to older horses, 2-year-olds spent fewer days, and a lower proportion of time in training preparation than older horses (Perkins et al., 2005a). They also took longer to progress through the stages of training, and spent more time working at a low intensity. Young horses also tend to take longer to get to their first trial, and have a longer duration between starts. This is predominately because the young horses require more education and conditioning than the older returning horses- older horses have already acquired the skills needed for race day.

A correlation between age, and training intensity for 2- to 4-year-old horses was reported by Perkins et al. (2005a), which suggests trainers manage their young horses more conservatively. Once horses reach 4-years-old, their race preparation duration plateaus. Furthermore, it is common for returning horses to be pre-trained / trained elsewhere before entering the stable, thus resulting in these horses entering the stable at a higher fitness than those that have not been pre-trained. This allows the horse to resume work at a higher intensity, and become ready for the races faster. Perkins et al. (2005a) states the plateau in the level of activity in older horses to be ~8 weeks into their preparation, at which time the horse is considered ready to trial/race.

#### **1.3.4. Wastage**

Wastage is a term which covers the losses from all areas of the supply chain of a race horse, from conception through to racing (Tanner, 2011). It can be simply defined as horses which failed to race, or participate to their full potential (McCarthy, 2009), and can be measured through; days of training lost, early retirement from racing, death, the cost of treatments for injuries, and the cost of investment (Bailey et al., 1997; Dyson et al., 2008). In New Zealand, approximately 22% of the Thoroughbred foal crop fails to be registered with a trainer on any given year (McCarthy, 2009). Perkins et al. (2004a) found that 16.6% of horses in training during their study, failed to start in an official trial or race.

One of the main causes of wastage in the Thoroughbred racing industry is lameness, leading to MSI (Stover, 2003), with MSI accounting for approximately one third of all loses in the racing industry (Bailey et al., 1999b; Perkins et al., 2005b). Often MSI can lead to a horse not fulfilling its career

potential (McCarthy, 2009), and in some cases, may be life threatening (Firth and Rogers, 2005). In studies in the United Kingdom, Australia, and South Africa, 5.8%, 2.1% and 8.1% of available days of training were lost due to MSI, respectively (Bailey et al., 1999a; Dyson et al., 2008; Olivier et al., 1997; Rosedale et al., 1985). Of the days lost in training, 68%, 56% and 72% of these were due to lameness relating to MSI, respectively. In New Zealand, 83.3% of the involuntary interruptions to a cohort of 2-year-old horses were due to musculoskeletal issues (Bolwell, 2011). These are similar findings to that of Perkins et al. (2005b) who reported 78.8% of interruptions to horses in their study to be due to musculoskeletal issues also. Other causes of wastage include delayed maturity, poor performance, and respiratory issues (Jeffcott et al., 1982). Temperament, other diseases (Jeffcott et al., 1982; Wilsher et al., 2006), and/or financial decisions by owners (Tanner, 2011) are also contributing factors to wastage.

The majority of MSI occur during training, rather than racing (Verheyen and Wood, 2004), with stress fractures regarded as one of the more major forms of injury (Dyson et al., 2008). Other common causes of lameness, especially in 2-year-olds, include Dorsal Metacarpal Disease (DMD) and Carpal, metacarpo/metatarsal-phalangeal joint pathology (MCP/MTP) (Bailey et al., 1999a; Wilsher et al., 2006). Factors which are commonly related to influencing stress fractures include; cumulative distance training, training/racing surface, returning to training, and failure to include gallops into training programmes (Brown-Douglas et al., 2004; Carrier et al., 1998; Parkin et al., 2004; Verheyen et al., 2006). These factors, plus age at entry of training have also been associated with incidences of DMD (Boston and Nunamaker, 2000; Verheyen et al., 2005).

Reducing wastage, particularly wastage related to MSI, is an industrywide goal, due to both the welfare aspects, and the financial aspects of the issue.

## **1.4. Normal Growth of the Juvenile Thoroughbred**

### **1.4.1. Growth in relation to musculoskeletal development**

Early in a foal's life, a period of rapid growth and development occurs. Genetic and environmental factors influence both the mental, and the physical attributes of the foal, thus determining its future potential athletic ability (Barneveld and van Weeren, 1999). When a mature Thoroughbred is in training, its bones and muscles continue to strengthen and develop (Nunamaker et al., 1990), however tendons, cartilage and ligaments have been found to only respond positively to stimuli early in the animals life (Rogers et al., 2012b). A number of studies have explored the impacts of different management practises during the first two years of a Thoroughbred horse's life on the conditioning and development of the musculoskeletal system. Barneveld and van Weeren (1999) found that young horses with free access to pasture had improved MS systems when compared to young horses confined to box rest, or box rest with short intense bouts of exercise. Furthermore, Rogers et al. (2008a) found that free paddock exercise, plus additional handler imposed exercise from 3 weeks old up to 18 months of age resulted in no negative impacts on the animals MS system, and advanced the development of the articular cartilage. Both Dykgraaf et al. (2008) and van Weeren et al. (2008) found the same positive results when they studied the same animals, but used different techniques to measure the responses of the same tissues.

One of the biggest implications of a modern Thoroughbred management system, is the significant reduction in the amount of free physical activity the horses are able to carry out from birth (Hampson et al., 2010b). The feral horse is naturally able to travel large distances from a young age; foals have been reported to travel up to 10km/day with their dams at just a few weeks old, in the Australian outback (Hampson et al., 2010b). This not only provides evidence for the idea that the modern domesticated horse is restricted of its natural amount of activity, (Hampson et al., 2010b; Kurvers et al., 2006; Rogers et al., 2012b), it also suggests that foals have evolved to partake in physical activity from birth. This therefore indicates that the confinement of, and/or structured routines of daily exercise associated with modern/commercial management systems are not natural, nor as beneficial for their physical health as if they were in a natural, feral environment.

### **1.4.2. Normal growth in Thoroughbred Foals**

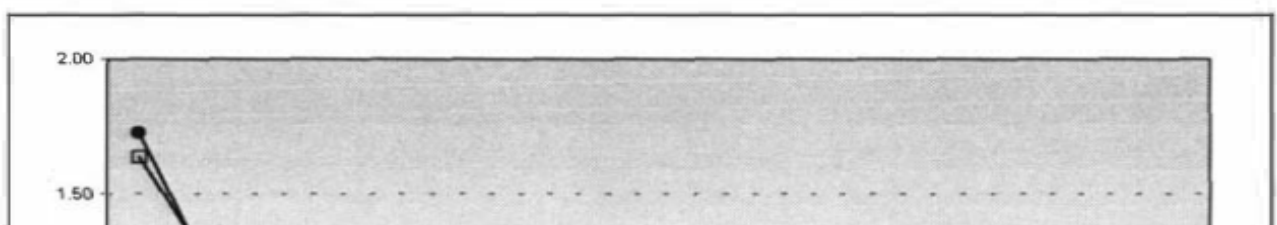
As with other livestock, horses have a natural growth curve, with ideal target live weights at specific ages. In an agricultural situation, farmers usually use the key targets of their animals as milestones, to ensure their stock are growing enough. In the Thoroughbred industry however, there is currently little in the way of accurate key targets for the southern hemisphere. Having said this, a New Zealand based

study by Brown-Douglas et al. (2005), concluded that the body weights of the pasture-raised foals were similar to those of horses in northern-hemisphere based studies. Although these results were from only one farm, this suggests there is potential to create an accurate growth curve of southern-hemisphere Thoroughbred foals using northern-hemisphere data, however further research into southern-hemisphere growth curves is required. Table 1 below shows a comparison of body weights of foals at different ages, between northern and southern hemisphere based studies.

### **Body weight and ADG**

In the northern hemisphere, a correlation between birth weight and mature body weight (BW) has been established by Hintz et al. (1979). It was found that assuming a mature TB mare weighs 500kg, and a mature TB stallion weighs 545kg, a TB foals reaches ~45%, ~65% and ~80% of their mature BW at 6, 12 and 18 months old, respectively. These findings are similar to those of Lawrence (2005), who related both height and weight mile stones, to maturity. He states that foals which are 10% of their mature BW at birth, then grow to be 46%, 65% and 90% of their mature BW by 6, 12 and 22 months old.

Throughout the four main phases of growth in a foals first years of life, the rate of growth declines as maturity approaches (Stanjar et al., 2004), thus average daily gain (ADG) declines as live weight (LW) increases (Pagan et al., 1996). This supports the findings of both Lawrence (2005) and Hintz et al. (1979). Hintz et al. (1979) found in the first 90 days of life, the foals in their trial gained ~110kg, in the second 90 days they gain 75kg, and by the fourth 90 days, they only gained 45kg. In a New Zealand base study, similar results were noted (Brown-Douglas, 2003). Between birth, and 4 months of age, foals went from gaining an average of 1.5kg/day, to gaining only 1.0kg/day. From 5 months old, until the end of the study, their ADG was between 0.5-0.7kg/day. The overall growth rate trend of Brown-Douglas (2003) horses is shown in Figure 1 below.



**Table 1:** Comparison of body weight (Kg) data from three Northern-hemisphere growth studies, and one southern hemisphere growth study. Note: Hintz data collected on days 32, 62, 187 and 352, Pagan Data collected on days 183 and 350.

Age (Months)	1		2		6		12	
	Colts	Fillies	Colts	Fillies	Colts	Fillies	Colts	Fillies
(Brown-Douglas et al., 2005)	105.8	102.4	142.2	142.4	254.4	248.6	361.1	357.3
(Hintz et al., 1979)	98	97	137	135	245	236	345	329
(Thompson, 1995)	98.2	100.5	132.9	134.2	260.5	256.4	364.5	363.3
(Pagan et al., 1996)	-	-	-	-	255.9	250.7	349.2	335.2

### Gender

It is commonly assumed that colts are heavier than fillies. However, multiple studies have found that this is not the case; studies have found that colts are often slighter heavier, but are not significantly heavier than fillies of the same age. Thompson (1995) study reported his colts and fillies to be 83.5kg, and 81.5kg on average, respectively, at 14 days old. By 18 months old, the colts were an average of 477.7kg whilst the fillies were 454.7kg. However, despite the variation between the two genders, the

differences were not significantly different. Multiple studies both prior to, and after this study have found a similar trend (Hintz et al., 1979; Morel et al., 2007; Pagan et al., 1996; Thompson, 1995).

### **Height**

Foals reach their mature height faster than they reach their mature weight (Hintz et al., 1979; Lawrence, 2005). Lawrence (2005) reports foals to be 64% of their mature height by 6 months of age, 94% of their mature height by 12 months old, and almost fully grown by 22 months old. Similarly, Hintz et al. (1979) found that foals grew to 83%, 90% and 95% of their mature heights by 6, 12 and 18 months of age, assuming mature height was 162cm for a stallion, and 160cm for a mare (Thoroughbred). These authors suggest that birth height may be used as a predictor of mature height, however further research is required to ensure accuracy. Such a tool, in hand with an established growth curve, may be useful in a commercial farming situation, as it would enable stud masters to monitor their animal's growth, and adjust management for those foals which may be lagging in growth.

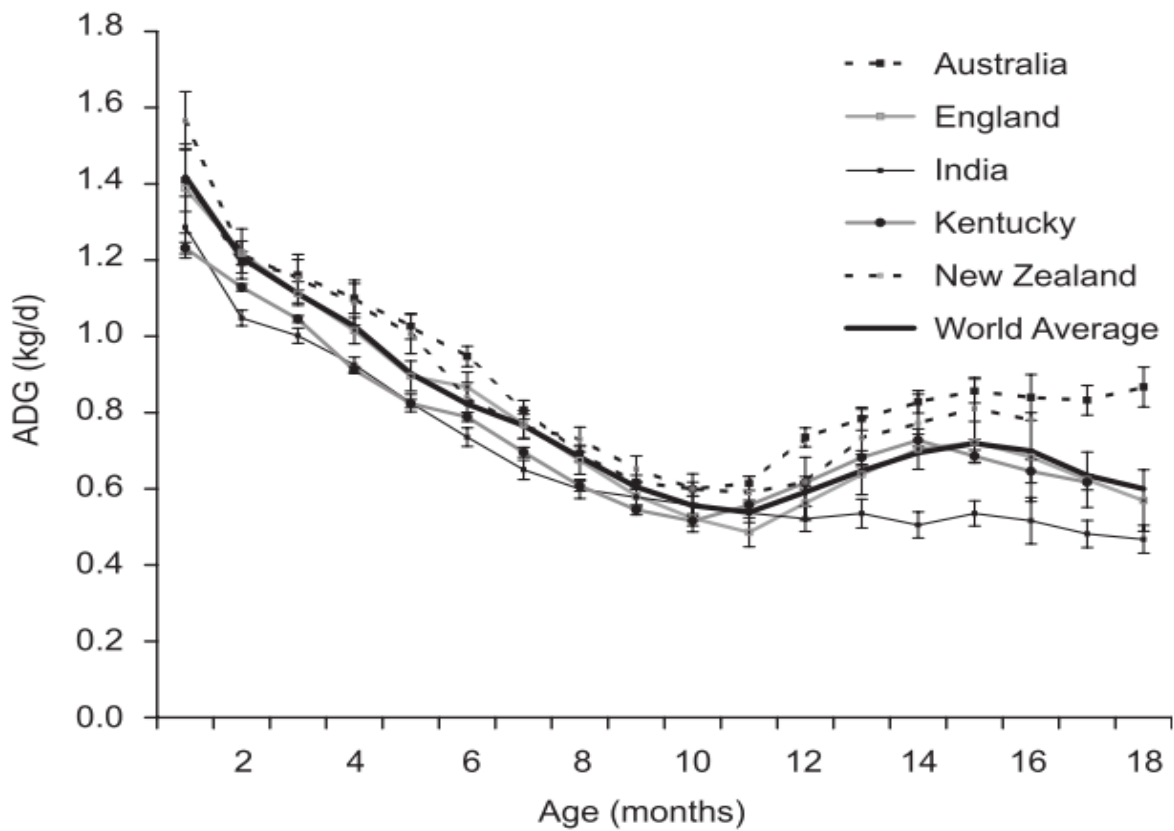
### **1.4.3. Factors affecting foal growth**

The official birth date of foals in the southern hemisphere is the 1<sup>st</sup> August, thus breeders aim to have offspring born as close to, but not prior to this date. This allows foals to grow as much as possible for their age group (Brown-Douglas et al., 2005). A foal grows most rapidly straight after birth (Rogers et al., 2004), ADG then declines as weaning approaches, increases post-weaning, plateaus, then slowly declines again as maturity approaches (Brown-Douglas et al., 2005; Rogers et al., 2004; Staniar et al., 2004). Factors such as geographical location, season, and future career all have an effect on the growth of Thoroughbred foals (Brown-Douglas and Pagan, 2016; Brown-Douglas et al., 2005; Hintz et al., 1979; Morel et al., 2007)

### **Geographical effects**

Due to the variation in foal management practises between the northern and southern hemisphere, growth curves cannot be assumed to be similar (Morel et al., 2007). The main cause of the difference in growth curves between the two hemispheres is suggested to be due to feeding regime and pasture access, or lack thereof (Pagan et al., 1996). In a New Zealand situation, the climate allows for all year round pasture-based production, with most nutritional requirements met by pasture alone, although the provision of some grain/concentrate supplements just prior to weaning is not uncommon (Rogers et al., 2007). Having said this, there can be variation in pasture growth and thus foal growth both seasonally, and yearly. Foals generally remain outdoors for the majority of their first year of life, the exception of stable confinement during weaning and yearling sales preparation (Rogers et al., 2007). This is a major contrast to systems in the northern hemisphere, where foals are usually confined to a stable in the winter, due to weather conditions.

A recent study which followed foals from New Zealand, Australia, Kentucky, England and India, found that the foals growth curve coincided with season in all countries except India (Brown-Douglas and Pagan, 2016); growth declined in winter, and inclined in spring. In India however, growth rate declined, and did not rise again, this is likely to be due to the Indian climate, as well as their intensive indoor management system. There were also geographical variations in the growth curves of the foals. Overall, India's foals were smaller, whilst the foals of the remaining countries all had similar growth curves until ~11 months of age. From thereon after, Australian and New Zealand based foals were larger (Brown-Douglas and Pagan, 2016). A summary of each countries growth curves is shown in Figure 2 below.



**Figure 2:** Average daily gain (kg/d) of Thoroughbreds reared in Australia, England, India, America and New Zealand. Adapted from: (Brown-Douglas and Pagan, 2016)

The variation in growth curves between countries is likely to be due to differences in the management practises of each country (Morel et al., 2007). For example, breeders in New Zealand and Australia tend to send their foals to the yearling sales in a well-rounded condition, in a higher than usual body condition score. In contrast, American foals are presented at the sales in a lean, athletic condition

(Brown-Douglas and Pagan, 2016). The preparation of, and physical condition of foals at the sales may coincide with the future intentions of the foals for each country. For example, America is renowned for breeding short distance 2-year-old sprinters, on dirt tracks, whilst English foals are bred for racing distances of over 1-mile, on turf tracks, at a slightly older age. Subsequently, English horses tend to take longer to mature and lean down. Australian and New Zealand bred horses however, are recognised for their size as yearlings, despite also being raced on turf (Brown-Douglas and Pagan, 2016).

### **Time of Foaling**

Due to the aim of breeders to grow their foals as large as possible by yearling sales, breeders try to get their mares in foal as early in the season as possible. Due to a common belief that later born foals grow too slow, and thus will not be large enough for the yearling sales, autumn born foals are uncommon in New Zealand (Brown-Douglas et al., 2005), and there is therefore a lack of data surrounding their growth. Previous studies based in the northern hemisphere (Hintz et al., 1979; MacCarthy and Mitchell, 1974; Pagan et al., 1996) all noted that the early born foals of their studies tended to be born lighter, and have poorer growth rates than later born foals.

A New Zealand based study comparing the growth rates of spring and autumn born foals was carried out by (Brown-Douglas et al., 2005). The authors found that spring born foals were slightly, although not significantly heavier than autumn born foals, and for the first 6 months of life, both groups of foals had similar growth rates. At ~6 months of age, spring born foals growth declined more rapidly than autumn born foals. However, by March the following year, the autumn born foals were a similar weight to the spring born foals if there were given supplementary feed over the summer. By the end of the trial, the spring foals were heavier than the autumn foals (17 months and 13 months old, respectively), however, the autumn foals had 'caught up', and were 88% of the body weight of the older foals, despite being 4 months younger. The authors of the study concluded that not only are autumn foals capable of reaching the weights required for yearling sales in January, they are capable of weighing similar weights to their older counterparts, if managed accordingly. The main factor which influences the growth of the autumn born foals, allowing them to 'catch up' to the older foals, is the seasonal influences on pasture growth at the time of weaning for each cohort.

#### **1.4.4. Musculoskeletal health in the growing horse**

There are two main factors which affect a horses bones throughout its life; the change in shape and size of the bones, and changes in the architecture of the bones (Stover et al., 1992). In the Thoroughbred horse, the distal limb is of the most concern. This is due to the vulnerability of the limb to damage and injury, which has come to light with the research surrounding the development of the



MS system in the young horse, and the long term impacts surrounding the animals racing career (Barneveld and van Weeren, 1999; Firth et al., 2011; Firth et al., 1999; Lawrence, 2005; Pagan and Nash, 2016; Rogers et al., 2012b; van Weeren and Barneveld, 1999; van Weeren et al., 2000; van Weeren et al., 2008).

It has been reported that approximately one-third of all losses/wastage in flat racing in New Zealand are due to MSI (Perkins et al., 2005a), with the dorsal cortex of the 3<sup>rd</sup> metacarpal bone being the most common subject of skeletal disorders in racing (Firth et al., 1999; Stover et al., 1992). Dorsometacarpal disease (DMD), which is commonly referred to as 'Bucked shins' or 'shin soreness', along with stress fractures have been reported to affect ~70% of TBs in racing, with 2-3yo horses being the most commonly effected (Nunamaker et al., 1990). Most MSI are widely accepted to be due to repeated mechanical loading and stress (Firth et al., 1999; Nunamaker et al., 1990) and the ability of the musculoskeletal system to adapt quickly to increasing loads of work (Rogers et al., 2008b).

Shin soreness is an example of a well-known issue which usually occurs in a young Thoroughbreds first year of training (Verheyen et al., 2005). Continuous research has led to the theory that DMD primarily results from the bones adaptive response to exercise, and associated with young horses exercising at speed (Nunamaker, 2002). Nunamaker (2002) concluded that horses which are exposed to small doses of high-speed exercise are protected against bucked shins, whilst horses which are exposed to long periods of galloping exercise are at increased risk.

Developmental Orthopaedic Disease (DOD) is another common issue found in juvenile horses. This included disorders such as physitis, angular limb deformities, and Osteochondritis Dissecans (OCD) (Pagan and Nash, 2016). DOD has been found to be influenced by pre- and post-natal energy intake and diet mineral imbalances (Gee et al., 2005; Pagan and Nash, 2016), and is thought to be related to early-age exercise also (Dykgraaf et al., 2008; Firth et al., 2011; van Weeren et al., 2008)

#### **1.4.5. Factors affecting skeletal health early in life**

##### **Rate of growth**

Although there is not yet an agreement surrounding the theory that rapid or compensatory growth can predispose horses to OCD (Morel et al., 2007), it does appear that some genotypes are more susceptible to it, and that rapid growth has some kind of linkage to OCD (van Weeren et al., 1999). Additionally, rapid growth caused by over feeding has been linked to DOD and unsoundness (Lawrence, 2005). The link between OCD and growth rate had been established in species such a pigs and poultry, however it is yet to be confirmed in horses, with varying results found between studies (van Weeren et al., 1999).

## **Diet**

Diet plays a role in a foal's skeletal soundness from as early as gestation. The diet of the broodmare has been found to impact both the size and soundness of the foal, with the last trimester being the most influential period, due to the majority of the foals growth occurring at this time (Pagan and Nash, 2016). Despite years of research, the pathogenesis of DOD, or more specifically OCD is still debatable (van Weeren et al., 2003), although there is agreement that the disease is most likely multifunctional in origin (Gee et al., 2005; Hurtig and Pool, 1996). Nutritionally, there are a number of factors that are likely to play a role in the development of OCD, such as; energy intake, protein intake and mineral intake/balance with minerals such as copper, calcium and zinc (Hurtig and Pool, 1996; Pagan and Nash, 2016; van Weeren et al., 2003).

Once born, a dam's milk is sufficient at a foal's energy demands early in life, however, both before, and after weaning, it is not uncommon for stud masters to feed supplementary feed to foals, in addition to pasture. Supplementary feeding prior to weaning is known as creep feeding, as previously mentioned, whilst supplementary feeding post-weaning is commonly carried out due to the belief that pasture alone is not sufficient for a foal's growth. However a study has indicated that over-supplementation may be increasing the risk of OCD in juvenile horses due to both energy and mineral intake levels (Pagan and Nash, 2016). A previous study carried out by Pagan (1998) related OCD to increase energy intake in foals resulting in increased growth, as previously mentioned. Additionally, copper deficiency has been targeted as a potential cause of OCD since the 1980s. The first study to suggest the role of copper reported OC-like lesions in copper deficient foals (Bridges et al., 1984). Dose response trials have since been carried out by both Knight et al. (1990) and Hurtig et al. (1993), with results showing a decrease in OC lesions in foals fed increased levels of copper. However, it was later found that the lesions seen in the low-copper foals were not the same as those which occur from the natural disease. A more recent study involved the dietary supplementation of Cu to both dams and foals. The treatment had a positive effect on the dams, resulting in a decrease in the occurrence of articular cartilage lesions in their foals postpartum, however the treatment had no effect on the foals in the trial (Pearce et al., 1998). It has also since been established that injectable supplementation of Cu to dams in late gestation is ineffective in the 'prevention' of lesions in foals (Gee et al., 2007; Gee et al., 2005). The continuing variations in results highlight the uncertainty surrounding OCD and its relation to Cu, and the need for further research.

## **1.5. Physical Activity of the Horse**

The modern domestic horse has evolved from covering large distances daily and grazing a high fibre diet, to being restricted of its free exercise, and consuming highly concentrated feeds in a short amount of time each day. The modern management practise of stable confinement has further contributed to the substantial decrease in a horses free activity (Hampson et al., 2010b), however it has become a common practise mainly to decrease the risk of injury (Werhahn et al., 2011), although factors such as availability of space, and climate also play a role (Brown-Douglas and Pagan, 2016).

Irrespective of species, there is a growing amount of evidence that supports the positive effects of exercise from a young age on a variety of aspects of the subjects growth and health (Rogers et al., 2012b). The future of a horse's athletic career is dependent upon optimising the growth and development of the animal from birth, thus making early physical activity important- any activity from birth onwards is influential in priming the components of their MS system for the workload they are going to encounter later in life (Firth et al., 2011; Kurvers et al., 2006). By preparing the horses bodies physically for their future, the likelihood of injury, and/or wastage is decreased (Rogers et al., 2008a), which is significant, due to one of the most common reasons for the loss of a competitive horse is lameness and/or MS issues (Rogers et al., 2012a).

### **1.5.1. The importance of physical activity**

For the first year of a foal's life, their musculoskeletal system goes through a period of growth, and remodelling, most dramatically so, during the first six months of life (Hintz et al., 1979; Lawrence, 2005). This includes changes in not only the muscles and bones, but also in the components that are only responsive to stimuli during the early stages of life- the tendons, ligaments and articular cartilage (Rogers et al., 2012b; van Weeren and Barneveld, 1999). Any exercise at a young age aids in improving factors such as bone mineral density, by improving the ability of bones to become more resistant to deformation, and reducing the risk of developmental diseases such as OCD (Barneveld and van Weeren, 1999; Rogers et al., 2008b). Having said this, the types of changes which occur within the musculoskeletal system depend on the amount and type of exercise which occurs (van Weeren et al., 2000).

In a natural situation a foal is able to gallop within only a few hours after birth (Firth et al., 2011), and have been seen to travel up to 10km/day in a feral situation with their dams (Hampson et al., 2010b). This highlights the idea that foals are naturally suited to large amounts of exercise even from a young age. However, as with domestic horses, feral horses also show signs of orthopaedic issues, such as osteoarthritis (Cantley et al., 1999). The disease starts with the abnormal differentiation of cartilage

into bone, and can eventually lead to altered bone growth, and impacted cartilage health and function (Stromberg, 1979). In feral horses the condition is thought to be more age related, due to “every-day wear and tear”, in the domestic horse however, such as the Thoroughbred, it is thought that the condition is due to the repetitive stress of training/racing (Cantley et al., 1999; Kidd et al., 2001).

The confinement of foals in a domestic situation limits the amount of activity carried out, and therefore the amount of mechanical loading is decreased. This reduction in osteo-inductive activity causes delays in the development of the foal’s musculoskeletal system and is thought to impact the long-term quality of the animals MS system (Barneveld and van Weeren, 1999; Firth et al., 2011; Rogers et al., 2012a; van Weeren et al., 2000). A previous study looked at the effects of three different management methods on the musculoskeletal system of foals from birth to 11 months old (van Weeren et al., 2000). The foals were split into one of three treatments; kept in boxes for 5 months, with no exercise; kept in boxes for 5 months but with gradually increased exercise, or left at pasture with their dams for 5 months. After 5 months, the foals were weaned, and kept in an open loose box, with access to a small paddock until 11 months of age. The authors found that the foals which were kept at pasture had stronger, better developed musculoskeletal tissues. They also provided further evidence that the first few months of a foal’s life are the most important for musculoskeletal conditioning. They found that after 5 months of age, the growth and remodelling of the musculoskeletal system slowed down, and components such as the articular cartilage had already finished their final development. When the unexercised, confined foals were released into loose boxes/small paddocks after 5 months, some compensatory development was seen, such as improved bone mineral density and glycosaminoglycan (GAG) content of cartilage and tendons; however, some biochemical aspects, such as the collagen characteristics of the articular cartilage remained impacted when compared to the other treatment groups. The authors concluded there were undoubtedly negative impacts of stable confinement.

## **1.5.2. Horse activity patterns**

### **Feral Horses**

There is very little data on the daily activity of any one specific feral horse breed however; there are reports of the movements and patterns of behaviour in feral equids in general. These parameters vary depending on the species, environment, and resource availability (Brooks et al., 2008; Hampson et al., 2010a; Kaczensky et al., 2008; Linklater et al., 2000; Scheibe et al., 1998)

One study carried out in Australia looked at 12 feral horses in two different geographical regions of Australia; central Queensland (CQL), and central Australia (CA) (Hampson et al., 2010a). They found

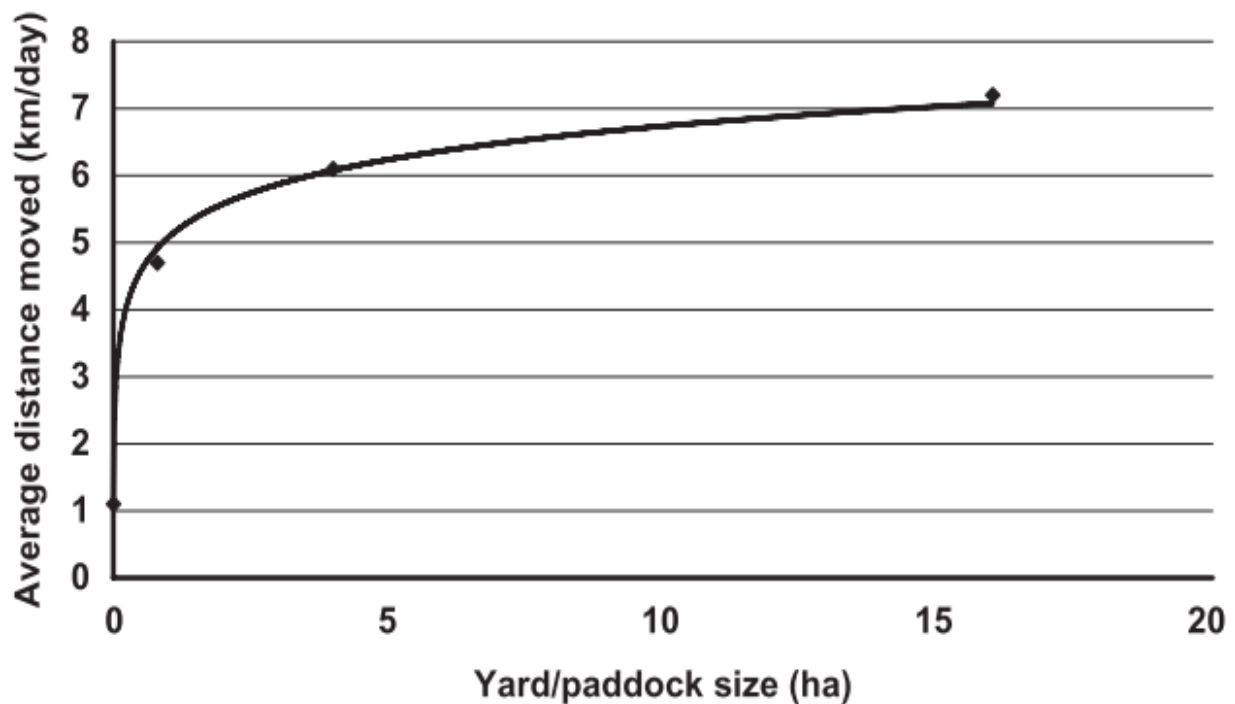
the CQL horses travelled an average of 16.8km/day, a similar distance to those in another Australian study (Hampson et al., 2010b), whilst the CA horses travelled an average of only 14.7km/day. Although the distances travelled between the two Australia herds were not significantly different, the patterns of travel were. The CQL horses travelled a similar distance most days, and were always within approximately 8km of a water source. The CA horses however, travelled a greater distance in a single day when travelling to, or from, water, and then travelled shorter distances to good feeding locations. In comparison, Kaczensky et al. (2008) found wild Przewalski horses travel a mere 3.5km/day, and noted that they always kept a water source within approximately 9km. Wild Asiatic asses, which were also monitored in the same study, travelled an average of 8.3km/day, and ventured approximately 13km away from water. Female zebras have been recorded to travel over 15km within a 12 hour period when migrating between watering holes and feeding grounds (Brooks et al., 2008). From this evidence, it has been suggested that resource availability, and the species and/or breed's ability to withstand conditions may be main contributors to daily travel distances (Hampson et al., 2010a). Female zebras have been reported to be without water for 3-4 days before walking back to the nearest watering hole (Brooks et al., 2008). Similarly, horses in CA were noted to travel up to 55km away from their sole water source, and to have a watering frequency of only every 4<sup>th</sup> day (Hampson et al., 2010a). This highlights the tolerance of dry conditions, and dehydration in both zebras and central Australian feral horses. The feral horses of CQL on the other hand, tended not to travel far from water, and grazed/ frequented gullies and lowland, where water is likely to pool (Hampson et al., 2010a). This indicates that some horses are perhaps able to cope with a lack of water better than other breeds/species. A study observing drinking behaviour and water consumption of horses in close-to-wild conditions (Scheibe et al., 1998) stated that although feral horses drink less frequently than domestic horses, they drink more water relative to their body size, which may give insight as to how feral horses are able to withstand such long periods without water. Additionally, it has also been suggested that some breeds/species of feral equids may be genetically adapted to be able to withstand hot dry conditions better than others, as an evolutionary strategy (Sneddon et al., 1991).

As well as long-term movement patterns, there is also a distinguishable diurnal pattern within the locomotor activity of feral horses. Berger et al. (1999) monitored the activity and feeding of Przewalski mares in semi-natural conditions, and found the patterns of these behaviours were closely related to sunrise and sunset, with the greatest amount of activity occurring during daylight hours. Having said this, the amount of time spent feeding, and being active varied according to season; feeding accounted for 40% of the horses total activity in summer, and 62% in spring (Berger et al., 1999). The presence of a diurnal pattern of activity was also identified by both Kurvers et al. (2006) and Giannetto et al. (2015) with studies of domestic horses.

### Domestic Horses

Since the domestication of horses, they have become more restricted in their physical activity, due to confinement in stalls and/or small paddocks. A horse which is confined to a box will walk approximately 1.1km/day on average, this is a fraction of the distance travelled by a horse in a large 'unrestricted area', of a 16ha paddock, (~7.2km/day) (Hampson et al., 2010a) (Figure 3). Hampson et al. (2010b) highlighted the trend of increasing distances covered, with increasing paddock size (figure 3), however the distances covered by domestic horses in a large, unrestricted area, still do not compare to those covered by feral horses.

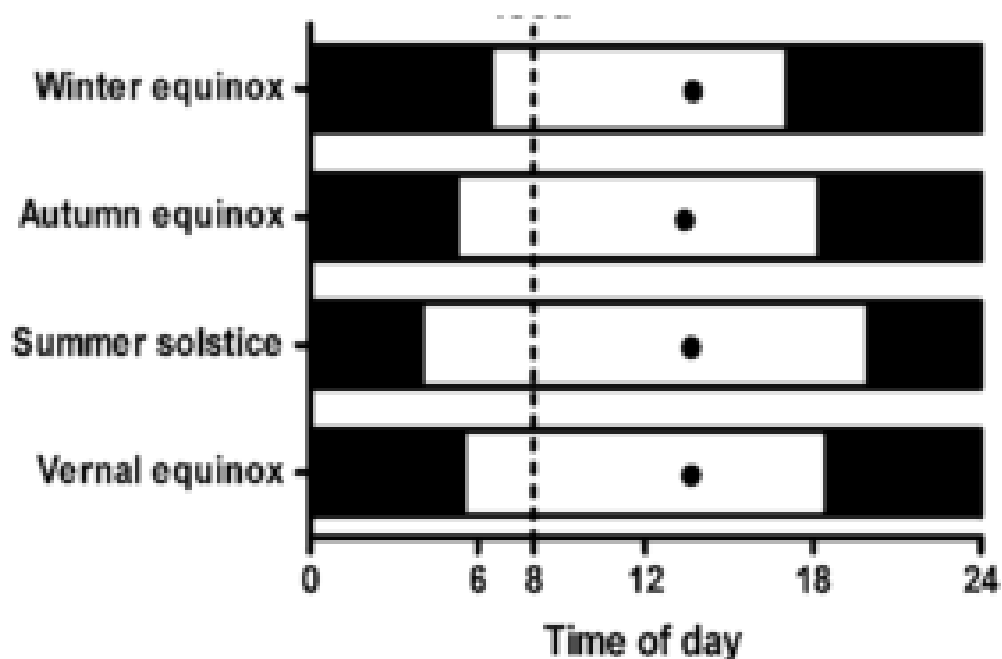
The impacts of restricted activity on the physiological, psychological and MS systems are not yet fully understood (Hampson et al., 2010a) however it is known that a lack of activity from a young age can have negative effect on the physical development of foals (Rogers et al., 2012b).



**Figure 3:** Scatter graph of average distances moved by groups of domestic horses against yard/paddock area and logarithmic line of best fit for average distance moved by group as a function of yard/paddock area. Retrieved from Hampson et al., (2010b).

As with feral horses, there have been clear patterns of activity established in domesticated horses, both seasonally, and daily. It has been suggested that the level of activity carried out by a horse may be associated to the length of photoperiod, and ambient temperature (Berger et al., 1999; Bertolucci et al., 2008). Bertolucci et al. (2008) noted that the level of activity in Italian Thoroughbred horses was

higher during the vernal and autumn equinoxes- the authors suggested it was due to the longer photoperiods, and warmer weather. The same authors also suggested the level of activity during summer may be lower during the day, because they often stood under trees/ in shade to avoid direct heat from the sun, and were more active during the night when temperatures were lower. The level of activity in these horses was lowest during the winter season, and was likely due to the shorter photoperiod and low temperatures. These seasonal trends are similar to those found by Berger et al. (1999). The authors of both these studies also noted that their horses 'acrophase' (the estimated time of peak activity) remained in the middle of the photoperiod throughout the year, despite changing sunrise and sunset times. Figure 4 below shows the acrophase of each season (black dot), in relation to both photoperiod and feeding time. It was suggested perhaps feeding time (0800hr daily) may act as a zeitgeber for activity level, as the acrophase does not change with photoperiod (Bertolucci et al., 2008), however this requires further research, to gain insight of the effects of time of feed supply on activity.



**Figure 4:** Acrophases of total activity rhythms during each seasonal equinox throughout the year. The black and white blocks indicate light/dark phases. Dotted line represents time of supplement feeding. Adapted from: Bertolucci et al. (2008)

As in feral horses, domestic horses have a clear daily pattern of activity. Both exercised (Bertolucci et al., 2008) and unexercised (Piccione et al., 2008) stabled horses show similar diurnal rhythms, with their locomotor activity levels higher during daylight hours, and peaking around the middle of the day

(Berger et al., 1999; Hampson et al., 2010a), however, the behaviour of domestic horses appears to also be affected by management.

A previous study looked at the locomotion activity of warmblood foals both at pasture, and in stables (Kurvers et al., 2006). The authors found that at pasture, the foals spent only a small fraction of their day carrying out high intensity behaviours such as cantering, galloping bucking and rearing (<1%), and spent approximately one third of the day grazing, and one third of the day standing, and the rest lying (~21%). The foals that were stable-confined at night however, spent more time cantering, trotting and grazing during the day, and less time lying down. This behaviour was suggested to be compensation for the lack of activity carried out whilst being confined (Kurvers et al., 2006), however further research is required to confirm this theory. Due to the link between confinement, lack of exercise, and poor MS development, more research comparing the musculoskeletal health of the partially-confined foals, to the pasture-only foal, would be beneficial for further insight into the effects of confinement, and whether the 'compensatory activity' is enough to minimise the effects of this confinement.

### **1.5.3. Quantifying activity**

#### **Time Budgets**

Time budgets are a commonly used tool to quantify a horse's activity, and establish patterns of behaviour (Benhajali et al., 2008; Berger et al., 1999; Boyd et al., 1988; Hogan et al., 1988). However, observing an animal for a lengthy period of time to establish a substantial amount of data is not only a timely method (Burla et al., 2014) but it can also result in discrepancies between observers, thus influencing results (Boyd et al., 1988).

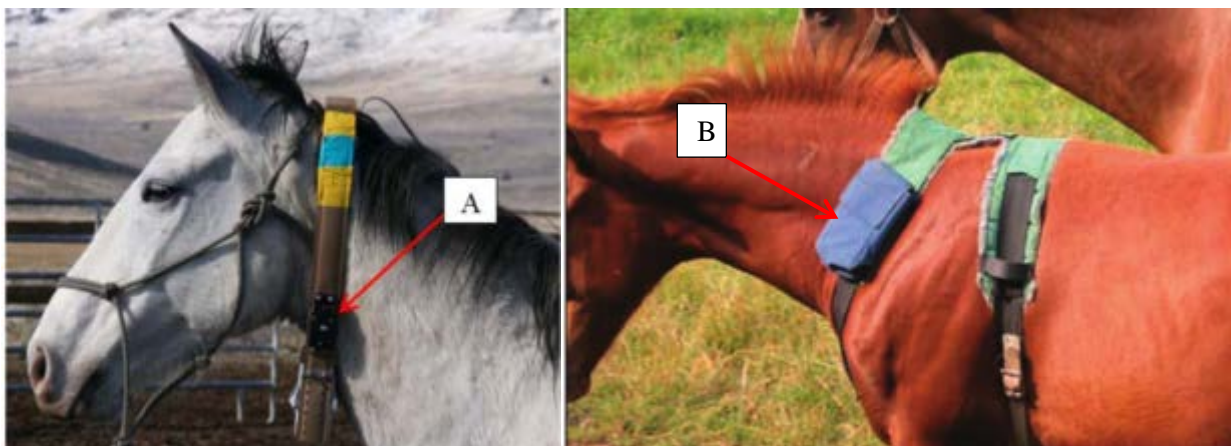
#### **Electronic Monitoring**

The two most commonly used electronic methods of activity monitoring include Global positioning system (GPS), and accelerometers, such as the ActiWatch Mini® or the MSR145 data logger. The GPS is a tool widely used to study wildlife, and determine information about their movements and activity via satellite and computer communication (Mech and Barber, 2002). Very High Frequency Radio (VHF) has been used in-hand with GPS, to locate and monitor animals such as migrating birds and many different mammalian species (Collins et al., 2014).

GPS collars have frequently been used to track horse activity and movement in both feral and domestic situations (Collins et al., 2014; Hampson et al., 2010b; Rose-Meierhöfer et al., 2010). Since being first introduced, the technology has become smaller and lighter, with lower costs, longer battery life and a larger data storage space (Mech and Barber, 2002). GPS technology has been used in a feral situation to monitor aspects such as distances travelled, range use, and patterns of movement (Collins



et al., 2014). The frequencies of behaviours, such as visiting watering holes (Hampson et al., 2010a; Scheibe et al., 1998), have also been monitored via GPS technology. The GPS has similarly been tested in a domestic situation to monitor and describe spontaneous activity in pasture based foals (Kurvers et al., 2006). The authors collected eighty hours of GPS data, with a sampling rate of 1 sample/second. They found the GPS to be accurate at determining walk, trot and canter, however the transition velocity between gaits for each horse had to be calculated to distinguish between gaits. Kurvers et al. (2006) noted it was not possible to distinguish between gaits with 100% certainty, due to the overlap in velocity ranges between gaits. They also found the GPS method unsuitable for determining low intensity activities such as grazing or resting, and were not able to distinguish between lying and standing with the GPS alone- a lying-standing sensor would have been required to rectify this issue. Authors also had issues surrounding reliability and durability. Overall, the study indicated that the GPS technique for monitoring activity may be better suited to a study which requires less behavioural details, such as Hampson et al. (2010b) study. GPS systems have also been noted to be unusable in a stable-confinement situation, due to loss of signal under roofing (Burla et al., 2014).



**Figure 5:** Examples of electronic monitoring. A). A domestic adult horse wearing a VHF/GPS collar B). A foal wearing a harness used to carry GPS equipment. Images adapted from Collins et al. (2014) and Kurvers et al. (2006), respectively.

A pedometer is another tool that can be used for collecting information concerning distances travelled. These non-invasive objects count single steps, and sometimes recognise lying down. The data is recorded continually, and is then stored periodically at a set time interval. However, this can lead to a loss of information due to pooling of data, and can also make it impossible to distinguish between individual gaits in the data (Burla et al., 2014). Authors found MSR145 accelerometers to be a reliable alternative for determining gait and resting in horses, using a sampling frequency of 50Hz (Burla et al., 2014).

Bertolucci et al. (2008), Giannetto et al. (2015) and Piccione et al. (2008) studies used ActiWatch Mini<sup>®</sup> acti-graphy based data loggers, using a sampling frequency of 5 minute intervals. These data loggers are acceleration sensors, which record a combination of intensity, amount and duration of movement in all directions (Bertolucci et al., 2008), and are commonly used for establishing circadian activity patterns. From these previous studies it is evident that the method of measuring locomotion and behaviour should be decided according to environment of the horses, and the level of accuracy required. GPS equipment has been proven suitable for feral situations on many different species, but may not be accurate enough for more specific/detailed data collection.

## **Chapter 2: The effects of partial stable confinement on the voluntary activity of weanling Thoroughbreds**

### **2.0. Objectives**

#### **Hypothesis**

The hypothesis of this study is that partial confinement in a stable will reduce the level of total daily activity each horse carries out, as well as the amount of high-energy activity carried out.

The objectives of this thesis are to:

- Compare the amount of total daily activity, and the amount of high- and low-energy activity, between each horse overall, on partially-confined days, and unconfined days
- Determine whether partial confinement causes a reduction in the total daily activity, or the amount of high- and low-energy activity in weanling horses
- Determine whether total activity, and amount of high- and low-energy activity is reduced during the hours of confinement

### **2.1. Methods and Materials**

#### **Animals**

The horses used in this study consisted of a convenience sample of two cohorts of Thoroughbred yearlings, one cohort of fillies (n= 3), and one of colts (n=6) of which 3 colts were involved in the study. All foals were based on the same commercial stud farm (Goodwood Stud, Palmerston North, New Zealand), and were all approximately 10 months old at the beginning of the trial (late June 2016). The foals were randomly selected for the trial, and the breeding and brandings were recorded for identification purposes. Monitoring began 22<sup>nd</sup> June 2016, and ended 9<sup>th</sup> November 2016.

#### **Management**

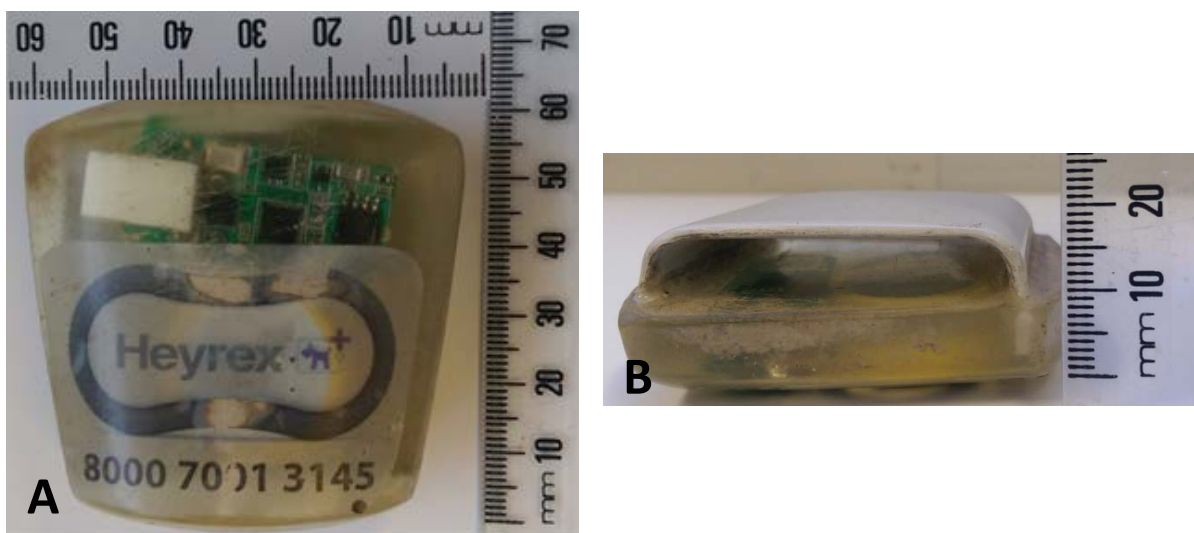
Goodwood stud is a commercial Thoroughbred stud farm. The farm consists of 101 ha, and contains broodmares, spelling racehorses, and grazing dairy cattle as well as young horses at certain times of the year. These numbers fluctuate depending on time of year and feed availability. Pasture dry matter ranges between 1800-2500 kgDM/ha, depending on time of year, stocking rate and grazing rotation.

The soil is Kairanga sandy clay loam. During the trial all yearlings remained under normal dietary management, which was decided by the stud master; yearlings were all fed the same pasture-based diet, with an additional 1.5 kg of Dunstan Fibre Grown/day post weaning, which was increased to 2-2.5 kg/day as they began yearling preparation, or as the stud master felt it was necessary. Due to the time of year during which the study was underway, and the nature of the farming system, the routine of the animals varied week to week. The cohorts of weanlings were rotated between paddocks every 4-6 weeks, with paddock sizes ranging between 2-3 ha. Body condition, growth and health were all monitored regularly by the stud master.

Due to the observational nature of the study, no strict routine of management was used throughout the trial period, however on most week days the fillies or colts were brought into the stable from the paddock for grooming and handling in the morning, as preparation for the yearling sales. The selection of which horses came inside for handling was at the discretion of the stud master. The horses were generally brought inside between 8-9am, fed their breakfast feed, and were then handled/groomed for the morning, and returned to the paddock by midday.

### Monitors

Heyrex Biosensor Monitoring technology was used to monitor the activity of the yearlings. There were two components of the Heyrex technology on the stud farm; biosensor monitors, and the Heyrex Receiver.



**Figure 6:** Heyrex monitors used on weanlings head collars, with scale. A) Front on view B) Side view, showing where the head collar was threaded through for attachment.

The biosensor monitors contained tri-axial accelerometer sensors, and collected raw data in the format of Delta-G; the change in acceleration from sample to sample, on each of the directional sensors of the monitor. The delta-G data recorded is 1/64<sup>th</sup> of a G. Cumulative activity was recorded in 15-minute increments. The sensors were capable of measuring activities such as; scratching, sleeping, alertness, walking, and running, however the sensors were programmed using dogs, and therefore the movements recorded did not necessarily match those which were actually being carried out by the horses. The monitors also recorded environmental temperature. The biosensors were able to hold approximately 7 days of data, however if they were not bought within range of the Heyrex Receiver before the memory was full, the sensors would stop recording.

The Heyrex Receiver is a wireless telemetry receiver, which wirelessly uploads data from the biosensor monitors to the Heyrex Data Analysis Servers, when the sensors are within range. The receiver is made of moulded ABS plastic (figure 6). The receiver ports include a 4 mm 5-volt DC socket for power, a RJ45 Ethernet socket, and a reverse polarity SMA Antenna Connector. It has a separate wall mounted, auto sensing switch mode power supply.

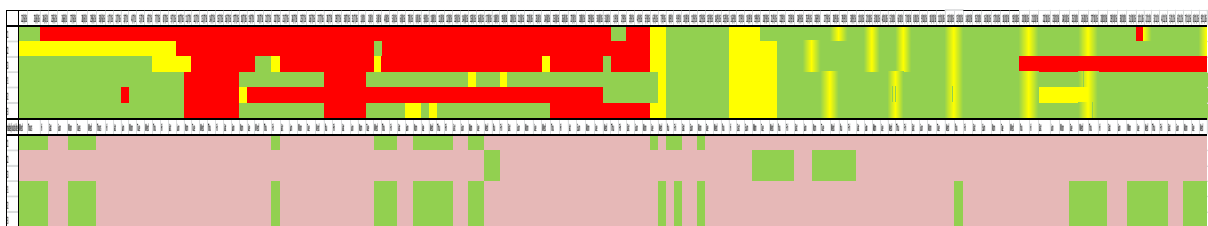
The range of the Heyrex monitoring system depends on the conditions and surrounding environment, as walls, fencing and roofing can all impact the receiver's performance. In optimal conditions, with an open space and direct line of sight between the sensors and receiver, the range can be up to 60m. In this study, the receiver was mounted inside the stable, out of reach on a support beam to allow maximum range whilst the yearlings were inside the boxes. The receiver was out of range while the horses were in the paddocks. Every seven days the receiver was removed from the stud farm and taken to a WiFi connection. This was to allow data to upload to the Heyrex Data Analysis Server, and Heyrex Vet- the online interactive website for Heyrex users to access the raw data.

The sensors were originally sewn into the subject's manes, but failed to stay in. They were then threaded onto the head collar of each horse for the remainder of the study.

### **Data Collection**

Every 7 days, all sensors came within range of the wireless receiver. If time did not allow for all six horses to be brought into the stable, the stud master would remove the halters from the horses and bring the halters in, to enable the sensors 6-8 hours minimum to fully upload all raw data to the receiver. If the halter had been removed, they were replaced onto the same horses, the next morning. Once the sensors uploaded to the receiver, and the receiver data was uploaded to Heyrex via WiFi, and the data became accessible via the Heyrex Vet website. This enabled us to see the year's overview of data volume, and daily activity graphs.

Figure 7 below was constructed throughout the trial to provide an overview of the successfulness of the data collection, as well as the stabling routine of each yearling. The red sections indicate no data was recorded on that day for that horse. Yellow indicates data was collected, however interference, removal of the sensors/halters from the horses or technological issues caused the data to be inaccurate or not contain a full 24 hours of data for that day. The green indicates a full 24hrs of successful data recording for that day. Beneath this, the pink and green section shows when each horses was bought into a stable for a morning; green indicates that particular horse was in stable confinement in the morning, whilst pink indicates the horse remained outside for the full 24hrs.



**Figure 7:** Data collection overview, showing the successfulness of data recording and stabling routine of each horse each day of the trial. The top green, red and yellow section shows days of successful (green), successful but unusable (yellow), and unsuccessful (red) data collection. The lower pink and green section shows which days each horse was unconfined (pink) or partially confined (green).

From Figure 7, Table 2 was generated, to distinguish the usable data, and identify which days each horse was stabled, and how many of those days had viable data. Together both Figure 7 and Table 2 were used to establish a suitable period to use for data analysis, where horses had a section of usable data, which consisted of both stable-confined and unconfined days.

**Table 2:** Overview of all used data from the data collection, showing the number of useable days, unusable days, and the number of stable confined days

	Usable			
	TOTAL	Paddock	Stabled	Unusable
<b>Colt 1</b>	141	44	5	92
<b>Colt 2</b>	141	35	6	100
<b>Colt 3</b>	141	30	6	105
<b>Filly 1</b>	141	80	27	34
<b>Filly 2</b>	141	53	16	72
<b>Filly 3</b>	141	69	27	45

**Table 3:** Summary of usable data, sectioned into ‘High’ and ‘Low’ energy activity counts for each data point

Horse ID	Stabled		Paddocked	
	High	Low	High	Low
Colt 1	17	518	175	3226
Colt 2	38	797	346	2851
Colt 3	70	193	314	1919
Filly 1	108	213	1140	3147
Filly 2	103	441	947	2727
Filly 3	66	1086	161	2911

### Data

Data were provided by Heyrex via an interactive Excel file. For each 15-minute data point, a delta-g value, and a duration value was provided, for each category of movement. Categories included: scratch, sleep, alert, walk and run. Values for average, minimum and maximum temperature were also provided. Total Delta-G per data interval was also added to the data spread. Data were then categorised into ‘High’ or ‘Low’, to specify whether the total Delta-G value was above or below 1500 units. Data categorised as ‘High’ were considered a point of high-intensity activity by the horse, and vice versa. Data were then compared to the Data Collection Overview table, in Figure 1, and

categorised into 'Good' and 'Bad' data, and 'Boxed' or 'Unboxed' to specify whether each data point was usable, and if the horse was stabled during that day- this led to the generation of Table 2.

Values for total Delta-G, Horse ID, High/Low and Boxed/Unboxed data were then reformed in Excel for analysis in SAS 9.4 (SAS Institute Inc., Cary NC, North Carolina).

### **Statistical Analysis**

Horses identification was recorded during the trial set up, and each horse given a number from 1-6. Gender, day of trial, total daily energy, the number of high counts, and low counts of energy, and whether the horse was stable confined on each day were transferred from Excel into SAS 9.4 (SAS Institute Inc., Cary NC, North Carolina). Days which had no data, or incomplete data were excluded from the analysis.

The normality of the data were tested using histograms and the Shapiro-Wilks test.

General linear models were used to test the effect of Horse ID, and stable confinement on total daily energy, and the effect of Horse ID on total daily energy on days of stable confinement.

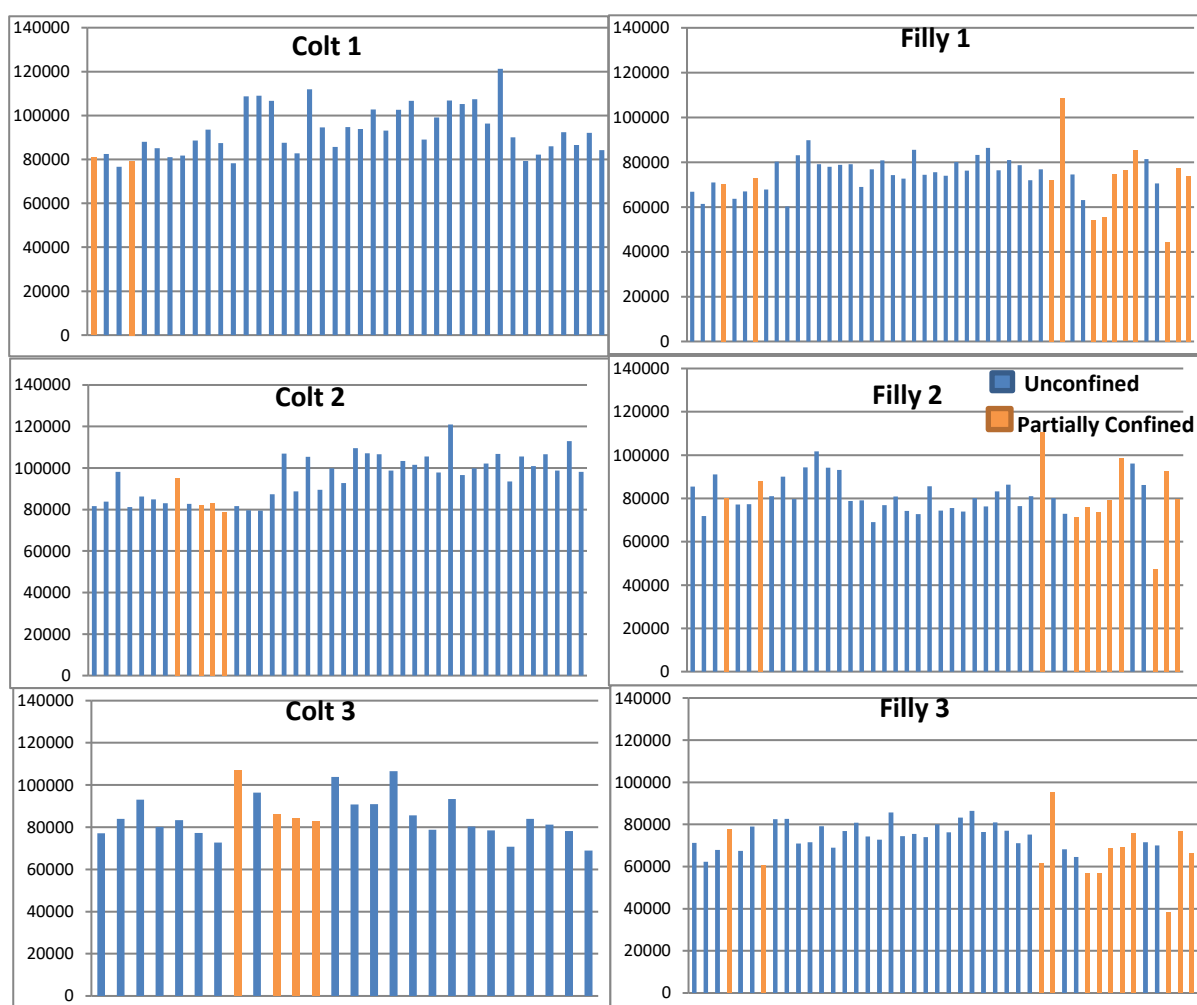
A Chi squared test was used to test the effect of stable confinement on the proportion of 'high energy' and 'low energy' activity counts for each horse, of both the total daily activity, and the daily activity between the hours of 9am-12pm each day.



## 2.2. Results

Data collection went for 141 days, from 22<sup>nd</sup> of June to the 9<sup>th</sup> of November. Due to operational difficulties, data prior to the 3<sup>rd</sup> of July were excluded from the analysis, resulting in 69 observational days per weanling, with 26-48 days of clean data per weanling. The total data set from July to November consisted of 39,372 individual 15-minute observation periods. Data from the 3<sup>rd</sup> of September onwards was used for analysis.

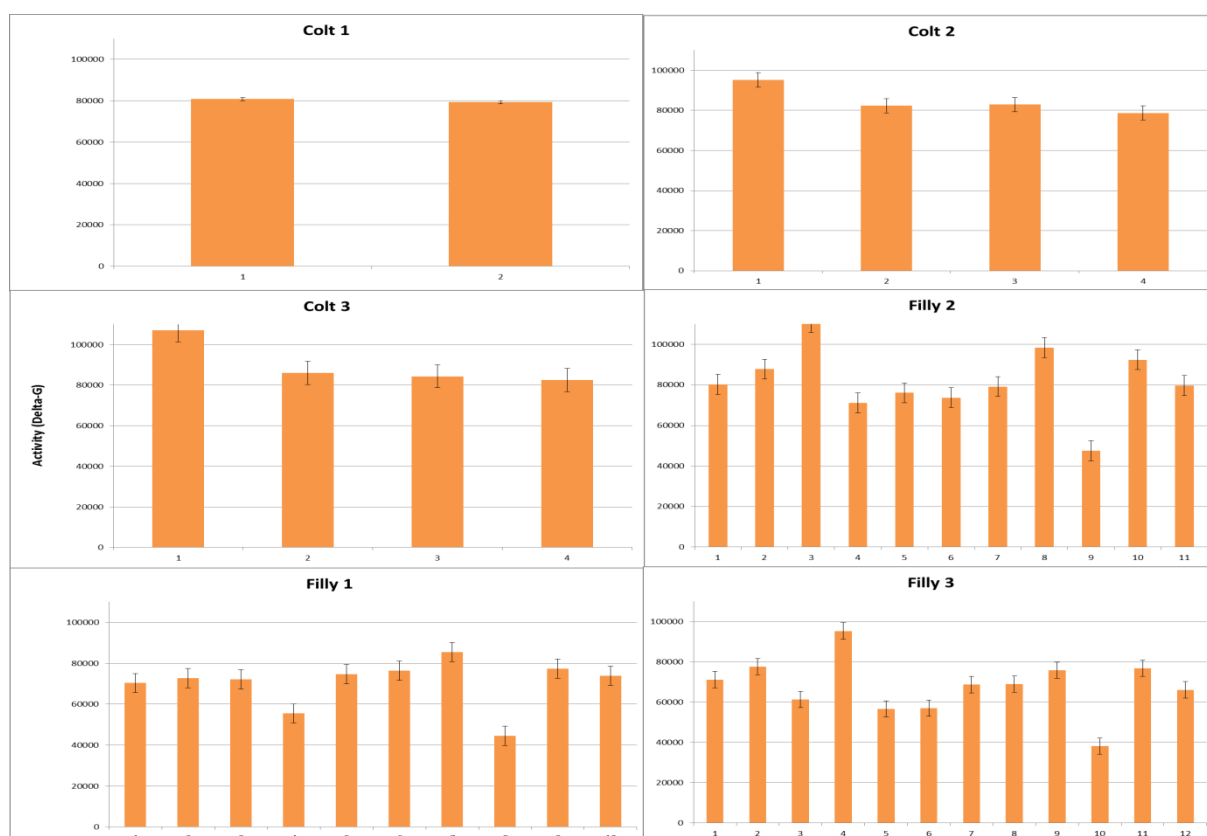
The total daily activity of all horses was normally distributed (Shapiro-Wilks test,  $P < 0.07670$ ). The weanlings had a mean activity of 83699 SD 13883 per day (Figure 8). Within the general linear model, both Horse ID ( $P < 0.001$ ) and stable confinement ( $P < 0.0088$ ) had a significant effect on total daily activity.



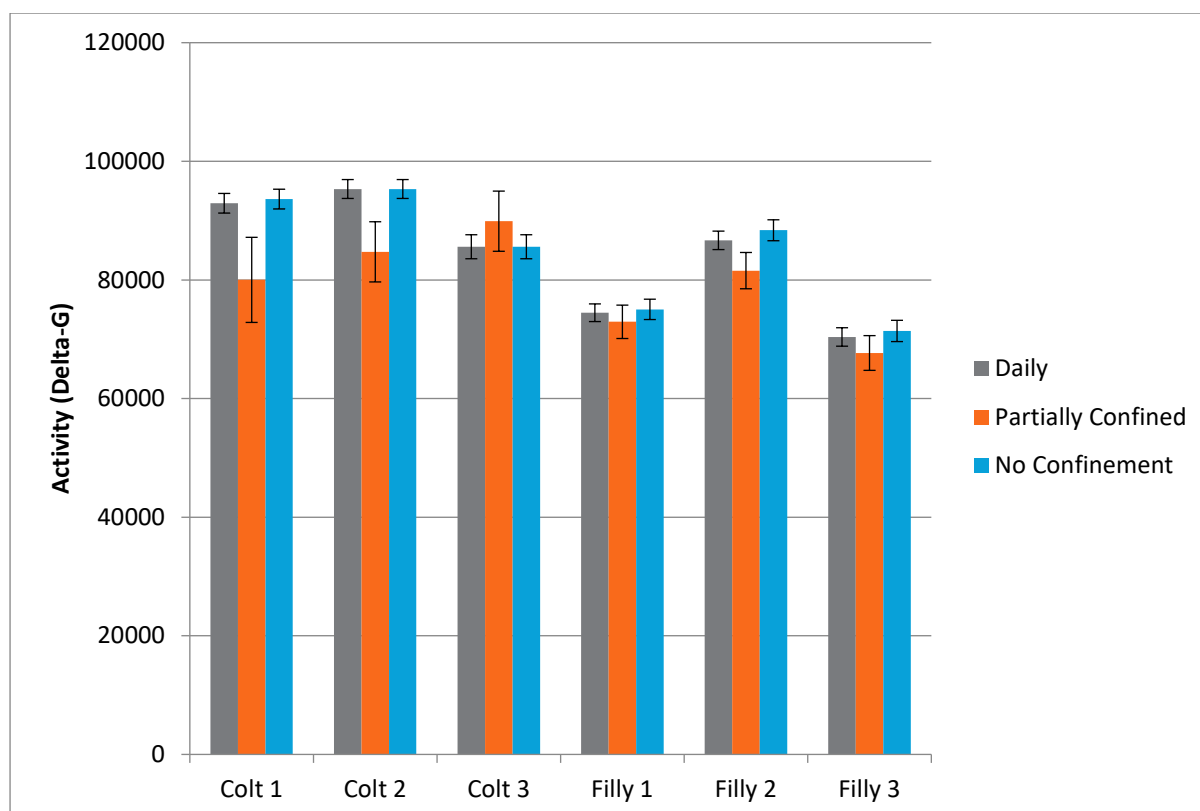
**Figure 8:** The average daily activity of each horse, each day of the trial. Blues is unconfined days, orange is days of partial stable confinement

Total daily activity for each horse on partially confined days is shown in Figure 9. The data on the 7<sup>th</sup> of November shows fillies activity to be low (day 8, 9 and 10 in fillies 1, 2 and 3 respectively), however detailed examination of the data file could not identify any abnormalities on this date. Due to the difficulties with data capture and operational logistics, there were varying days per horse when data was captured for stable confinement within the loose boxes. Within the general linear model for data on the days when the horses were partially stabled, there was no significant effect within the model for horse ID ( $P < 0.066$ ). However, post hoc tests found significant differences in daily activity between some horses (Figure 10).

The total daily activity for each horse per day throughout the study and on both partially confined and unconfined days is shown in Table 4 and summarised Figure 10. Colts 1 and 2 had the greatest total daily average activity overall ( $92931 \pm 1653$  and  $95331 \pm 1593$  respectively) and on unboxed days ( $93630 \pm 1668$  and  $96446 \pm 1646$ , respectively), followed by Colt 3 and Filly 2. Fillies 1 and 3 had the lowest. Colt 3 had the greatest total daily activity on boxed days ( $89903 \pm 5073$ ), whilst Filly 3 had the lowest ( $67682 \pm 2929$ )



**Figure 9:** Total activity of each horse monitored on days with partial confinement



**Figure 10:** Comparison of total averages of each horse for partially stable-confined, unconfined, and total daily activity. Blue bars are total daily activity, orange is total activity on partially confined days, and grey is total activity on days of no confinement

The general linear model for total daily activity included Horse ID and stable confinement effect, and had an  $R^2 = 0.33$  ( $P < 0.001$ ). Stable confinement did not affect the number of counts of high ( $P < 0.0852$ ) and low ( $P < 0.9314$ ) energy activity overall. There was however, a significant Horse ID effect on the number of count of high energy activity ( $P < 0.001$ ). The number of counts of low energy activity was also significant, however only between some of the horses ( $P < 0.001$ ). There was a significant interaction between Horse ID and stable confinement ( $P < 0.0098$ ) on the number of counts of low energy activity.

**Table 4:** Mean  $\pm$  SEM of the average total daily Delta-G for each horse overall, on boxed days, and unboxed days.

ID	Colt 1	Colt 2	Colt 3	Filly 1	Filly 2	Filly 3
<b>Unboxed</b>	93630 $\pm$ 1668 <sup>ab</sup>	96446 $\pm$ 1646 <sup>a</sup>	84813 $\pm$ 2163 <sup>b</sup>	75037 $\pm$ 1715 <sup>cd</sup>	88375 $\pm$ 1766 <sup>b</sup>	71399 $\pm$ 1793 <sup>d</sup>
<b>Boxed</b>	80009 $\pm$ 7174 <sup>bcd</sup>	84737 $\pm$ 5073 <sup>bc</sup>	89903 $\pm$ 5073 <sup>ab</sup>	72938 $\pm$ 2814 <sup>d</sup>	81570 $\pm$ 3059 <sup>bc</sup>	67682 $\pm$ 2929 <sup>d</sup>
<b>Daily</b>	92931 $\pm$ 1653 <sup>a</sup>	95331 $\pm$ 1593 <sup>a</sup>	85596 $\pm$ 2024 <sup>b</sup>	74469 $\pm$ 1490 <sup>c</sup>	86674 $\pm$ 1556 <sup>b</sup>	70385 $\pm$ 1556 <sup>c</sup>

<sup>a, b, c, d,</sup> means with different letters in the same rows are significantly different ( $p < 0.05$ )

**Table 5:** Mean  $\pm$  SEM of the number of counts of 'high' and 'low' energy activity overall while in stable confinement, and the paddock, for each horse.

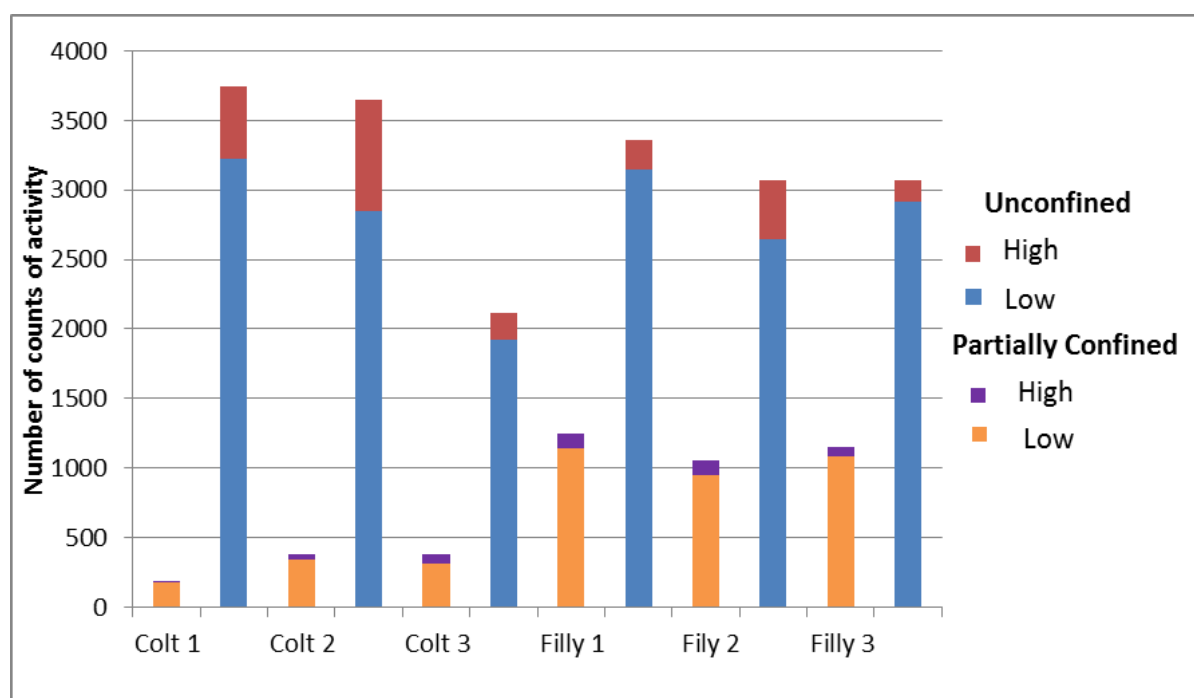
Treatment	High					
	Colt 1	Colt 2	Colt 3	Filly 1	Filly 2	Filly 3
<b>Stabled</b>	10.50 $\pm$ 4.55 <sup>bcd</sup>	12.250 $\pm$ 3.218 <sup>bcd</sup>	17.50 $\pm$ 3.218 <sup>ab</sup>	8.307 $\pm$ 1.785 <sup>de</sup>	9.909 $\pm$ 1.941 <sup>cde</sup>	5.417 $\pm$ 1.858 <sup>de</sup>
<b>Unconfined</b>	13.324 $\pm$ 1.058 <sup>bc</sup>	20.158 $\pm$ 1.04 <sup>a</sup>	8.772 $\pm$ 1.372 <sup>de</sup>	6.086 $\pm$ 1.088 <sup>de</sup>	13.333 $\pm$ 1.120 <sup>bc</sup>	4.906 $\pm$ 1.137 <sup>e</sup>
Treatment	Low					
	Colt 1	Colt 2	Colt 3	Filly 1	Filly 2	Filly 3
<b>Stabled</b>	85.50 $\pm$ 4.58 <sup>abcd</sup>	83.75 $\pm$ 3.239 <sup>bcd</sup>	78.50 $\pm$ 3.239 <sup>de</sup>	87.692 $\pm$ 1.796 <sup>ab</sup>	86.091 $\pm$ 1.953 <sup>abc</sup>	90.583 $\pm$ 1.870 <sup>ab</sup>
<b>Unconfined</b>	82.676 $\pm$ 1.065 <sup>cd</sup>	75.947 $\pm$ 1.051 <sup>e</sup>	87.772 $\pm$ 1.38 <sup>ab</sup>	90.086 $\pm$ 1.095 <sup>ab</sup>	82.667 $\pm$ 1.128 <sup>cd</sup>	91.094 $\pm$ 1.870 <sup>a</sup>

<sup>a, b, c, d, e,</sup> means with different letters in each row in High, and Low, are significantly different ( $p < 0.05$ )

The mean numbers of counts of high and low activity, for each treatment, for each horse, are presented in Table 5. Colt 2 had the highest average number of counts of high energy activity on a non-confined day ( $20.158 \pm 1.04$ ), whilst Filly 3 had the lowest ( $4.906 \pm 1.137$ ). On days of stable-confinement, Colt 3 had the greatest average number of counts of high energy activity ( $17.50 \pm 3.218$ ), whilst Filly 3 had the lowest ( $5.417 \pm 1.858$ ).

On days of no confinement, Filly 3 had the highest average number of counts of low energy activity ( $91.094 \pm 1.870$ ) whilst Colt 2 had the lowest ( $75.947 \pm 1.051$ ). During the days of stable confinement, Colt 1, and Fillies 1, 2 and 3 all had a similar average number of counts of low energy activity, however Colt 3 had the lowest average number of counts of low activity ( $78.50 \pm 3.239$ ).

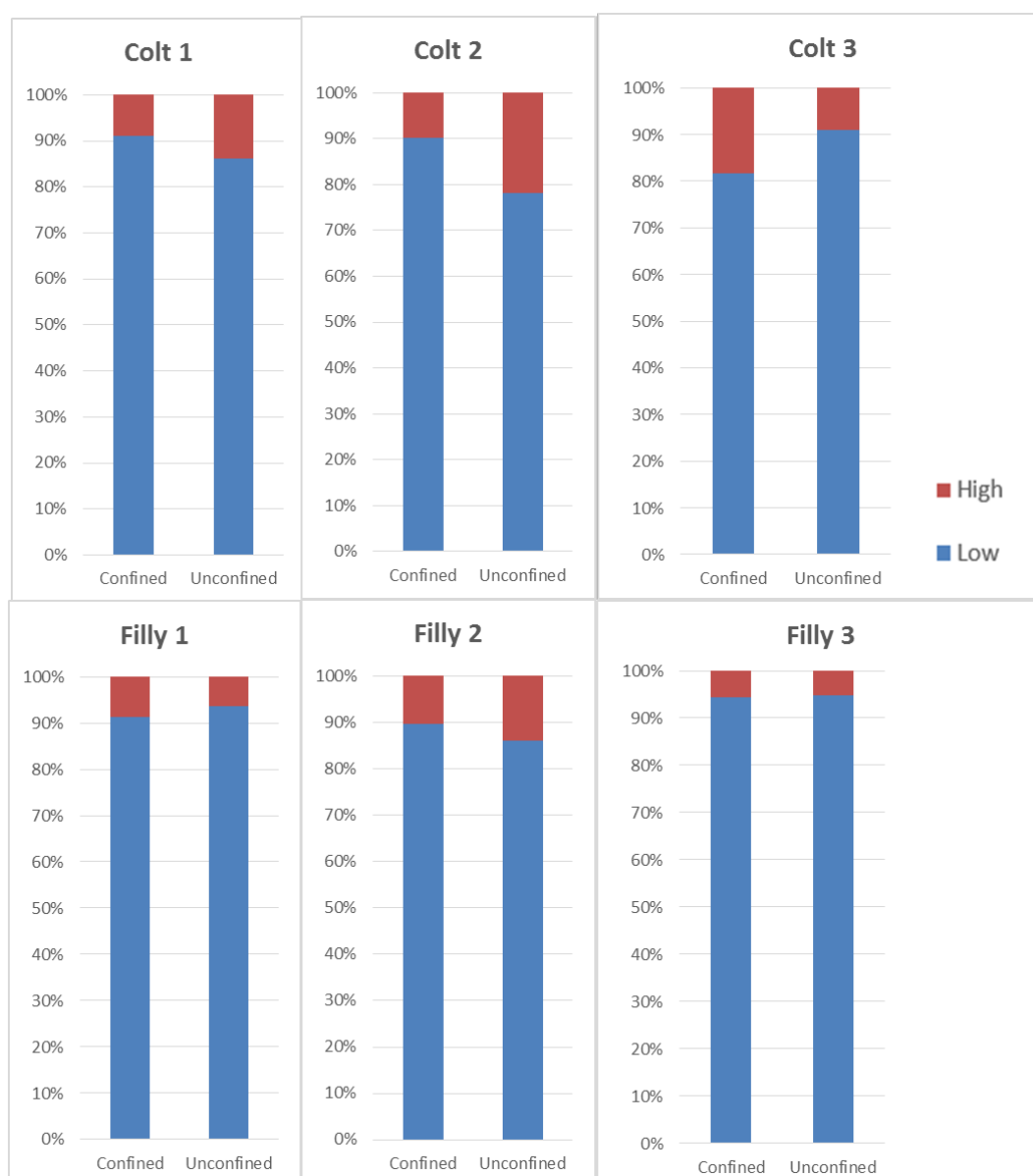
The total number of counts of high and low energy activity for each horse on stable-confined days, and unconfined days is shown in Figure 11. The total number of counts of energy for the horses on unconfined days is larger due to more observation days in part due to the observational nature of the trial.



**Figure 11:** The total number of counts of 'High' and 'Low' energy activity per horse during stable confinement days, and unconfined days. Red sections are unconfined, high activity, blue is low. Purple sections are stable-confined High energy activity, orange is Low energy activity.

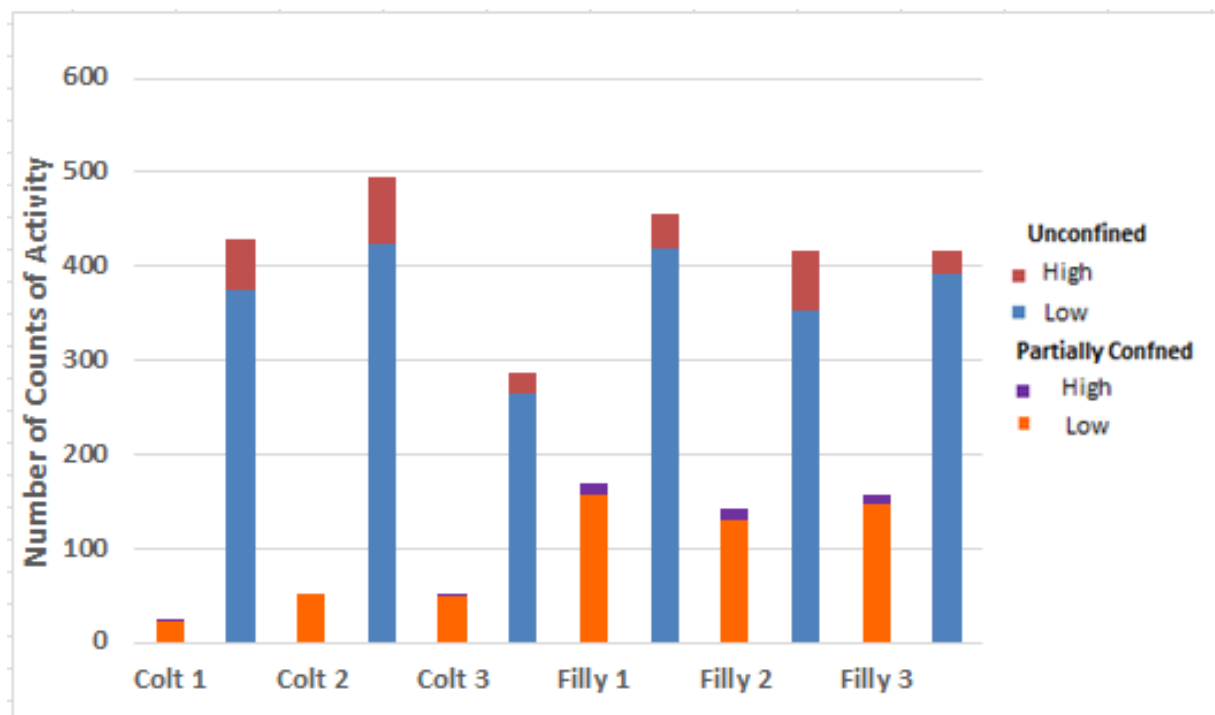
Figure 12 below shows the proportions of counts of high and low energy activity, on partially confined and unconfined days. Partial confinement resulted in a reduction in the proportion of counts of high energy activity for colts 1 and 2 and fillies 1 and 2. There was no effect of partial confinement for filly 3. In contrast to the other horses, partial confinement resulted in a greater proportion of counts of high energy activity in colt 3 during his time in the stables, rather than when he was in the paddock.

Confinement within the stable for approximately 3 hours per day had a significant effect on the proportion of counts of high and low energy activity counts in Colts 1, 2 and 3 had a ( $P < 0.0495$ ,  $P < 0.001$ ,  $P < 0.001$ , respectively) as well as fillies 1 and 2 ( $P < 0.0061$ , and  $P < 0.0031$ ). However, stable confinement didn't influence the proportions of counts of high and low energy activity in filly 3 ( $P < 0.5308$ ).



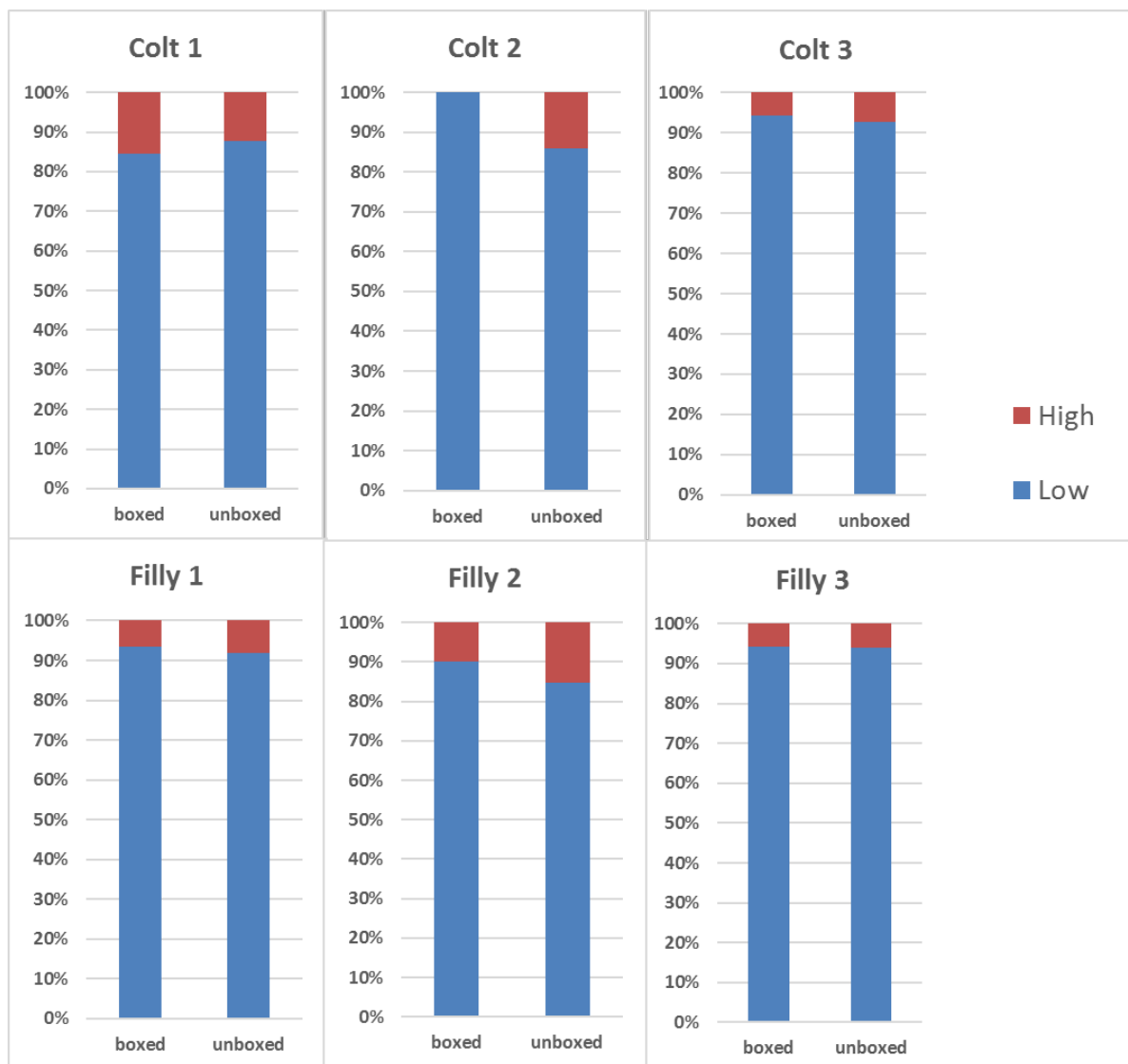
confined and unconfined days. Red sections are high activity, blue is low.

The total number of counts of high and low energy activity for each horse during the hours of stable-confinement (9am-12pm), on both partially confined, and unconfined days is shown in Figure 13. Due to the observational nature of the study, the window of time that the horses were confined for each time varied at the stud masters discretion. The total number of counts of energy for the horses on unconfined days is greater due to a greater number of unconfined days in the observational dataset.



**Figure 13:** The number of counts of 'high' and 'low' energy activity for each horse on confined, and unconfined days, between 9am-12pm. Red sections are unconfined, high activity, blue is low. Purple sections are stable-confined high activity, orange is low

Figure 14 below shows the proportions of counts of high and low energy activity for each horse during the period of time which stable confinement usually occurred (9am-12pm). Colt 2 was the only horse which had a significant difference in its proportions of counts of high and low energy activity when comparing data on confined, and unconfined days  $P < 0.0036$ ).



**Figure 14:** The proportions of 'high' and 'low' activity counts for each horse during the period of time which boxing occurred each day, between 9am-12pm.



## 2.3. Discussion

### 2.3.1. Heyrex biosensor Technology

#### Data Collection

The motion sensors used in this study had problems associated with both the physical attachment of the device, and unsuccessful data collection. Although the trial originally began in late June, a lack of successful data collection meant there was no viable data until early July. The earlier section of the missing data was due to a misunderstanding of how the device worked, resulting in data overlap, and deletion. Some missing data was due to technical difficulties/interference between the sensors and the receiver. The remaining loss of data was due to the loss of sensors; 4 sensors were lost during July, and only two were found. Two new sensors were provided as replacements by August, however the loss of sensors resulted in a period of no data collection for 4 of the horses until sensors were found/replaced. Due to the lack of continuous data during the first two months of the trial, data analysis excluded all data prior to the 3rd of September, until all 6 horses were successfully collecting continuous data.

#### Attachment

At the beginning of the trial, the sensors were stitched into a plait in the horse's manes, however this resulted in the loss of sensors, as mentioned above. Therefore, the monitors were attached to the head collars for the remainder of the trial. Although the sensors did not fall off the halters, one was broken. This may have been due to another horse, or by rubbing against a post/fence. The breakage of the device's mould plastics suggests they may not be durable enough to withstand the day to day activities of a young horse. In the future, the placement of the sensor could be reconsidered; attachment to a location such as the foreleg, as in Burla et al. (2014) study may be better suited. This positioning could result in more reliable recordings of locomotion, due to each data point being a reference of a leg movement, rather than head movement. It may also allow the sensor to distinguish behaviours such as sitting / lying down more clearly, due to the tri-axial nature of the technology. Most previous studies have placed their monitoring technology on the horses neck, via a collar, (Brooks et al., 2008; Collins et al., 2014; Hampson et al., 2010a; 2010b), above their withers, via a harness (Kurvers et al., 2006), or in the mane (Giannetto et al., 2015). This is likely to be because many of the studies were using GPS technology as well as an accelerometer/pedometer, which requires an antenna to be vertical, with a full sky view.

### 2.3.2. Total daily activity

The total average daily activity varied between each horse, however within each horse's data, their total daily activity remained relatively constant. This suggests that each individual weanling may be primed for a certain amount of exercise each day; it has been proposed that in a natural situation, young horses may only exercise themselves as much as necessary for optimal musculoskeletal development (Kurvers et al., 2006). It is therefore likely that the same applies to young horses in a paddock- they may only carry out as much exercise as necessary, with each horse's needs being different.

Most commercial studs confine their young stock to stables for periods of time during both weaning and yearling preparation. In the current study, stable confinement saw a reduction in five of the six horse's total daily activity, despite the period of confinement being an average of only 3 hours long. This supports Hampson et al. (2010b) statement that stable confinement restricts physical activity. This reduction in activity has been found to negatively impact young horses MS development, due to a lack of mechanical loading, and musculoskeletal stimulation (Barneveld and van Weeren, 1999; Hiney et al., 2004). Colt 3 was the only weanling which had an increased total average daily activity level on days of partial confinement in comparison to days of no confinement. This may be due to an ethological aspect of that particular horse. Due to horses naturally being social animals, single stable confinement may have resulted in an increased stress level, and increased stereotypical behaviour, such as walking the box, or weaving (Houpt et al., 1984). Alternatively, previous studies have found that colts are typically more playful than fillies (Kurvers et al., 2006; Tyler, 1972), which may also explain an increase in activity whilst in confinement.

### 2.3.3. Level of activity

In the current study, only 5-23% of the horses total activity throughout the trial was high-energy activity. this agrees with previous studies which have noted that foals and horses spend majority of their time performing low impact activity, with only a small amount of intensive, high-impact locomotion each day (Boyd et al., 1988; Kurvers et al., 2006). The amount of high-energy activity carried out by the weanlings was reduced on days of stable-confinement in four of the horses, had no effect on one horse, and caused an increase in the amount of high-energy Colt 3. Although this horse carried out more high-energy activity on days of confinement, it had a lower total average daily activity than other horses, and it is therefore possible that the increased level of high-energy activity whilst in confinement is sufficient for the 'pre-programmed requirements' of that horse's musculoskeletal system.

When each horse's activity was refined to the 3-hour window between 9am-12pm, during which confinement would normally occur, the amount of high-energy activity was similar irrespective of confinement or not. This suggests confinement had little effect on the amount of high-energy activity the weanlings carried out in the morning. Colt 2 however, carried out no high-energy activity during this period of time, on days of confinement. Although this reinforces the idea that stable confinement results in a lack of activity, and therefore musculoskeletal stimulation, this only occurred in one horse, thus it may be insignificant. Once again this may also be due to ethological aspect of this specific horse, resulting in a more sedentary behaviour than other horses whilst in confinement. This lack of high-energy activity during confinement provides support for studies which have stated horses carry out compensatory activity when they are released from confinement (Chaya et al., 2006; Kurvers et al., 2006), as Colt 2 spent approximately 21% of the trial carrying out high-energy activity- all of which was during time in the paddock. Although Colt 2 may be carrying out compensatory activity for that which was not carried out during confinement, it has been noted that any compensation is unlikely to be 100% (Kurvers et al., 2006), and therefore any free activity after a period of confinement should not be considered as full compensation; total daily activity is likely to still be reduced. Due to the lack of evidence of high-energy compensatory activity in the other horses of the current study, it is possible that their activity was not restricted enough for it to negatively impact their structural development. This may be partially due to the nature of the study as previously mentioned, as the horses were bought in, and turned out from the stables at the stud masters will, rather than at the same time each day. It is therefore possible that these weanlings were able to carry out enough stimulating activity each day, despite periods of confinement.

If these horses were stabled for a longer period of time, with a restricted ability to carry out voluntary activity at pasture, their behaviour and activity patterns are likely to be different. Chaya et al. (2006) concluded that horses which were given more freedom at pasture, with less time in confinement, were less active at pasture when compared to horses which were confined and given only a short period of pasture access. Similarly, Piccione et al. (2008) reported the activity of unconfined horses to be overall less intensive than horses kept in stables, both during the day and at night.

Overall, the current study suggests that each horse carries out a unique level of average daily activity, consisting of different levels of low- and high-energy activity, and short periods of confinement are unlikely to affect this daily total. However, each horse may react differently to stable confinement, and therefore their individual daily patterns levels of high- and low-energy activity may be affected.

These results may be beneficial to the industry, as being able to identify the way each horse reacts to stable confinement, may make it possible to manipulate their management, to encourage increased

high-energy activity and therefore further stimulation of their musculoskeletal system. Increased exercise from an early age is not only beneficial for their immediate growth and development, but is proven to also lead to improved success in their early racing careers (Rogers et al., 2008a).

Further research is required, as the number of days of stable confinement of each horse varies in the current study, and data is limited for some horses. Extended periods of confinement may also produce clearer results. Additionally, research is required to further establish the types of activity being carried out within a typical commercial stud situation, especially during the periods of high-energy activity. This will aid in establishing what the optimal amount of exercise is that a young Thoroughbred requires for their development, and highlight ways management practises can be further improved to influence this development.

## **2.4. Conclusion**

In conclusion, due to the small scale of the experiment, the effects of partial confinement on the spontaneous activity of Thoroughbred weanlings are still inconclusive. Although partial confinement caused a reduction in the average total daily activity in these horses, it did not have a significant impact on the intensity and timing of their activity. The confinement appeared to affect each of the horses differently in terms of their high-intensity activity, and thus further investigation is required to establish the typical responses of weanlings when in a partially confined system, in order to utilise the findings in a practical sense.

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